教研论文

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4	校企合作培养应用型人才的研究和实践	中国管理信息化	2016	吴修国（1/2）	23-29
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索 引

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基于教育大数据挖掘的大学生学业预警研究*

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摘　要:教育大数据挖掘通过对教育领域的各种海量数据进行分析,发现其中存在的规律,从而指导教育教学管理水平。文章在对现有研究存在的问题进行分析基础上,首先给出教育大数据挖掘的学业预警研究框架;之后,通过对大学生在校成绩数据进行整合管理,基于关联规则算法给出大学生不及格课程之间的关联关系,以此为大学生学业提出预警(课程不及格以及留级)提示。研究结果表明,该方法为管理者有针对性地对预警学生进行帮助和干预提供了数据支撑,具有较强的应用价值,可有效提升高校教学管理水平和管理质量。

关键词:教育大数据;数据挖掘;关联规则;学业预警
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一、引言

近年来,随着高校规模不断扩大以及外界因素的影响,大学生的学习能力与素质基础出现了不同程度的下降。据统计,每年各高校都有部分学生因为课程挂科等原因,无法顺利毕业,对学生个人、家庭以及学校而言都是难以挽回的损失。学业预警是学校对在校大学生的学业表现(包括成绩、出勤、作业情况等)进行评估之后,根据其学业表现情况,对学生下一步的学习进行及时提醒的一种监督管理制度。一方面,学业预警可以帮助学生合理规划后续课程的学习;另一方面,也可以有效提升教育教学管理水平,促进和谐高校质量建设。与此同时,随着教育信息化的不断深入,各个高校都开发了相应的教学管理信息平台,存储了大量与教学相关的数据(比如上课出勤情况、去图书馆自习时间等),称为教育大数据(Education Big Data,EBD)。[1]如何找到隐藏在这些数据中的某些关联关系、挖掘出有价值的信息,从而对以后的教学活动提供有效指导,不论对学习者还是教学管理者来说都具有十分重要的意义。目前,学生以及教学管理人员,可以通过校内的信息管理平台方便地查找到每个人的课程成绩情况,然而,这仅仅属于教育数据利用的初级阶段。对隐藏在数据中的价值没有进行充分的利用,难以对学生学习以及教师的教学活动进行有效指导。例如,对学生而言,无法得到下一步课程学习的有效建议;而对教学管理者而言,也不能根据现有的成绩,对任课教师的教学方法、教学内容、教学模式给出指导性意见,没有数据的支持,无法确保建议的有效性和合理性,因此无法保证教学的效果。[2]

数据挖掘技术的发展为教育大数据的研究与应用提供了重要的工具。越来越多的研究者从不同视角、利用不同方法逐渐展开数据挖掘的研究,他们提出了许多数据挖掘方法与技术,同时也为不同领域的决策者提供了决策依据。然而,数据挖掘在教育领域尚未得到广泛应用。作为教育管理者,通过对学生历史数据的分析,一旦发现学生某门课程的成绩出现问题时,要及时对他进行提醒,并采取有效措施避免问题的发生,而不是等到问题发生后再去采取措施进行补救,这是我们教育的本质所在。由此可见,在进行基本的教学信息管理时所产生的教育大数据,不管是涉及学生还是教学管理者,重心应该是发现隐藏其中的有价值信息,为决策提供数据支持,这相比过去只靠经验并进行判断而言,无疑是一个重大创新。可见,大数据不仅是技术手段,更是一种思维方式,为教育带来深刻变革。[3]为此,本文通过整合管理学生在校成绩数据,基于关联规则算法给出大学生不及格课程之间的关联关系,以此为大学生学业提出预警(课程不及格以及留级)提示。

二、基于教育大数据挖掘的大学生学业预警研究框架

1.问题分析

学业预警是高校加强学生学习管理、提升教育教学管理水平的重要手段。国外的研究始于 20 世纪 90 年代,目的是帮助在校学生按时完成学业。美国的普渡大学(Purdue University)、宾州滑石大学(Slippery Rock University of Pennsylvania)将学生在校表现情况作为学

*基金项目:本文系 2018 年度山东省本科教改项目“基于教育大数据挖掘的大学生学业预警研究”(项目编号:208)、山东财经大学研究生导师指导能力提升项目“基于数据挖掘的多策略研究生学业预警研究”的研究成果。

业预警的数据来源,取得了不错的效果。相比较而言,我国的大学生学业预警研究起步较晚,早期的研究主要以制度创新来应对学生学业问题。近年来,有部分研究者依据大学第一学期的成绩以及高考成绩,预测和解释有学业风险的学习表现,从而帮助实施学业预警。[3][4]总体来看,目前的预警研究尚存在以下一些问题:①预警的方法、机制比较简单。往往以学生成绩作为预警的重要依据,对课程之间的关系考虑较少。②缺乏相应的数据支撑,预警效果一般。预警没有考虑学生成绩之外的学业表现,比如课堂出勤情况、图书馆借书情况等。③没有对学业问题进行深入分析。往往是就事论事,没有从全局的视角对学生学业进行客观评估。

基于教育信息化技术的发展,在进行数据管理的同时,也能保存大量与学业相关的信息,通过这些信息可以对学生学习进行可靠评价,为教育和管理者提供服务,帮助管理者做出科学的决策。[4][5]当前许多研究者以教育数据为基础提出了许多建设性成果,但直接将其应用在学业预警研究中,尚存在以下问题:①缺乏个性化的学业预警,只依赖于当次考试成绩进行粗放式预警的方法,无法有效地对学生学业进行指导。对每个学生而言,知识背景、学习能力、兴趣点等存在很大差异,需要有个性化的预警措施。②不论在模型上还是算法上,尚没有基于数据挖掘的预警研究,尤其是针对管理学科偏重于理论这一特点,使现有的数据挖掘工具无法直接应用,迫切需要结合学生专业特点,从多个维度挖掘分析学生学业数据,特别是那些学业成绩不良的数据,从而为高校人才培养提供决策支持。③缺乏针对管理学科学业的预警机制,一旦发现问题不知道如何及时有效地补救。科学合理的预警对于可能会出现学业或就业困难的学生而言,可以起到预警作用;而对于未来发展可能比较好的学生,学校可以提前有意识地培养。

基于上述分析,本文针对大学生教育多年来积累的大量数据信息,引入数据挖掘技术中关联规则、聚类分析、决策树等挖掘算法,对学生课程、学业计划、课程成绩等数据间的相关性和依存性进行分析,挖掘出的结果将为学生学业预警等提供有效的决策支持。

2.基于教育大数据挖掘的大学生学业预警研究框架

基于教育大数据挖掘的大学生学业预警研究,主要包括不及格课程之间的关联关系挖掘、延期毕业学生特征挖掘以及毕业学分绩点预测等。如图1所示。

(1)首先,提出大学生学业的综合评价考核体系的指标模型(基本属性、学习情况属性、社会活动情况属性、主观评价属性等);其次,根据不同复杂程度和目标,选取相应的数据挖掘方法,比如关联规则、决策树等;最后,提出大学生学业预警机制模型,对出现的预警及时进行处理。

(2)基于教育大数据的大学生学业预警算法设计,主要包括:①以教学运行数据为基础,利用数据挖掘中的关联规则方法,对学生教学成绩库进行挖掘作业,从而发现课程之间,尤其是先导课程与后续课程之间的成绩相关性,特别是那些一旦先行课程没有学好、势必会影响后续学习的课程,及时对学生学习提出预警。②以学生基本属性数据、社会行为数据、学业成绩等为基础,运用K-Means聚类算法进行挖掘,总结延时毕业学生的总体特征。③以已经毕业学生学业数据、课堂表现数据等为基础,利用决策树分类理论分析出学生学分绩点特征,对现有在校学生的未来毕业学分绩点进行大体上的预测,对达不到毕业学分要求的学生进行预警。高校大学生学业预警机制与援助保障体系构建主要包括预警与援助机制建设、援助工作方案、预警平台发布以及反馈保障等。[6]

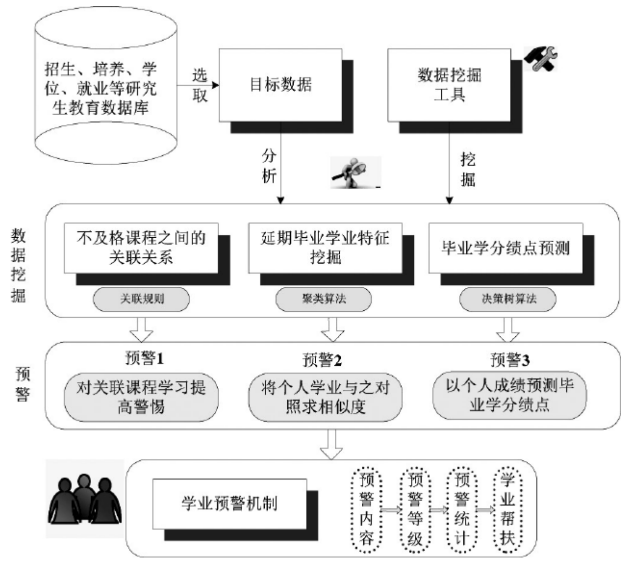

图1 基于教育大数据挖掘的大学生学业预警研究框架

(3)大学生学业预警系统设计。基于Java平台设计并实施基于数据挖掘的大学生学业预警平台设计,基本功能模块包括数据预处理、关联课程学习预警、延时毕业学生预警、毕业学分绩点预警、精准个体帮扶等。

(4)高校大学生学业预警机制与援助保障体系构建。主要包括预警与援助机制建设、援助工作方案、预警平台发布以及反馈保障等。

三、基于教育大数据挖掘的不及格课程关联规则分析

关联规则是由Agrawal等人在1993年提出的,用于发现大量数据中项集之间的重要关联或相关联系。[7][8]本节以山东财经大学管理科学与工程学院大学生挂科课程数据为挖掘对象,利用关联规则挖掘找出课程之间的

隐含联系,为后续课程学习提供预警信息。

1.数据预处理

本研究主要通过对学生挂科课程进行数据分析,目的是发现它们之间存在的相互联系,以此对学生课程学习进行有效指导。主要的研究数据是从学校教务处教务管理信息系统数据库中获取学生历史成绩数据,该数据包含大量编码,需要借助于相关编码表进行解析。原始数据如表1所示。

表1 学生历史成绩表

XN	XQ	QDXN	QDXQ	XM	XH	KCDM	KCMC	KSCJ	BZ	…
2016	1	2016	1	***	***	C06…	管理学	93	正常	…
2016	2	2017	1	***	***	C07…	运筹学	良好	正常	…
2017	1	2017	2	***	***	C06…	数据结构	-1	缺考	…
…	…	…	…	…	…	…	…	…	…	…
2018	1	2018	2	***	***	C06…	物流学	65	补考	…

学生历史成绩表包含字段较多,本文只选取了一些关键字段,分别是考试学年、考试学期、取得学年、取得学期、姓名、学号、课程代码、课程名称、考试成绩以及课程标志。其中的考试学年、考试学期、取得学年、取得学期反映了大学生考试的通过情况:考试学年和考试学期表示该学生第一次参加该门课程考试的学年和学期(1表示第1学期;2表示第2学期);取得学年、取得学期表示学生最后一次参加该课程考试的学年和学期。考试成绩分为百分制和五级制两种方式。课程标志包括正常、重修、补考、缓考和缺考等。

在数据预处理阶段,主要包括数据清理、数据整合、数据转换、数据规约以及数据离散化和概念分层等几个部分。在数据清理阶段,主要是将异常数据和重复数据清除,以解决孤立点和数据不一致等情况带来的问题。对一些由于退学、休学等原因造成学生数据缺失等情况,采用了人工填补、平均值和牛顿差值等方法进行数据补充,保证数据完整性。

2.挂科课程关联挖掘框架设计

图2给出了基于FP-Growth算法的大学生课程关联规则挖掘模型。算法的基本过程主要包括频繁模式挖掘以及关联规则发现。在频繁模式挖掘阶段,将每一门不及格课程作为一个项,所有学生的不及格课程构成项集;将每个学生的不及格课程作为一个事务,利用关联规则的两个测度,度量最小支持度和最小置信度,对得到的频繁项集和关联规则进行筛选。在这个过程中,链接和剪枝是两个重要的操作。

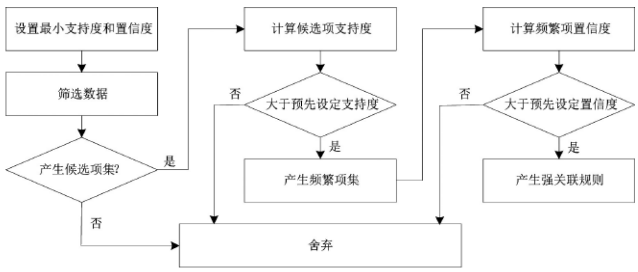

图2 课程关联分析模型

3.挖掘结果与分析

通过FP-Growth算法得到频繁项集如表2所示。以第一行为例,Key=C06310002表示该课程号的频繁项集,([C06310081],13)表示C06310081共出现了13次,([C06330085,C06340068],7)则表示C06330085和C06340068一共出现了7次。

快速发现感兴趣的关联规则还是比较困难的;同时,大量的频繁项集中必然夹杂很大比例的无效关联规则和弱关联规则,需要对挖掘到的频繁项集进一步处理。合并所有键值相同的对,去掉大部分无效关联规则和弱关联规则;同时,在保留有限关联规则前提下,将支持度设为0.12,置信度设为0.6,对挖掘到的频繁模式进行处理,共筛选出120条规则,部分如表3所示。

由以上规则可以看出哪些课程不及格,容易导致其他相关课程也出现不及格的情况,比如[数据结构]→[运筹学],支持度表示数据结构和运筹学均出现不及格的情况占总体不及格课程的16.1%,置信度表示数据结构出现不及格情况的学生中80%的学生运筹学课程也出现了不及格情况。究其原因,一方面可能是学生的学习

表2 挖掘得到的部分频繁项集

Key	Value
C06310002	([C06310081],13),([C06330085,C06340068],7)
C06310081	([C06310004],11),([C06330043,C06330085],9),([C06310082,C06340068,C06330083],9),([C06310005,C06310082,C06310431,C06330085],7),([C06310005,C06310082,C06310431,C06330085,C06340068],5),([C06310005,C06310082,C06310431,C06330085,C06340068,C06340083],3)
C06310081	([C06310004],11),([C06330043,C06330085],9),([C06310082,C06340068,C06330083],9),([C06310005,C06310082,C06310431,C06330085],7),([C06310005,C06310082,C06310431,C06330085,C06340068],5),([C06310005,C06310082,C06310431,C06330085,C06340068,C06340083],3)
C06310082	([C06330043],6)
…	…

(下转第62页)

系统试运行至今，已完成1200人次预约。以我校之前每次停车换证平均耽误访客2分钟时间计算，系统共为访客节约40小时的等待时间，提升了通行效率和访客体验。

五、结束语

当前高校普遍采用收费、换证、身份查验等传统方式管理访客车辆，不能做到同时兼顾校园安全和访客体验。本文提出了使用预约系统管理访客车辆的方案，设计并实现了高校访客车辆预约管理系统。该系统能够让用户与学校提前约定来访车辆信息，实现了用户线上预约、车辆线下通行的功能。本文的工作优化了当前高校访客车辆的管理模式，提升了工作效率，具备一定的应用和推广价值。

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表3　关联规则筛选结果

Antecedent	Consequent	Support Degree	Confidence Degree
[C06310081]	[C06330043]	0.161	0.80
[C06310081，C06310002，C06310052]	[300850631]	0.120	0.75
[C16210002]	[C16210016]	0.481	0.632
[C06310001，C06310052，C06330083]	[C06340068]	0.350	0.682
[C06310001，C06310052，C06330005]	[C06340068]	0.343	0.680
…	…		

态度不端正，放松了对专业知识的学习，这就需要专业教师加强学生基础知识的教学，辅导员及时督促学生掌握理论基础知识；另一方面可能数据结构作为先导课程有一定难度，学校可尝试适当调整培养方案，巩固基础知识，加深学生对专业知识的理解。[9-11]

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■ 集体生活是儿童之自我向社会化道路发展的重要推动力；为儿童心理正常发展的必需。一个不能获得这种正常发展的儿童，可能终其身只是一个悲剧。

——陶行知

■ 教师应当善于组织，善于行动，善于运用诙谐，要既快乐适时，又要生气得当。教师应当能让自己的每一举动，都能对自己起教育的作用，并且永远应当知道当时自己所希望的是什么，所不希望的是什么。如果一个教师不了解这一点，那他还能教育谁呢？

——马卡连柯

■ 任何人都应该有自尊心、自信心、独立性、不然就是奴才，但自尊不是轻人，自信不是自满，独立不是孤立。

——徐特立

■ 要知道，由活的人所说出来的话，不单是只靠它的内容来激发对方的思想和感情的。这里有交谈者的一副兴致勃勃的面孔。有一双一忽儿在科学的丰功伟绩面前燃烧着赞美的火光，一忽儿又好象在怀疑所作的结论的正确性而眯缝起来的眼睛，有表情，还有手势……。

——（前苏联）赞科夫

■ 中国留学生学习成绩往往比一起学习的美国学生好得多，然而十年以后，科研成果却比人家少得多，原因就在于美国学生思维活跃，动手能力和创造精神强。

——杨振宁

■ 学校应当成为学生和老师最向往的地方，使学生对老师尊重的唯一源泉，在于教师的德和才。

——爱因斯坦

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语　录

■ 才需学也，非学无以广才。非志无以成学。

——孔明

■ 学习任何知识的最家途径是由自己去发现，因为这种发现理解最深，也最容易掌握其中的规律、性质和联系。

——波利压

■ 我们的教育方针，应该使受教育者在德育、智育、体育几方面都得到发展，成为有社会主义觉悟的，有文化的劳动者。

——毛泽东

■ 知道事物应该是真么样，说明你是最聪明的人；知道事物实际是什么样，说明你是有经验的人；知道怎样使事物变得更好，说明你是有才能的人。

——狄德罗

■ 民主的教师，必须具有：（一）虚心；（二）宽容；（三）与学生共甘苦；（四）跟民众学习；（五）跟小孩子学习——这听来是很奇怪的，其实先生必须跟胆小孩子学，他才能了解小孩子的需要，和小孩子共甘苦。……（六）消极方面，肃清形式、教条、先生架子、师生的严格界限。

——陶行知

■ 不要把儿童培养成奴隶，而要培养成自由的公民，……那种不能尊重儿童个性，不考虑儿童个性的教师无论如何也是一个不称职的教师……。

——［苏］克鲁普斯卡娅

语 录

■ 路是脚踏出来的，历史是人写出来的。人的每一步行动都在书写自己的历史。

——吉鸿昌

■

我的基本原则永远是尽量多地要求一个人，也要尽可能地尊重一个人。

——马卡连柯

■

人之学也，或失则多，或失则寡，或失则易，或失则止。知知其心，然后能救其失也。

——《礼记 学记》

■

教师常常忘记，品德首先是在人们相互交往中形成的。伟大的义务感，只有当它能在生活实践的每一步中得到生动体现时，才能成为人的行为准则。在培养未来的一代人时，我们应当首先在个人领域，即在青年人靠良心的驱使而产生并得到控制的相互关系领域里，培养最纯洁，最富有人道主义的情感。

——[苏] 瓦・阿・苏霍姆林斯基

■

教育植根于爱

——鲁迅

■

不能把教师对儿童的爱，仅仅设想为用慈祥的、关注的态度对待他们，这种态度当然是需要的，但是对学生的爱，首先应当表现在教师毫无保留地贡献出自己的精力、才能和知识，以便在对自己学生的教学和教育上，在他们的精神成长上取得最好的成果。因此，教师对儿童的爱应当同合理的严格要求相结合。

——（前苏联）赞科夫

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基于创新实践能力培养的电子商务人才培养模式研究

王洪海，刘培德

（山东财经大学，济南 山东 250014）

摘 要：学生创新实践能力的培养是高水平应用型本科专业建设的核心。本文以培养学生创新实践能力为主题，提出培养满足区域经济和社会发展需求具有较高实践能力的高素质应用型人才，并从引导学生自主学习、改革完善教学模式和课程体系、探索大学生导师制和优化师资队伍建设等方面进行了一些探索和研究。

关键词：创新实践能力；电子商务；人才培养模式；自主学习

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随着互联网技术的迅速发展，电子商务已经渗透到人们工作生活的方方面面，电子商务创新应用模式层出不穷。社会对电子商务人才的创新意识和实践能力要求也越来越高，如何进一步明确经济新常态下电子商务专业培养目标，完善满足社会需求和区域发展的电子商务人才培养体系，优化有利于创新实践能力培养的教学体系，是电子商务专业建设和人才培养的当务之急。如何在国家开展双一流建设和高水平应用型专业建设的大背景下，改革传统的教学模式和课程体系，培养具有较高创新实践能力的电子商务应用型人才，既是当今时代对高等教育提出的改革与发展要求，也是时代赋予高等院校教学的新任务。

一 我校电子商务专业人才培养目标

十多年来，高校培养了大量电子商务专业人才，电子商务的发展也亟需大量电子商务专业人员，但目前在电子商务人才需求方面存在结构失衡问题。一方面电子商务专业毕业生找不到满意的工作，就业率不高或流失到其他行业。另一方面市场需求量很大，但企业招聘不到满意的电子商务人才。其主要原因是电子商务专业学生理论知识有余，创新能力和实践能力不足，与企业期望的掌握信息技术与商务理论及实务的复合型人才需求还有一定的距离。鉴于以上分析，我们立足学校办学特色和学科优势，以社会需求为导向，以提高学生综合素质和培养创新实践能力为目标，在对电子商务专业人才培养现状进行深入分析的基础上，不断创新人才培养模式，提出为区域经济和社会发展培养具备人文精神、科学素养和诚信品质，能从事电子商务系统研发和电子商务运营管理等工作的高素质应用型人才，并根据学生兴趣和特长分为电子商务开发技术和电子商务运营管理两个培养方向，逐渐形成“面向社会需求，以创新实践能力培养为主线，加强信息技术与商务管理融合”的专业特色。

二 激发和引导学生自主学习，构建学生自主学习教学体系

在互联网发展的大背景下，积极探索以学生为中心，以创意启迪为手段，充分发挥学生学习的主观能动性，建立以多元化的知识获取方法为基础的开放式教学模式，培养学生的发散思维和创新实践能力，使学生从被动学习转变为主动学习。教师在激发和引导学生自主学习过程中起到关键作用。一方面是通过在教学过程中开展教学体系创新、教学内容创新和教学方式创新，最大限度激励学生发挥主观能动性，促进学生的自主学习积极性。另一方面是在实习实践过程中通过明确实习规范、增强实践体验、提高实习价值等措施激发和引导学生的自主学习。

学生在构建自主学习教学体系过程中起到主体作用，同时强调外在环境在学生自主学习过程中的作用和调节。一方面提供“学科群平台 + 模块”的课程结构体系，扩大学生自主选择学校教学资源的权利，建立一个以激励学生自主选择、促进各教学要素不断优化为宗旨的创新人才培养模式。另一方面通过电子商务专业学科多元化教学发展，根据学生的特长和兴趣开设专业方向课和第二课堂，吸引学生进行选修和参与，激发和引导学生产生自主学习兴趣。

三 改革和完善教学模式与课程体系，提升学生创新实践能力培养

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作者简介：王洪海（1978-）男，山东泰安，副教授，硕士，研究方向：电子商务、信息化。

针对创新实践人才的培养，我们在广泛调查分析社会需求、电子商务本科专业知识结构体系和管理科学发展趋势的基础上，提出了创新实践人才培养的知识、能力和素质模型，并结合专业定位、培养目标和财经院校学生个性化特征，积极探索开放互动式教学模式，构建知识、能力和素质培养动态融合的课程体系，提出多维度、模块化、立体化实践教学体系。

（一） 探索开放互动式教学模式

以学生为中心，以创意启迪为手段，将创新实践人才的成长要素如批判式思维、团队协作精神、知识获取能力等有机地融合到教学模式中，延伸了学生的学习时间、拓展了学生的学习场地、学习视野和学习领域，培养了学生的发散思维和创新能力，引导学生积极主动地学习，建构自己的知识体系，促进学生全面发展和优秀个性的形成。

（二） 构建知识、能力和素质培养动态融合的课程体系

在知识、能力和素质培养动态融合的课程体系中，既要发挥课程在本课程群中的独特作用，又要加强各课程之间的有机联系，增强其内在逻辑性，在传授知识、培养能力和提高素质动态融合层面上设计各课程群和各门课程的内容结构。课程体系突出了教学内容的系统性、逻辑性和实践性，既充分体现了教学与科研相融合、理论教学与实践教学相融合以及多学科融合的专业特点，又重点考虑了课程体系是否有利于学生进行知识体系的自组织，具有较强的自适应性。

（三） 提出多维度、模块化、立体化实践教学体系

根据电子商务学科的特性和社会对电子商务人才多层次、多元化的需求，提出以“一个目标、两种能力”为引领、“三大平台”为基础、“四个抓手”为支撑的电子商务专业多维度、模块化、立体化实践教学体系。一个目标：以培养高素质创新型应用人才为目标；两种能力：以学生的创新能力和实践能力为重点培养内容；三大平台：理论和实践相结合的课堂教学和实验平台、产学研合作平台、第二课堂拓展平台；四大抓手：以实验课程为抓手，支撑动态实验教学体系；以综合竞赛为抓手，支撑学生实践新机制；以科研训练为抓手，支撑创新能力培养新模式；以专业实习和创业教育为抓手，支撑创业实战训练体系。

四 探索实施大学生导师制，提高学生自主学习和创新实践能力

大学生导师制旨在专业导师和学生之间形成一对一的支持和帮助关系，学生会受到导师的关注、鼓励、帮助和指导，从而达到发展学生智力，提高学生自主学习能力和创新实践能力，为学生全面发展以及将来能够更好地适应社会打下良好的基础。专业导师职责是指导学生专业学习，为其在学习过程中遇到的问题提出指导性意见，并答疑解惑。通过实施大学生导师制，建立和完善学生与专业指导教师的长期联系，使得学生在大学专业学习中能够得到针对性、专业化的指导意见，能够充分发挥专业教师在学生大学学习生活中的指导作用，及时、有效地解决学生在大学学习中的各种茫然与困惑，有助于学生专业学习和个人发展。专业导师在学生学习生活中会在入学专业教育，专业方向选择，专业选修课选择、创新实践活动、学年论文撰写、毕业实习和毕业设计等众多方面给予学生一对一的指导。不仅有助于学生专业学习的进步，还会有效提升师生关系。通过专业导师对每一位学生的言传身教，对他们的思想、生活、学习等各方面产生积极影响。导师还可以及时发现和了解学生的特点和动态，因材施教提高学生的学习兴趣和主观能动性性，从而提高整体的专业教学效果。

五 建设高水平应用型师资队伍

高水平师资队伍建设是落实人才培养模式的关键，是提高专业教学质量的关键。根据电子商务专业的培养目标和课程设置，坚持开放式办学，统筹校内校外教学资源，通过双师型教师培养、行业企业师资引进以及学校师资再培训等形式建设高水平创新应用型师资队伍。电子商务专业与产学研合作企业和专业教学实践基地建立了长期师资培养合作关系，每年循环委派专业教师到企业接收培训、挂职工作和实践锻炼。同时，积极引进和聘请相关企业优秀专业技术人才、管理人才和高技能人才到学校担任专兼职教师，开展讲座、开设课程、与教师学生进行交流学习，提升了专业教师整体实践教学水平和应用技术研发能力。另外，为了加强对现有专业教师的学历、知识结构的培养，建设一流师资队伍，我们积极与国内外知名高校广泛开展学科、专业学术交流活动，了解、学习国内外知名高校学科、专业建设的理念、经验。鼓励教师赴国内重点大学或国外高校进修，并尝试合作开展教学研究和工程技术研究。

六 结语

随着互联网技术在我国传统行业和领域的不断渗透，电子商务在社会生活的诸多领域得到广泛应用，社会亟需大量的高素质创新型电子商务应用人才。本文立足学校特色和学科优势，对我校电子商务专业人才培养模式做一些有益的探索和改革实践，旨在培养满足区域经济和社会发展需要的创新型电子商务应用人才。

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基于综合实验平台的物流管理专业实验教学体系研究*

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【摘 要】物流管理专业具有理论教学和实验教学并重的特点,实验教学环节对于培养物流管理专业学生的动手能力和实际操作能力具有重要的作用。文中针对物流管理专业的特点,提出了基于综合实验平台的物流管理专业实验教学体系,该体系确定了基于能力体系的物流管理专业实验教学体系的要求和目标,设计了实验教学体系的内容和实验教学环节的考核评价标准。该套实验教学体系已应用到实际教学环节,有效提高了学生的专业能力和动手能力,提升了物流管理专业整体教学质量。

【关键词】物流管理; 实验教学; 综合实验平台
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Research on Experiment Teaching System of Logistics Management Education Based on Integrated Experimental Platform

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【Abstract】Logistics management education emphasizes both on theory teaching and experiment teaching,and experiment teaching has an important role in training the practical ability of the students. In view of the characteristics of logistics management education,this paper puts forward experiment teaching system of logistics management education based on integrated experimental platform. This system determines the requirements and objectives of experiment teaching system based on ability system and designs the contents and the evaluation criteria of experiment teaching systems. This experiment teaching system has been applied to the actual teaching,and effectively improved professional ability and practical ability and improved the whole teaching quality.

【Key words】logistics management; experimental teaching; comprehensive experimental platform

1 引言

近几年,在电子商务迅猛发展的推动作用下,我国物流产业发展迅速,物流需求呈级数逐年放大,物流人才的需求量出现缺口,但学生的就业情况仍不乐观,究其原因,主要是学校的培养和社会的需求之间发生了脱节。社会需要的是理论和实践并举的综合性人才,而大多数高校培养的则是侧重专业知识的理论人才。因此,为了满足社会的需求,在今后的物流人才培养过程中,物流管理专业的学生不仅需要具备综合性和专业性的理论知识,更需要动手能力和实践能力的培养;但由于办学时间短,经费短缺等诸多原因,实践教学环节正是物流管理专业整个教学体系中最薄弱的部分。如何根据企业和社会对物流人才实践能力的需求,推进物流管理专业实践教学进程已成为物流管理专业教学和发展迫切需要解决的问题。

2 国内外研究现状

在物流管理专业实践教学方面,西方一些发达国家重视实验环节,重视学生专业能力的培养,实验环节在教学大纲中得以体现,并在学习环节和学时上得以保证。例如美国的加州大学、麻省理工学院、德国的慕尼黑大学、科隆大学等高校都建有先进的物流实验室,在实验教学方面都有深入的研究和实践,培养出大量的具有专业能力的综合性人才。这些大学很多先进的经验值得我们学习和借鉴。

在我国,一方面,随着《关于进一步加强高等学校本科教学工作的若干意见》和《国家中长期教育改革和发展规划纲要

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(2010－2020 年)》等文件的相继出台,国家明确要求“大力加强实践教学,切实提高大学生的实践能力”,国家和各高校越来越重视实验教学的开展,加大对实验室建设的投入; 另一方面,随着当今社会对综合能力型物流人才需求的加大,物流实验在教学中的地位和作用也日益增强; 但是由于物流实验教学工作起步较晚,因此,在发展过程中还存在一定的问题,例如,实验教学体系还不够完善; 实验教学内容有待进一步改进; 实验教学的管理和评价体系还需要调整等等。目前对于物流管理专业实验教学体系建设的研究不少,例如,温州商学院的戴晓震等[1]从实践教学环节设计、实践环境搭建、实践队伍建设和实践管理保障四个方面构建实践教学体系,保障物流管理高技能人才的培养。安徽财经大学的韦道菊和许晶晶[2]通过对暨南大学、中山大学、安徽大学和安徽财经大学等高校物流管理专业本科实验教学情况的问卷调查,分析目前我国高校物流管理本科实验教学中普遍存在的问题,并提出了改进措施。这可以为其它院校发现本院校物流管理专业实验教学环节目前存在的问题和如何改进提供借鉴。华北电力大学的杨淑霞教授[3]从培养学生具有良好专业技能的角度出发,从掌握物流管理基本要求、提高要求、动手设计三个层次考虑,提出了物流管理专业应设计基本性实验、提高性实验、研究创新性实验三个环节的实验教学体系。这种设计思路有利于学生从感知到参与到动手到创新一步步融入实验,提高教学效果。重庆交通大学的谌微微和曾文杰[4]根据理论课程的梯度教学,将专业认知度不同的学生的实验教学分为基础、关键、提高和扩展四个阶段。这在一定程度上有利于学生循序渐进的掌握专业知识和技能。一些其他的学者[5－10]也提出了一些宝贵的建议。这些经验和建议有其重要的参考价值,但是本身也有一定的局限性,主要是针对特定高校的物流管理专业的现状提出来的,而每个高校都有其自身的环境和特点,必须根据自身的条件和特点来构建相应的实验教学体系。

论文基于物流管理专业的特点,结合山东财经大学物流实验室建设情况,建立了一套基于综合实验平台的实验教学体系,这一实验教学体系不仅适用于学校的物流管理专业,同样也可以给省内乃至全国的其他院校的物流管理专业作为参考,有其重要的参考和应用价值。

3　物流管理专业的能力体系构建

现代社会需要的物流人才是多元化的人才,因此,对物流管理专业的学生的能力要求也更高,更多元化。在物流管理专业的人才培养中,本文提出了“三种能力、一种技能”的物流管理专业本科能力体系标准。

①协调沟通能力。

现代物流业属于服务业范畴,要求从业人员具有更高的协调能力和沟通能力,能够及时、完善的处理顾客的各种需求和问题。

②信息处理能力。

目前,越来越多的物流企业或企业物流部门,采用了物流信息系统作为物流业务的操作和管理平台,因此,在这些企业或部门,几乎所有的物流业务从业人员都必须懂得物流信息技术的操作和管理。甚至连基层的作业人员,也需要懂得怎样使用像条形码等基本的应用系统。这就要求在物流管理专业的教学过程中,必须加强信息处理能力的培养。

③科学决策能力。

现代物流业涉及的环节多,内容复杂,即使在任意环节中,也涉及很多复杂问题,例如: 物流成本问题,物流运输问题,物流仓储与配送问题,物流信息处理问题等等。因此,要求从业人员能够做出科学的判断,及时制定出正确的决策方案,这就需要在日常的教学过程中,培养学生发现问题、分析问题和解决问题的科学决策能力。

④物流操作技能。

作为物流管理专业的本科学生,物流操作技能是学生必须具备的基本能力之一,在学生培养的过程中,应当加强物流操作技能的培养,例如,仓库的出入库操作,物流信息管理系统的操作,运输与配送的基本操作,包装与装卸等基本物流环节的操作等等。

4　物流管理专业实验课程体系的设计

根据物流管理专业本科能力体系的构建,确定了物流管理专业的学生需要具备的能力和技能,由此设计实验课程体系。

综合实验平台是实验教学环节的基础和保障,根据我校物联网与智能物流实验室的建设情况,构建由课程实验、仿真实验和综合实训实验组成的实验教学体系。

①物流管理专业课程实验设计。

课程实验是指理论课程教学中设置了一定课时的实验教学,用以对理论课程的内容加深理解和验证。

②物流管理专业仿真实验课程设计。

物流仿真实验可以从多个方面比较全面地培养学生的实践能力,但实施的关键在于如何设计行之有效的实验内容与案例内容,让学生应用仿真软件来解决物流管理中存在的问题。因此,仿真实验不能仅仅要求学生像传统实验一样模仿教师授课的案例模型,而是要提出问题,培养分析问题、解决问题的能力。

③物流管理专业综合实训实验课程设计。

综合实训实验课程主要是为了促进学生对物流管理专业知识的综合运用。因此,在设计的过程中应和传统的实验模式不同; 首先,根据要达到的目标,确定相应的授课内容,然后根据循序渐进的原则确定相应的流程,可以采用单机实验,分角色模拟实验,轮岗制操作实验等多种实验模式,让学生能够接触和亲身体会到物流的各个环节,并运用所学的知识分析问题、解决问题,从而提高学生综合运用所学知识发现问题、分析问题和解决问题的能力。

④物流管理专业实验教学环节的考核评价体系建设。

首先,确定考核评价体系的构建原则,然后根据课程实验、仿真实验和综合实训实验课程各自的特点,确定每一环节的考核方法和考核指标,构建一套科学、完善的考核评价指标体系。

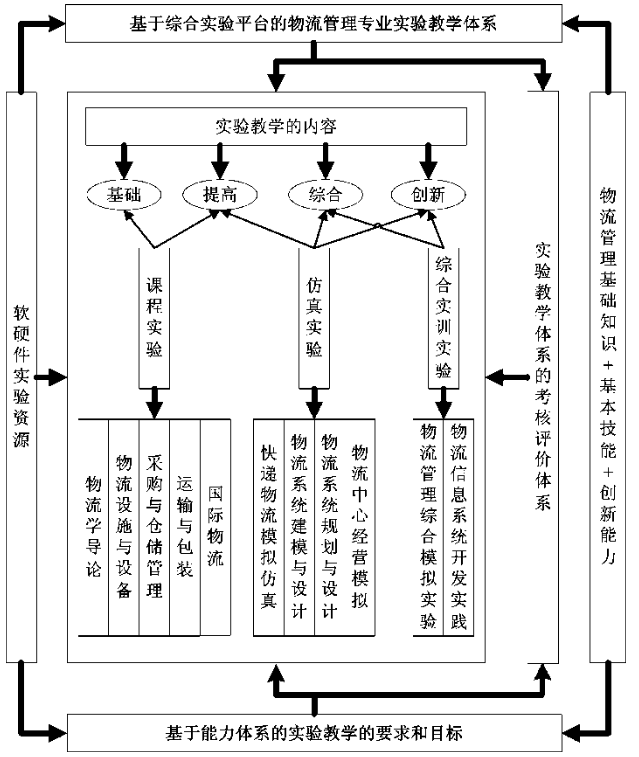

图 1 基于综合实验平台的物流管理专业实验教学体系示意图

综合物流实验室的软硬件实验资源和学生具备的物流管理基础知识、基本技能以及创新能力是物流管理专业实验教学体系的前提和基础，是确定基于能力体系的实验教学的要求和目标的保障。

《物流学导论》和《物流设施与设备》等课程实验是认知和理解层次的实践能力培养，即是后续理论学习和实验教学的基础《采购与仓储管理》、《运输与包装》和《国际物流》等课程实验主要是关于物流基本活动的认知和操作，属于基础和提高层次的实验。

《快递物流模拟仿真》、《物流系统建模与设计》、《物流系统规划与设计》和《物流中心经营模拟和仿真》等仿真实验以前面所学的理论知识和所积累的实践经验为基础，通过仿真软件可以模拟物流系统、排队系统等多种实际生活问题，属于提高和综合实验课程，并进一步向创新层次提升。

《物流管理综合模拟实验》和《物流信息系统开发实践》等综合实训实验课程是对前面所学知识的综合运用，培养学生分析问题和解决问题的能力，属于综合和创新阶段的实验课程。

考核评价体系贯穿于物流管理专业实验课程的所有环节，对于整个实验体系具有辅助和促进的作用。

5 结束语

以物流管理专业能力体系的要求和目标，确定了课程实验课、仿真实验课和综合实训实验课以及考核评价指标设计的实验教学体系，有助于完善物流管理专业学生的专业知识体系，增强学生的实践能力和创新能力，提高学生的综合素质。

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教育教学研究 JIAOYU JIAOXUE YANJIU

校企合作培养应用型人才的研究和实践

吴修国，何　丽

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摘　要 校企合作是实现应用型本科人才培养的重要途径，也是应用型本科教育改革和发展的目标之一。通过剖析当前应用型人才培养过程中存在的问题，以信息管理与信息系统（软件外包）专业校企合作人才培养实践为例，从人才培养目标、教学体系构建、协同育人机制等对地方性本科院校校企合作培养应用型人才培养进行初步探讨，并对下一步的发展提出具体的指导性建议。

[关键词] 校企合作；应用型人才；信息管理与信息系统；实践

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培养应用型人才是各地方院校本科人才培养目标之一。然而，在应用型人才培养过程中普遍存在人才培养目标定位偏高；偏重理论缺乏实践；运行机制偏离等问题。校企合作教育是通过一定的组织形式，由高校与社会各部门紧密合作，将理论学习与实践训练相结合，培养学生实践能力和创新精神，全面提高学生综合素质的新型教育模式；是高等教育发展的必然趋势，也是培养高素质应用型人才的必然选择。基于上述分析，本文针对目前信息管理与信息系统（软件外包）专业在培养应用型人才过程中存在的问题，通过厘清专业办学定位，明晰应用型人才的规格和素质，构建教学体系等，提出适合于长期发展的基于“校企合作”的应用型人才培养模式。

1　“应用型”人才与“校企合作”的内涵

根据联合国教科文组织《国际教育标准分类法》的相关标准可以将高等教育人才培养种类分为三种，即学术研究型、知识应用型和职业技能型。“应用型”是相对的概念，其相对性可从两个方面去理解。首先，应用型是相对于理论型而言的；其二，应用型的相对性表现在不同的历史时期和不同的层次教育有不同的内涵。本科教育应用型人才是相对于基础性人才而言的，是能够把已经发现的一般自然规律转化为应用成果的“桥梁性”的人才。

校企合作，顾名思义，是学校与企业建立的一种合作模式。当前社会竞争激烈，包括教育行业、大中专院校等为谋求自身发展，有针对性的为企业培养人才，注重人才的实用性与实效性。校企合作做到了应社会所需，与市场接轨，与企业合作，实践与理论相结合的全新理念，为教育行业发展提供了新的思路。

2　“校企合作”培养应用型人才的探索与实践

近年来，山东财经大学为推动应用型人才的培养，积极进行“校企合作”培养应用型人才的探索与实践。2010 年开始，按照“注重应用、学用结合、校企合作、内外结合”的思想，根据专业培养特点，积极探索校企合作的新模式和新途径，提出与 IT 企业联合实施“$2+X$”人才培养模式，即前两年在校内完成理论教学、实验教学环节，从第三年开始在浪潮基地完成校外实习，之后回到学校继续学习。该模式充分体现了“能力向导、个性培养、校企联动、创新机制”的人才培养理念。

2.1　信息管理与信息系统（软件外包）专业人才培养目标

信息管理与信息系统（软件外包）专业人才培养目标为：培养具有比较扎实的管理学、经济学、计算机科学的理论基础知识，掌握信息系统分析与设计、信息管理、计算机应用及常用的定量分析理论与方法等方面的知识和能力，能够承担信息系统分析与设计、建设和管理以及信息资源开发利用等工作，具备良好的人文素养和科学精神，基础知识扎实、知识面较宽、适应能力强、具有较强实践能力和创新精神的复合应用型高级专门人才。

2.2　基于校企合作的实践教学体系重构

共建课程体系是进一步强化实践环节的要求，为此部分专业课程都是围绕应用能力培养目标而设置的。如大部分的专业课程其实践课时占 50%以上，课程设计、课程实验实训采取校企共同实施的方法，浪潮技术人员把实际的企业项目作为课程设计、课程实验实训的案例，力求学以致用。在实践教学体系设计方面以软件项目为载体，采用基于软件开发工作过程的项目实践，设计四层递进的实践教学体系：

（1）课程实验。针对课程的知识点而设计的单项性实验项

[收稿日期] 2016-06-07

[基金项目] 2014 年山东财经大学教研项目（jy201410）以及特色项目（面向计算思维培养的信管专业特色建设）成果。

[作者简介] 吴修国（1975-），男，博士，山东财经大学管理科学与工程学院副教授。

目，主要包括验证性实验、综合性实验和设计性实验，如数据库的创建、对象建立、友元函数、类的继承等，在任课教师的指导下由学生单独完成。课程实验使学生学会使用至少一种开发语言或工具，掌握常用算法和数据结构，具备软件开发的初步思想和相关技能。

（2）课程设计。针对整门课程而开设综合性实践项目，如“Web 开发基础”、“Java 程序设计”、“C# 程序设计” 等课程设计，单个课程设计周期为 1~4 周，该类项目采用分组形式，在组内模拟软件企业运行模式设置相关岗位角色，学生在仿真企业环境中，利用仿真的软件开发项目，进行轮岗和角色体验，培养学生的软件工程应用能力、软件项目开发与测试能力、职业素质等，从而使学生熟悉软件项目开发流程和规范，养成良好的软件开发习惯。

（3）企业实训。针对专业方向课程群而开设的企业实训，在工程实训中心引进企业项目，如软件系统设计与开发、WAP 开发等，周期为 8 周，学生在企业技术专家的指导下，开展以真实项目为载体的技能训练，提升软件系统分析与设计、软件开发实践、软件工程项目管理的能力。

（4）综合实践。针对学生的知识、能力、素质进行立体训练而开设的综合性工程实践项目，包括毕业实习与毕业设计、行业技能培训与职业资格认证、顶岗实习、仿真模拟与创新实践、工程与社会应用实践等。采用双导师制，学校与企业派专人指导，校内导师负责学生实习与毕业设计相关理论与文档规范的指导与审定工作，企业导师为学生提供工程实践环境、工程项目及其技术指导工作。学生在真实的企业环境中进行项目开发并完成毕业设计，在学校专业教师和企业项目经理指导下，在项目需求分析、建模、设计、代码编写、测试、部署全过程得到知识与能力训练，增强工程项目经验。

2.3 “以社会需求为导向”的信息管理与信息系统专业产学研协同育人机制

信息管理与信息系统专业坚持“育人为本、知行合一，教学、科研与社会服务和谐发展”的建设理念，形成了“开放、先进、重实践”的鲜明特色，确立了“以社会需求为导向”的信息管理与信息系统专业产学研协同育人机制。所谓“开放”是指坚持校企、校政、校校合作。与 IT 企业合作，共建实践教学基地，为学生提供实践机会；与财政、审计、经信等部门合作，开展课题研究、人才培训和智囊决策支持等工作，支持山东省社会和经济发展；加强与国内外知名高校合作，开展学生和老师的互访和交流。所谓“先进”，是指瞄准社会需求的最新变化，及时更新培养方案和课程体系。与浪潮合作，招收“软件服务外包方向”本科生，并引入软件服务外包方面的实训、实战课程。所谓“重实践”，是指产学研合作：依托本专业所在学院承担的“山东省企业电子商务工程技术研究中心”和“山东省信息化与工业化融合促进中心”等产学研合作平台，结合山东省的特色和发展方向，搭建产学研合作服务平台。围绕学科科研人员创新创业、产学研合作中利益分配机制、产学研领军人才及团队的奖励政策，探索创新产学研合作的新模式和新途径。

2.4 毕业生就业情况

信息管理与信息系统专业（服务外包）方向首届毕业生就业率 86%（2014），毕业生就业去向以 IT 业、金融业为主，就业企业的层次逐年提高，有多位同学被阿里巴巴、人人网、浪潮、中创等标杆性 IT 企业录用。国家级软件园—齐鲁软件园园内的 IT 企业十分认可我校“信息管理与信息系统”专业的学生，愿意提前接受学生去实习。2014-2015 网络专业排行榜中山东省普通高校中唯一四星级信息管理与信息系统专业（人民网：2015 山东省大学三星级以上专业排行榜，http://edu.people.com.cn/n/2015/0519/c396273 -27024173.html）。2013、2014、2015 连续三年“服务外包”方向一志愿报考率 100%。就业情况如图 1 所示。

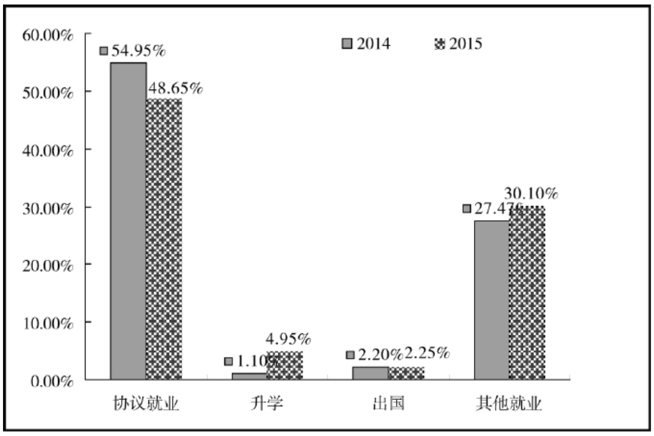

图 1 校企合作毕业生就业情况

3 结 论

信息管理与信息系统（软件外包）在基于校企合作的应用型人才培养过程中进行了有效地探索与实践，在下一步的工作中，应处理好以下几方面的关系：

（1）正确引导学生积极从事校企合作实践。长期以来，受社会环境的影响，家长和学生更倾向于各自原有的职业目标，如：考研、考公务员热，这一现象还将在较长一段时间存在，这样就影响到学生到企业进行实践实习，学生对校企合作的认识程度、对企业实训和实战的参与和配合程度还有待于进一步提高。因此，下一步需要对学生做宣传、引导工作，处理好企业实践与考研、考公等的关系。

（2）正确处理好实际动手能力提升与竞赛成绩的关系。为提高学生的创新思维和创新能力，学院出经费支持学生参加各类科技竞赛活动，学生在参加各种大赛中锻炼了自己的动手能

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计算思维信息管理与信息系统专业教学改革实践

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摘　要 计算思维是信息管理与信息系统专业人才培养的重要目标之一。结合实际教学工作,通过明确教学目标;优化教学内容;改进教学模式等,将计算思维能力的培养渗透到各个知识点和模块的教学中,培养学生利用计算机分析问题和解决问题的意识和能力。

[关键词] 计算思维;信息管理与信息系统;教学改革
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0　引　言

信息化时代,计算机的应用非常普及,计算的思维过程即设计程序的思维过程,可以有效解决很多的实际问题。信息管理与信息系统专业是多学科交叉的边缘性学科,涉及管理科学、计算机科学、经济学、行为科学、运筹学、社会学等多学科的内容。

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2014年7月,第三届计算思维与大学计算机课程教学改革研讨会明确提出将“培养学生的计算思维”能力作为课程改革的三个目标之一。作为应用型本科专业,信息管理与信息系统专业要培养既懂管理理论又懂信息技术的复合型人才,要求学生具备良好的计算思维能力,重点是编程思路、实际应用解决问题的能力。

比较中美大学管理信息系统专业课程设置,可以发现目前大多高校的信息管理与信息系统专业课程设置的概论性课程较多,深度不够。信管专业或学科的最终目的是如何更好地把系统科学与信息技术应用到管理实践中,提高管理的规范化、科学化

专业特长,到学院合作企业进行工程实践训练与学习,目前已有多位教师到广州、上海等地的企业进行为期半年的学习与实践。

(5) 在2012级信管专业进行了人才培养模式改革试点,按照“2.5+1.5、3+1、4年制”三种模式进行分类培养,由学生根据自身专业兴趣和职业规划自行选择其中一种模式进行培养。“2.5+1.5”模式是指学生在校内完成两年半的课程学习,选择进入信工学院、深圳软件产业人才基地,以及金蝶软件集团校企合作部三方共同举办的“金蝶软件2015专才计划班”学习,学生离开学校,进入深圳软件产业人才基地学习,课程由金蝶软件校企合作部制定,学生完成学习并考核通过后直接到金蝶软件合作公司进行实习,由企业教师进行实习指导,并结合实习内容完成毕业设计工作,由企业与学院教师共同进行毕业答辩,学生不再回校学习,实习结束后直接进入相关岗位就业,目前有20位同学选择这个方向,正在实习之中,并已取得良好的效果。“3+1”模式是学院与长沙中软教育科技有限公司联合举办的软件开发技术实践班,学生在校完成三年的专业学习后,第四年进入中软广州教育基地接受软件开发方面的学习与实践,完成学习后进入企业提供的岗位实习,并在企业教师的指导下完成毕业设计工作,学生毕业后从事软件开发工作,目前有6位同学选择了这个班,并已进行企业学习。第三种模式就是剩下的学生继续留在学校完成四年的学业,经过这次改革,2012信管班60多名同学在专业能力提升方面有了更多的途径,对个人职业规划有了更明确的定位。

经过几年的改革与实践,留关学院提出以培养高素质应用型信管专业技术人才为目标,以服务学生为宗旨,以高质量就业为导向,以学院与企业教学资源协同共享为手段的应用与创新人才培养模式,建立校、企、学生多方受益的可持续发展的协同育人机制,建立“以项目驱动为导向、突出能力培养”为主的应用型人才培养教学体系。这些措施的实施将会满足信管专业学生各种能力培养需要,人才培养质量将会有大的提高。

3　结　语

通过以上分析可知,学生的能力培养是应用型人才培养的核心,传统的培养模式已不能满足现代社会对信管专业学生能力与职业素质的要求,普通本科院校要根据本校的专业优势,选择合适的企业进行合作,按照联合办学、协同育人的模式,才能培养出高素质的应用型信管专业人才。

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水平，目前在实践中尚存在两大问题：一是信息管理与信息系统专业现有课程体系不尽合理，相关课程具有内容重复与知识或缺问题，即课程中大家总会发现正在学习的课程内容往往都是以前学习过的或是相关类似的，不容易调动学生的积极性；二是与实践结合较弱，学生动手解决实际问题的能力不强，盲目照搬照抄成功模式，不能符合学校实际的培养目标，没有形成专业特色。信息管理与信息系统专业必须在专业人才培养上拥有自己的特色和优势，既要能在自己的学科课程体系中充分发挥，同时，要培养“像计算机科学家一样思考问题”的计算思维能力。改革信息管理与信息系统专业课程体系，明确面向计算思维能力培养的专业目标，提供满足社会需求的高级专门人才，是信管专业教学亟待解决的问题。

2　面向计算思维培养的信息管理与信息系统专业的教学目标定位

计算思维概念不仅仅局限于计算机科学领域的计算，也不应该仅仅涵盖计算机科学。它的本质是指在信息社会人们在面对大量的信息处理或计算的时候，应该通过非人工的方法实现，这其中包括，信息的表达和信息的转换两个过程。简单来说，计算思维就是利用计算机等工具实现信息的表达与转换等。同时，不能仅从计算机科学的角度去定义和理解计算思维，而应该从更广义的角度去认识计算思维。广义的理解计算思维，应该是指人们对于现实世界进行信息抽象并利用工具实现信息转换的一种思维方式。今日的计算思维是围绕计算机科学，而明日的计算思维或许会围绕化学、物理等学科，或许会产生新的学科，但核心一定是关于信息的表达和转换。

显然，计算思维能力的培养在信息管理与信息系统专业的教学目标中具有十分重要的作用，必须在专业人才培养目标上培养“像计算机科学家一样思考问题”的计算思维能力。因此，在信息管理与信息系统专业建设中应该将计算思维贯穿于素养的培养与知识讲授的教学过程中，但在实际的计算思维教学中存在一些问题：①没有意识到计算思维培养的重要性。计算思维概念的出现对信息管理与信息系统专业的人才培养提供了全新的思路和方向，目的是培养利用计算机分析问题和解决问题的意识与能力。②重技术教育，轻思维训练和人文素养、伦理道德的培养。目前的信息素养教育过多地强调信息技能的学习，忽视了思维训练，学生缺乏应用计算机知识和技能解决实际问题的能力。

因此，需要将计算思维能力的培养纳入到信息管理与信息系统专业的教学目标中。该专业是多学科交叉的边缘性学科，涉及管理科学、计算机科学、经济学、行为科学、运筹学等多学科的内容，同时，要强调学生的实践能力、服务能力，特别是求解实际问题的能力。信息管理与信息系统专业主要学习信息的存储、加工、处理，对一个计算机系统来说主要就是数据的操作，具体而言就是对数据的规范化处理，即按一定的格式存储起来，这是初级技术也是信管专业的基本技术；更高级一点的技术则是对数据处理后的查询、分析、挖掘，即信管专业与计算机相关但更着重于对数据的处理而不是整个系统的完整的开发。

3　面向计算思维培养的信息管理与信息系统专业的教学体系

为加强信息管理与信息系统专业学生计算思维能力的培养，适应社会对专业人才提出的新要求，确定教学体系是首要解决的问题之一。为此，我们主要从以下两个方面入手：一是强调IT技术，弱化现代管理理论与方法；二是强调求解实际问题的能力，即不但要掌握现代信息系统的规划、分析、设计、实施和运维等方面的技术与方法，还要强调具有现代管理科学思想和较强的信息系统开发利用以及数据分析处理能力。基于上述思路，我们设计了旨在培养学生计算思维能力的信息管理与信息系统专业的教学体系，见图1。

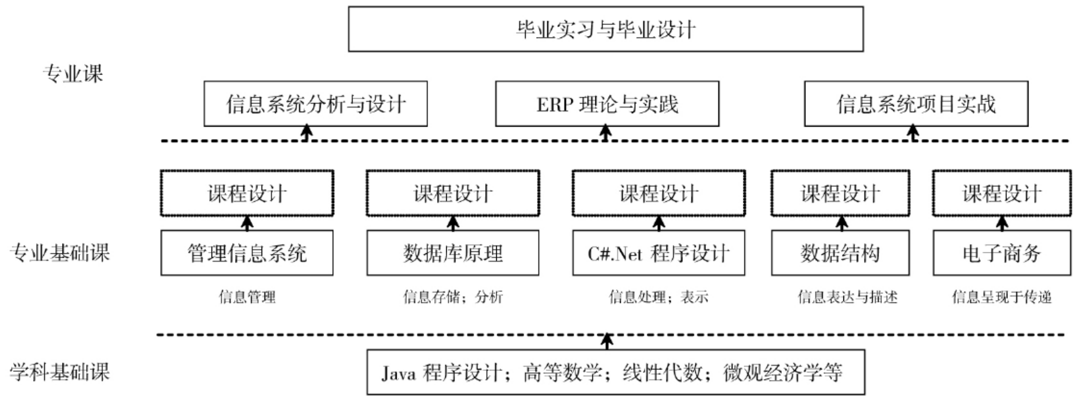

图1　面向计算思维培养的信息管理与信息系统专业的教学体系

上述课程体系主要围绕计算机科学与技术、管理学、管理科学与工程等主干学科，不仅设置了国内高校信管专业常设的管理学、统计学、管理信息系统、数据库原理与应用、数据结构与算法分析、计算机网络基础与应用、Java程序设计、电子商务等课程，还设置了数据仓库与数据挖掘、商务智能与人工智能等相关课程，使学生在理解新兴数据处理模式的同时，其智能化数据分析处理及决策支持能力得到训练。

4　面向计算思维培养的信息管理与信息系统专业的教学模式

任务驱动案例教学、课堂研讨等教学方法对培养和提高学生学习的自主性、主动性、创新性和协作性具有重要作用，是典型的基于计算思维的教学方法。在教学过程中，将这些教学方法恰当地运用到实践中，有助于奠定学生在教学活动中的主体地位，创建和谐活跃的教学氛围，提高教学效率以及学生的计算思维能力培养。为此，我们设计了面向计算思维培养的信息管理与信息系统专业教学模式，该模式以任务为中心，由其驱动教学过程进行，学生围绕任务学习，教师围绕任务教学，如图2所示。在这个过程中，要面向计算思维，通过搜集资料、深入探究、协作学习、交流讨论、巩固拓展、迁移新知、重组转换等手段，发掘蕴藏

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大数据背景下经管类专业Java程序设计教学模式探索

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[摘 要] 传统的Java程序设计采用教师在讲台上讲解PPT加上机模式,形式较单一,是面向单一技能的灌输式的培养教育方法。在提出大数据背景下,经管类专业Java程序设计的教学模式应充分利用网络资源,教学过程中要以数据处理为重要切入点,重在培养学生的数据分析能力。经过两年的实践教学表明,该模式显著提高了Java程序设计课程的整体教学水平。

[关键词] Java程序设计;大数据;教学模式

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1 引 言

在社会经济的发展过程中,信息和数据扮演着越来越重要的作用,特别随着"大数据"时代的到来,如何利用数据做出快速、准确的决策成为全球各国及企业所共同关注的重点问题之一。对高等学校,特别是经管类大学毕业生,培养数据分析能力,重视"数据意识"的培养,已成为人才培养的重要目标之一[1-2]。Java语言具有简单易学、高效、可移植性和安全等特性,随着Java语言的普及和应用领域的扩大,各大高校计算机与信息类相关专业纷纷开设Java程序设计课程。经管类专业教学中Java程序设计是在计算机基础课程上开设的,目的是培养学生利用现代信息技术分析、解决问题的能力,为各专业的学科基础课和专业课的学习提供技术基础[3-4]。

Java程序设计是一门典型的工科类课程,采用传统的PPT讲解加上机的教学模式,对经管类专业学生而言,存在学习积极性不高、学习效果差等问题。大数据背景下,经管类专业Java程序设计的教学模式与传统模式有较大差别[5]。如何让Java语言学习与现在所处的大数据背景结合,探讨适合大数据时代的经管类专业教学模式是目前高校教学亟待解决的问题之一。

2 存在的问题分析

Java程序设计是理论与实践结合密切的课程,在教学过程中大部分老师仍然沿用传统的教学模式,致使学生学习时出现理论与实践脱节。特别是大数据背景下,问题尤为严重,存在的问题包括目标主体不明确、忽视实践教学、学习知识不系统等。

2.1 教学目标主体不明确

传统的教学模式完全以教师为主体进行:由教师安排教学内容;由教师的理论教学为主、实践为辅;由教师设计实验,这严重忽视了学生在学习过程中的主体地位以及Java语言极强的重实践特性。尤其是,近年来教授该课程的教师大都为工科背景,在教学过程中往往按照计算机专业方法教学,导致学生学习的主观积极性和创造性不高,学生为过分依赖教师,不能独立的分析和解决问题[6]。

2.2 过分强调语言,忽视实践教学

语言是Java程序设计的基础,但是过分强调Java语言学习,忽视实践,会导致学生无法将理论与实践联系起来,让学生体会不到学习的目的,或者将来的具体的实际应用,从而对学习Java语言失去兴趣[7]。

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2.3 学习知识不系统

在传统的教学过程中,各知识点相对独立,不能形成完整的软件编程系统,只能编写一些孤立的算法实例,这种教学模式下学生对知识点的认识停留在表面,无法理解更深层次的含义,不能提高学生系统编程的能力。尤其是遇到一个完整的项目需求时,不能系统的给出项目的解决方案。

总之,传统的"填鸭式"教学模式下,学生仍然是被动学习,教师是教学的主导,由教师负责课程内容设计、实验课程设计、作业检查等。学生只能被动地按照教师所教授的步骤按部就班地执行,根本无从发挥自己的积极性和创造性。在大数据背景下,要以数据可视化为重要切入点,训练学生的数据分析能力,教会学生"用数据讲故事",为此,要改变传统的教学模式,设计适应经管类学生Java语言学习。

3 大数据背景下Java程序设计教学模式探讨

大数据背景下经管类专业Java程序设计课程的教学模式要围绕提高学生数据处理能力展开,注重学生自主学习和持续学习能力的培养。主要包括"网络教学+课堂教学";面向数据处理的案例教学以及基于数据分析的教学反馈等。

3.1 "网络教学+课堂教学"的教学模式

大数据背景下,网络中出现了很多在线教育平台,比如慕课教育平台,edX,Coursera,Udacity,以及学堂在线,中国大学MOOC,全国地方高校UOOC等。作为一种新型的教学理念与教学模式,网络在线教育打破了原有高等教育的资源体系,使得海量优质资源的共享共建成为现实。对于一般学习者来说,这种教学资源和学习方式,价廉而有弹性,有助于缓解教育公平的问题。随着越来越多的大学与教育机构参与到网络教学的开发,利用网络学习将逐步成为一种高度国际化的发展趋势。当然,网络教学模式的出现,也引发了社会对于学术自由、教育公平、商业模式等深层问题的思考。有学者认为,常春藤名校提供的优质教学资源,影响了其他大学教授的"学术自由"和"教学权利"等。从微观层面上来看,网络教学尚存在社会认可,商业模式,学分互认等问题[8]。

为此,将Java程序设计课程分为语言基础和面向对象技术两部分,在语言基础部分由学生通过网络教学平台学习考核;而面向对象技术部分由于理论部分较难理解,则在课堂由教师讲解,之后通过网络学习平台理解巩固。具体安排如表1所示。

3.2 面向数据处理的案例教学

Java语言在实际应用中才能体现出其应用价值。面向数据处理的案例教学,就是在Java课程的讲解中,改变传统的Java语言教学模式,采用一个或几个以数据处理业务作为案例实施教学。这些案例尽可能涵盖Java知识点,且难度适中,同时,数据业

表 1 “网络教学+课堂教学”的教学模式设计

序 号	章标题	教学模式
第 1 章	Java 语言概述	网络教学
第 2 章	Java 语言基础	网络教学
第 3 章	流程控制	网络教学
第 4 章	数组与字符串	网络教学
第 5 章	类与对象	课堂+网络
第 6 章	抽象、封装、继承	课堂+网络
第 7 章	图形用户界面编程	课堂+网络
第 8 章	网络编程	课堂+网络

务也要和学生专业相结合，充分体现出学以致用的学习目的，增强学生学习的兴趣与动力。如在审计专业的案例设计思路如下：

(1)转换角色。要将传统的以教师为中心转变为以学生为主导，教师在整个过程中起引导作用，重在讲解项目的流程以及需求，明确项目训练的目标，通过多种途径为学生提供学习资源，营造良好地协作学习环境。

(2)项目的选择。在面向数据处理的案例教学中，项目的选取尤为重要，一方面，选取的项目要依托于教学内容，同时又要考虑项目的规模和难度，还要兼顾学生所在的专业；在内容上既要包括基本的 Java 语言语法知识，还要体现图形用户界面设计；在实施时，既要考虑增强学生的编程水平，还要关注学生求解实际问题的能力，还要激发学生进一步学习的热情。

(3)项目的分工与合作。如果要实现良好地教学效果，有效地对项目进行分工是一个关键步骤。在教学环节中，一方面要对项目功能分工明确；同时还要考虑各分项目之间的接口易于实现，建立模块化的编程思想和规范有助于培养良好的职业素养和团队协作精神。

(4)项目评价。项目的评价很大程度上决定了面向数据处理的案例教学的成败，因此，要慎之又慎，确保项目的成果真正反映出学生的学习能力、解决问题能力以及团队协调能力都能。

基于上述考虑，在 Java 程序设计的教学中，设计了如表 2 所示的教学案例，这些案例大都以数据处理为中心展开。

表 2 面向数据处理的教学案例设计

章标题	案例名称	小组人数	考核内容
流程控制	(1)商品拍卖流程设计 I (2)约瑟夫环问题	3	需求是否满足；流程是否合理
数组与字符串	(3)银行业务数据统计 (4)企业财务分析	3	功能是否完善；算法效率高
类与对象	(5)银行信息系统类设计 I	2	设计需求是否满足
抽象、封装、继承	(6)银行信息系统类设计 II (7)证券公司员工类设计	2	实现是否合理
图形用户界面编程	(8)银行业务系统界面设计	3	界面美观；功能完善
网络编程	(9)商品拍卖流程设计 II (10)网络财务设计	3	设计界面；流程是否合理；功能是否完善

3.3 基于数据分析的教学反馈

大数据背景下 Java 程序设计课程的教学中要以数据可视化为重要切入点，在遇到学生感兴趣的话题时，可以在课内组织分组讨论，以交报告的形式汇报讨论结果；在遇到较难理解的理论问题时，先给出日常生活中的一些应用，让学生有一定的感性认识以后再讲解理论等。

同时，及时与学生沟通交流，就学生学习效果进行反馈，对提高教学质量，培养其解决实际问题的能力具有重要意义。湖南大学何人可教授指出："利用信息技术工具和交互理论，提供学生 Anylearn(Anywhere、Anytime、Anydevice)学习环境，…。"[9]为此，在教学过程中不断地通过网络工具获取学生在学习过程中的反馈，设计了包括教学内容、学习兴趣、学习效果、具体建议等反馈信息，依据学生的反馈情况，进行归纳、总结，进行系统数据分析，以指导下一步的教学工作。

4 结 语

经过近两个学年的教学实践，大数据背景下经管类专业 Java 程序设计教学模式的实施，不论是教学效果，还是学生反馈等方面均取得了显著效果。学生们的学习积极性和学习热情得到了充分调动，教师们也在教学中逐渐将教学的主导地位转向学生，不再是枯燥的课堂授课，取而代之的是一种面向数据处理的教学模式。总之，大数据背景下经管类专业 Java 程序设计教学模式，充分体现了学生的主体地位，提高了 Java 程序设计课程的整体教学水平。

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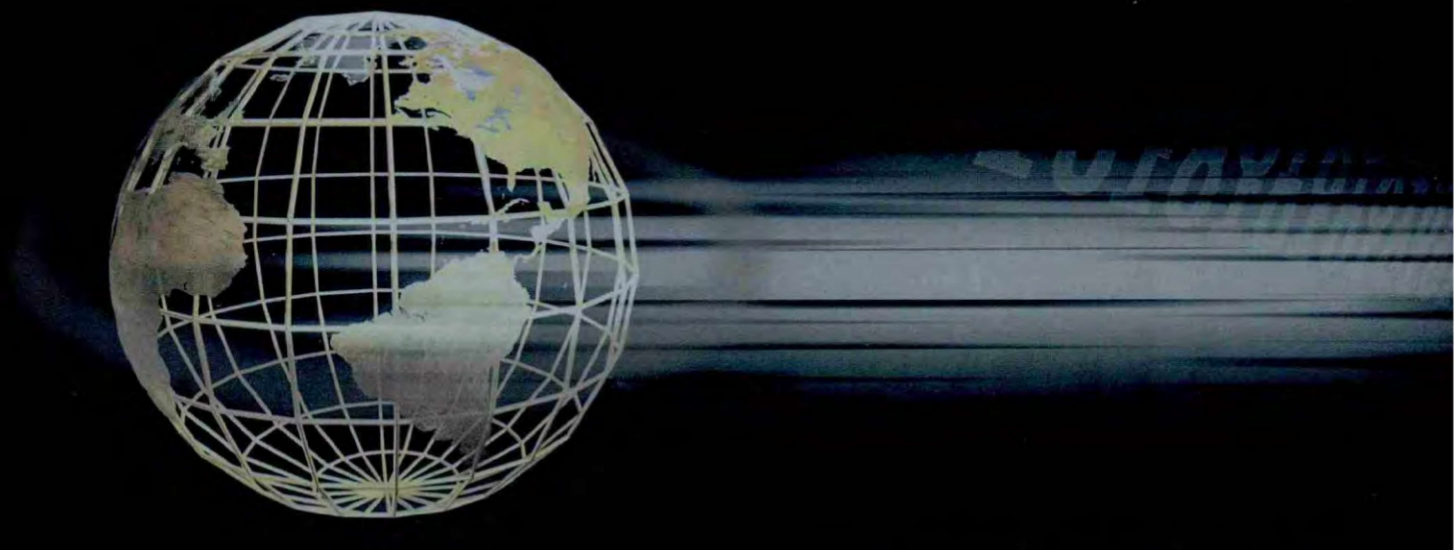

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大数据背景下经管类专业IT支撑课程群教学体系构建

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[摘 要] 大数据背景下,在经管类专业IT支撑课程群教学体系中增加数据分析、处理等内容,对提升学生综合素质具有重要意义。本文将IT支撑课程群分为低阶课程和高阶课程两部分,低阶课程为“计算机信息技术基础”,高阶课程包括编程语言类、数据库类、软件开发类等,以此构建大数据背景下经管类专业IT支撑课程群,以期提高经管类专业IT支撑课程群教学质量。从学生反馈以及考试结果来看,学生学习兴趣以及学习效果均取得了较大提高。

[关键词] IT支撑课程群;大数据;经管类专业
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1 背 景

参照国家教育部学科分类办法,经管类专业指经济学与管理学两个大的一级学科下的各专业。在经管类专业教学过程中,为培养学生利用现代信息技术分析、解决问题的能力,相关计算机课程的学习是必不可少的。山东财经大学的大多数专业为经管类专业,在本科一批中的招生人数占全部招生人数的75%以上(数据来源于我校招生信息网)。在前期专家论证和多年教学工作的基础上,我校目前已建立起能够贯通经管类专业的相关计算机类课程,作为学科基础课和专业课的先修课程,它们对各专业的后续课程学习形成有效支撑,称之为IT支撑课程群,在整个课程体系中的层次如图1所示。在我校的经管类专业教学中,IT支撑课程群主要包括Visual Foxpro (VF);Java语言;C++;Visual Basic (VB);Access等。多年教学实践表明,通过IT支撑课程的学习,一方面为下一步专业课程学习奠定有力的工具基础,另一方面为学生自身综合素质的培养、创新能力的提高提供技术支持。

近年来,云计算、物联网、社交网络等新兴服务,促使人类社会的数据种类和规模以前所未有的速度增长,从而迎来了大数据时代的到来。在大数据时代,数据成为继人力、资本后的一种非物质生产要素,“用数据说话,做科学决策”成为企业提高经营管理水平的必然选择。为提高公民整体素质,提高国家竞争力,培养具备基本的数据分析能力的高素质人才,成为各高等学校的人

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课程的作业信息;在线测试版块主要是提供一些课程的测试题目,让学生可以随时检验自己的学习成效;实践活动版块主要是提供学生实践活动的教学资源和教学任务;课程评价版块主要是介绍该课程的评价方式、评价规则等。这些信息都可以通过后台进行添加。

5.4 资源下载模块

资源下载模块主要是提供课程相关资源的下载,包括视频类、课件类等资源,资源主要格式有RAR、JPEG、DOC等,这些资源可以通过后台进行添加、删除。学生可以通过该模块下载自己所需的学习资源,进行自主学习,实现了资源的共享,也有利于学生的主动学习。

5.5 短信和留言模块

管理员、教师和学生可以通过该模块发布信息,运用短信息进行交流、学习,该模块主要包括学习通知、考试安排、作业布置3个版块,学生可以通过该模块了解课程最新的教学安排、作业等信息,教师也可以通过该模块及时发布课程信息,该模块是教师和学生进行交互的重要渠道,用户可以在模块看到彼此交流的状态,对短信进行回复、点评。这是目前的移动学习支持系统的基本功能之一,它可以支持基于短信息的移动学习模式。

通过留言模块,学生或者教师可以在该模块里面清楚地了解目前论坛的活动情况,他们可以在论坛上互相交流协作,共同讨论课程学习中遇到的问题。教师和学生可以在该模块上发表新帖进行互动交流,也体现了WAP 2.0注重交互的特点。

6 总 结

本研究将移动技术理念融于网络学习,以“计算机文化”课程为例,开发了一个移动学习支持系统。限于时间、精力和知识面,本研究对移动学习支持系统的研究尚存在许多不完善之处,还有许多工作需要完善。

(1) 继续完善系统的功能。该移动学习支持系统的功能还不够完善,如移动学习考试系统、移动博客的开发以及更多移动学习资源的设计与开发等,使系统功能实现多样化、实用化,以便更好地为广大师生服务。

(2) 完善系统应用的支持服务。在移动学习实施过程中,发现很多学生在移动学习过程中出现盲目、效率低下等现象,这跟移动学习支持服务不够完善有很大关系,我们将在以后的教学工作中进一步完善移动学习支持服务,使学生学习方向更明确,学习更有效。

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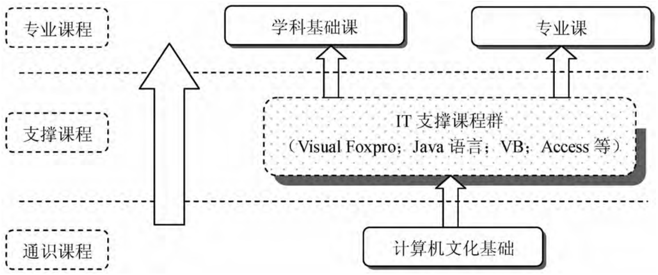

图 1 IT 支撑课程在经管类专业教学中的层次关系

才培养目标之一。我们要充分认识到，数据分析能力已成为经管类大学毕业生在职场中生存的一项重要技能，在学生的培养定位中要重视“数据意识”的培养，以应对社会对数据分析人才的强劲需求与高等学校经管类专业毕业生就业难并存的局面。

2 IT 支撑课程群教学体系存在问题与分析

目前，我校经管类专业 IT 支撑课程可以分为 3 类，即编程语言类、数据库类、软件开发类，如图 2 所示。

图 2 IT 支撑课程群

经管类专业 IT 支撑课程群的学习大都安排在入学后第二学期，在教学内容、教学方法上和计算机专业教学基本相同，与培养学生数据分析与处理能力的目标尚有一定差距。究其原因是教学内容设置中，缺少系统的数据收集、存储、管理等与数据分析相关的一些内容。同时，各门课程的教学资源未能实现有效的整合，比如编程语言仅仅是对编程方法进行讲授，缺少如何存储数据、连接数据库，实现对数据的分析等环节，数据库作为数据存储的主要形式仅以 Access 为例讲述，对目前作为大数据存储的重要工具，比如 SQL Server 以及 Oracle 等未涉及，缺少对数据存储、分析、处理等内容，因此不能为“统计学”和“市场调查与预测”等课程提供数据分析的工具基础。

在大数据时代，大规模、自动化收集相关数据成为可能，研究方式从问卷式、抽样化向自动式、全数据转变，从而实现更加全面、细致的研究。因此，构建面向数据能力培养的 IT 支撑课程群教学体系，培养具备基本的大数据收集、存储、表示、管理与分析等能力的经管类专业人才，是迫切需要解决的问题。

3 大数据背景下经管类专业 IT 支撑课程的教学体系构建

为提高经管类专业学生信息思维能力、数据分析能力，我们围绕数据处理构建了 IT 支撑课程教学体系，将 IT 支撑课程群分为低阶课程和高阶课程两部分。低阶课程为“计算机信息技术基础”，高阶课程包括编程语言类、数据库类、软件开发类等；低阶课程为必修，高阶课程为多选一选修模式。如图 3 所示。

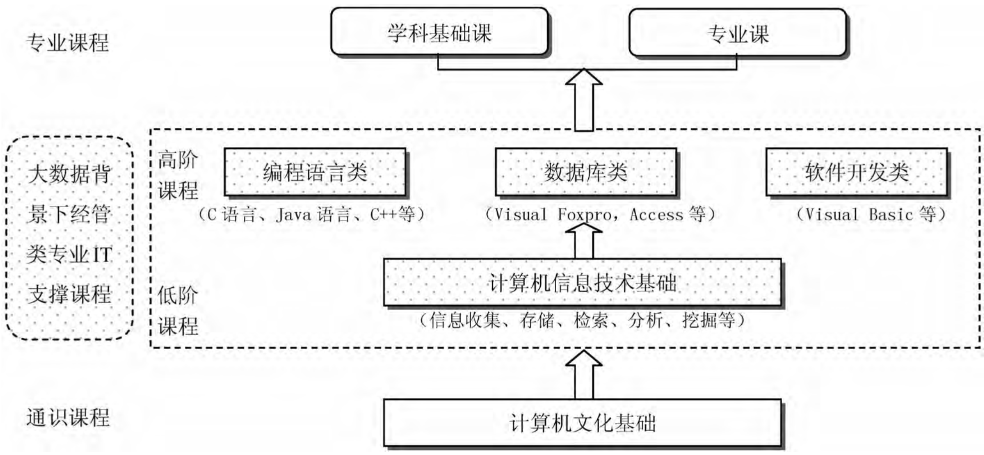

图 3 大数据背景下经管类专业 IT 支撑课程的教学体系

具体来说，大数据背景下经管类专业 IT 支撑课程的教学体系，最底层为全校通识课程“计算机文化基础”，该课程主要是要求学生掌握基本的计算机操作能力、熟练应用 Office 软件等。在此基础上，将大数据背景下经管类专业 IT 支持课程分为低阶课程和高阶课程两个阶段。低阶课程为“计算机信息技术基础”，目的是让学生了解大数据时代下信息技术的发展现状和趋势，特别是结合经管类学生的专业特点，介绍相关的数据分析处理技术及其原理，内容主要包括“信息处理技术基础”和“大数据时代的数据分析”两个部分。“信息处理技术基础”主要是以信息作为核心，将信息处理的过程（信息准备、信息传输、信息加工处理、信息存储、信息展示）全面展开，同时介绍大数据时代下特有的技术，例如数据存储技术、并行处理技术、移动计算技术以及云计算技术等，如图 4 所示；“大数据时代的数据分析”部分主要介绍大数据时代的数据处理方法、基于大数据的数据分析以及具体应用等。

图 4 围绕信息处理组织课程内容

高阶课程安排在低阶课程之后，主要是强化处理数据的练习，突出数据可视化理念，重点讲解不同的数据可视化技术的应用场景，使学生具备自主选择可视化工具、清晰表达观点的能力。选取编程语言类、数据库类与软件开发类3类，将所有财经类专业按不同大类的专业特点具体安排课程内容与教学计划，使其与各专业的教学体系有效结合与渗透，对专业基础课形成有效支撑，达到培养学生数据分析与处理能力的目的。高阶课程教学安排见表1。在当前的教学计划、培养方案不做大的调整情况下，低阶课程和高阶课程的授课时间仍为一个学期。具体两者之间的时间分配可以通过实践教学活动调整。

表1　高阶课程内容设置

	编程语言类	数据库类	软件开发类
授课课程	C语言；C++语言；Java语言	Visual Foxpro；Access	Visual Basic；Visual J++
课程内容	模块1 语言基础 模块2 流程控制语句	模块1 数据库基础 模块2 数据库编程方法	模块1 软件设计基础 模块2 软件编程方法
	模块3 数值分析		
对应专业	工商管理；市场营销；财务管理；会计学	经济学；保险学；审计等	物流管理；管理科学与工程

4　实践与总结

山东财经大学是一所经管类高等院校，目前拥有56个本科专业，其中绝大多数为会计、工商管理等管理与经济类专业。在新修订的本科教学计划中，要求培养具有专业理论基础和实践能力，能够从事经济分析、预测、管理等工作的应用型人才。因此，旨在培养具有较高数据分析能力的、大数据背景下经管类专业IT支撑课程群教学体系构建成为必然。为实现这一目标，我们积极探索面向数据处理的教学。每学期末，都要对学生从教学内容、教学效果等方面进行问卷调查，并对学生考试成绩进行分析，结果见表2。通过近两年的教学实践来看，取得了较好的成果。

表2　各学期教学效果评价调查情况

时　　间	教学内容满意率(%)	教学效果满意率(%)	学生成绩高分率(%)
2013–2014学年第1学期	82	78	76
2013–2014学年第2学期	87	85	82
2014–2015学年第1学期	94	93	85

在探索面向大数据时代的经管类专业IT支撑教学体系构建过程中，还有很多工作要做，在下一步的教学研究中，我们将对大数据背景下经管类专业IT支撑课程教学模式以及考核模式设计等进行探讨。

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教育教学研究 JIAOYU JIAOXUE YANJIU

财经院校电子商务专业实践教学体系研究

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摘　要 本文以山东财经大学电子商务专业为例,以培养电子商务高级应用人才为目标,构建"以学生为主体、教师为主导"多维度、模块化、立体化电子商务专业实践教学体系,并从实践教学目标体系、内容体系、管理体系、保障体系和质量评价体系等5个方面进行了论述。

[关键词] 财经院校;电子商务专业;实践教学体系

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1　引　言

近年来,电子商务给世界贸易格局和经济增长方式带来巨大的变革。电子商务在各领域的广泛应用降低了企业经营、管理成本,促进了资金、技术、信息、产品、服务等在全球范围的流动,推动了经济全球化的发展。电子商务的应用已成为决定企业竞争力的重要因素之一。目前,电子商务已成为我国中长期发展纲要、"十二五"规划的重点方向,2012年教育部最新版的《普通高等学校本科专业目录》将电子商务升级为一级专业类,反映出电子商务已成为当前社会经济发展中的支撑行业,也体现了国家对电子商务的高度重视。

电子商务是一门以经济学、管理学、计算机科学、法学为基础,以基于互联网的商业贸易为核心的电子事务应用作为研究对象,为社会培养电子商务应用人才的综合性、边缘性学科。电子商务专业旨在培养既懂信息技术又懂商务管理的复合型人才,因此其实践教学体系建设至关重要。目前社会对电子商务专业毕业生实践能力的要求不断提高,如何进行有效的教学改革、完善实践教学体系已经成为当前电子商务专业建设亟待解决的问题。

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2　山东财经大学电子商务专业人才培养目标

按照山东财经大学(以下简称"我校")"培养理论基础扎实、知识面宽、实践能力强、综合素质高、具有国际视野的应用型人才"总体培养目标定位,我们在对社会人才需求、电子商务专业人才培养现状、培养目标进行分析的基础上,提出了"加强信息技术与商务融合,以实践能力培养为主线"的电子商务专业复合型高级应用人才的培养目标。具体来说,我校电子商务专业培养具备管理、经济、法律、计算机、电子商务等方面知识,具备人文精神、科学素养和诚信品质,能在企事业单位从事网站网页设计、网站建设维护、企业商品和服务的营销策划、客户关系管理、电子商务项目管理、电子商务活动的策划与运作等工作的应用型、复合型人才。根据学生兴趣分电子商务开发技术和电子商务运营管理两个专业方向进行培养。

3　构建电子商务专业实践教学体系

由于电子商务的变革几乎涉及人类经济生活的所有方面、所有层次,而不同方面和层次又各有其自身的特殊性,这就使得企

验,没有亲身经历过具体的业务环境,很难达到预想的实践效果。虽然也有一些教师有实践工作经历,但现代社会新知识、新技术层出不穷,会计领域改革频繁,教师实践技能可能跟不上知识的发展变化。另外,对专业教师来说,由于理论教学与科研的压力,在实践指导上投入的精力往往有限。

2　改进中职会计专业实践教学的有效途径

2.1　完善实践教学体系

中职会计专业实践教学应构建完整的实践教学体系,课程设置应体现具体的实践性内容,既包括专项实践性教学,又包括综合实践性教学;既包括校内实践内容,又包括校外实训任务。因此课程设置应体现理论与实践课的匹配,树立"理论够用,实践为重"的教学理念,让学生边学边实践。同时要结合教学规律和学生的认知规律,形成系统的实践训练模块,包括认识教学模块和技能动手模块。另外实践教学计划应满足实践能力培养的要求,逐步安排进行,先进行单项训练,可以随堂进行必要的训练;再进行综合训练,课程结束后进行集中综合训练;毕业前进行岗位模拟实习,通过仿真实训室进行岗位业务核算。这样形成完善的实践教学体系,有利于学生实践能力的提升。

2.2　规范实践教材编写

实践教材是实践教学的指导,是实现实践教学的重要基础。选择实践教材应突出知识性、应用性、启发性、可操作性,将有关的内容融入实践教材中。同时实践教材还要增加新理论、新政策。

2.3　加强实训基地建设

校内实训注重模拟实践,学校加大投入,完善模拟实训室,配置相应的设备,建立仿真性强的实训室。实训室应包括手工和电算化模拟实训室,确保基础设备和所需资料齐全,提高学生的实践操作能力。学校可以多渠道建立稳定的校外实训基地,推行工学结合、校企合作等人才培养模式。同时有条件的学校可以成立代理记账公司、会计师事务所等,不仅能给学生增加实训的机会,还能把产学研有机结合起来。

2.4　丰富实践教学形式

要引导学生深入理解所学内容,必须丰富实践教学形式,采用多种形式的教学方法。教师可以用多媒体展示教学内容,增强内容的真实感,调动学生的积极性,激发学生兴趣。同时实践教学中教师可以边讲边练,让学生明白所以然。对一些操作性、技能性较强的问题,教师可以做示范,并让学生当堂练习,从而提高学生的动手能力。

2.5　加强师资队伍建设

实践教学中必须注重"双师型"队伍建设,进一步完善师资队伍结构。一方面学校应积极加强对教师实践能力的继续教育,鼓励教师到企业兼职,以提高其实践能力与动手能力。另一方面应从企事业单位聘请一些经验丰富的高级会计人才到校承担实践教学工作,这不仅能提高实践教学质量,还能促进教师专业知识的交流。

业、社会对于电子商务人才的需求是多层次、多元化的。因此，普通高校应该按照社会和企业对电子商务专业人才的需求，结合本校的办学风格和特色，对电子商务人才培养目标进行合理规划和定位，把学生实践能力和创新能力培养放在教学的核心地位。

电子商务学科的特性和社会对电子商务人才多层次、多元化的需求，决定了电子商务教学必须创新教育教学理念，采用灵活多样的实践教学方法，以培养学生实践能力和创新创业能力为导向，构建电子商务专业“以学生为主体、教师为主导”多维度、模块化、立体化实践教学体系。

我们在对高等院校电子商务专业实践教学体系现状分析和社会对电子商务专业人才的需求预测基础上，结合经济社会对电子商务人才的需求变化，在深入研究电子商务专业的知识体系、技能体系和专业胜任能力基础上，依据专业人才培养目标和能力分解目标将电子商务专业实践教学体系分为实践教学目标体系、实践教学内容体系、实践教学管理体系、实践教学保障体系和实践教学质量评价体系等 5 部分。构建适应社会需求的电子商务专业实践教学体系不是一蹴而就的，它是一个闭环、迭代的过程(如图 1 所示)。需要根据实践教学质量评价体系的结果反复修订优化实践教学体系其他几方面内容。

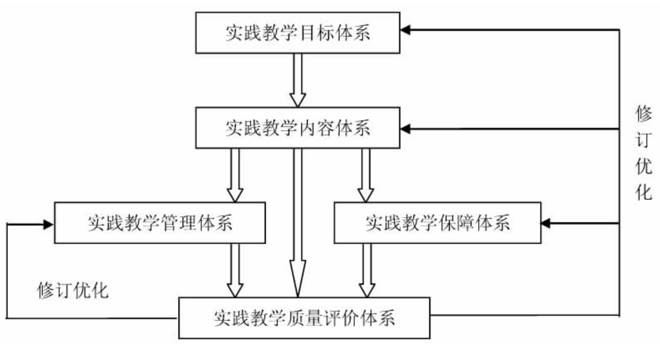

图 1　电子商务专业实践教学体系架构

3.1　构建多层次、动态化的电子商务专业实践教学目标体系

电子商务专业实践教学目标体系是实践教学体系的核心，它应该根据社会需求的变化不断进行调整，是动态化的。构建电子商务专业实践教学目标体系必须以电子商务技术发展和社会对电子商务人才的要求为背景，以基本能力训练为基础，以专业综合素质培养为核心，以创新创业精神教育为主线，确立电子商务专业实践教学体系的总体目标是：基本认知能力—专业胜任能力—创新创业能力。电子商务专业的实践教学目标是培养具有创新精神的高素质应用型人才。

3.2　构建层次化、模块化的电子商务专业实践教学内容体系

电子商务专业实践教学内容体系是实践教学目标体系的具体实现，是一个层次化、模块化的体系。电子商务专业应用性较强，为了实现专业培养目标和教学目标，实践教学活动包括基本认知性实践、专业综合性实践和创新创业性实践，通过三类实践教学活动的递进提升学生的专业技能和职业素质，提高学生的实践能力和创新能力，为学生的就业、创业奠定基础。实践教学环节由课程实验、素质拓展与职业技能培训、课程设计、学年论文、研究设计型实验、社会实践、社会服务、科技创新活动、专业综合实训、创业教育与实践、毕业实习、毕业设计(论文)等模块组成，各模块之间的功能相互衔接、互补互动。

3.3　构建科学规范的电子商务专业实践教学管理体系

电子商务专业实践教学管理体系包括实践教学组织管理、制度管理和质量监控。

3.3.1　实践教学组织管理

由学校对实践教学进行宏观管理，制定相应的管理办法和措施。各二级学院作为办学实体，具体负责实践教学的组织与实施工作。

3.3.2　实践教学管理制度

为充分发挥实践教学的作用，提高学生的实践能力，达到理论与实践相结合、培养学生创新能力和创新精神的目的，应在实践教学环节制定详细的管理制度和考核制度。制定“开放性实验教师守则”“开放性实验学生守则”“仪器设备保障与管理办法”“开放性实验考核办法”和“开放性实验室管理制度”等教学管理制度；建立网络教学平台和开放实验管理系统。

3.3.3　实践教学质量监控

建立由教学实验考核办法、课程设计考核办法、学生实习考核办法、毕业论文(设计)考核办法等环节构成的一整套开放式教学质量监控体系。实践教学质量监控的对象包括实践教学人员和学生两部分；对实践教学人员的监控内容主要有出勤、工作态度、完成实践教学工作量、教学总结等；对学生的监控内容主要有出勤、学习态度以及实验报告、调研报告、实习报告等完成情况。

3.4　构建电子商务专业实践教学保障体系

实践教学保障体系由师资队伍、实验室软硬件设施和教学环境 3 个方面组成，对实践教学起着支撑、保障作用。

3.4.1　加强实践教学师资队伍建设

教师是实践教学的组织者和指导者，实践教学师资队伍的建设是开展实践教学的重要保证。因此专业的实践教学要求指导教师既具有较强的专业理论水平，又要有较强的实践操作技能。没有高素质的实践教学师资队伍，实践教学任务和目标完成质量难以保证。因此，“双师型(讲师+导师)”教师队伍建设是构建实践教学体系的基础。

在师资队伍建设上，一是立足于内部挖潜和培养，出台优惠政策，鼓励教师进修学习，提高学历、学位、学识，尽快让教师从单一的课堂讲授型向讲授和实践结合型转变，鼓励教师进企业，顶岗实践，鼓励教师到行业挂职锻炼，鼓励教师拿第二证书，申报第二职称。

3.4.2　切实规范和完善实验室建设

按照规模、结构、质量、效益上一个新台阶的发展思路和实践教学目标体系的有关要求，集中力量与条件建设好电子商务专业实验室，深化“人、机、教师、实训室合一”的实验环境建设，为提高教学水平和育人质量提供良好的物质保障。

3.4.3　建立与完善校内外实践教学基地

要确保各种实践活动按计划进行，有步骤地组织学生到已经建成的实践教学基地进行现场教学、间歇性实习、毕业实习或毕业设计。突破仅限于感性认识、技能训练的旧模式，使之成为学生实践能力、创新能力综合教育训练的课内外实践教学基地。要建设相对稳定的校外实习基地，改善实习条件，健全实习管理规章制度。尽可能做到同实习单位相关工作优势互补、互利互惠，取得校外实习单位的理解和支持。通过实习工作，努力把实习基地办成教改实验基地、生源基地、毕业生就业基地。

实践教学保障体系建设已成为影响实践教学效果的重要因素，其成功与否决定着实践教学的成败。

3.5　构建多主体、多层次、高效的电子商务专业实践教学质量评价体系

教学质量是高校的生命线，提高人才培养质量是高等教育

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基于社会需求的信息管理与信息系统专业人才培养模式研究

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摘　要 近年来大学生就业问题成为社会关注的焦点之一,因此高校如何培养出能够满足社会需求的专业人才成为当前高校的研究热点。根据多年的教学实践,本文提出财经类院校在教学实践中,应关注经济发展前沿、把握市场需求导向,根据社会对信息管理与信息系统人才的多样化和层次化需求,着力构建与完善既符合当代经济社会实际需要,又体现各自培养特色的需求导向型培养模式。

[关键词] 信息管理与信息系统;人才培养;模式;社会需求

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0　引　言

"人才培养模式"是高等院校为被培养对象构建的知识、能力、素质结构以及实现培养功能的具体方式,它从根本上确定了被培养对象的基本特征。"基于社会需求的人才培养模式"是指在人才培养的整个过程中,以社会需求为导向开展教育教学建设及各项人才管理工作,同时实施与之相适应的规范与灵活并重的培养模式。

近年来大学生就业问题成为社会关注的焦点之一。本质上,大学生就业难的原因不是总量问题而是结构问题,主要原因在于长期以来,我国的高等教育学科专业设置与培养普遍遵循供给导向型原则,专业设置与市场需求出现脱节。传统的人才培养模式与人才知识结构、素质结构,已经不能适应我国经济发展的实际。因此,解决大学生就业难的问题,关键在于利用劳动力市场提供的信号,按照社会需求的规律改革与完善高等教育体制,构建与创新需求导向型人才培养模式。换言之,教育部门应根据市场人才供求的动态信息,及时地进行学科、专业和教学内容的调整,以较好地适应与满足市场的需求。显然,建立这样一种市场信号生成机制、传导机制和调整机制,需要需求导向型的教育机制与创新型人才培养模式的建立和完善。

当前,知识经济正以全新的姿态迅速兴起和发展,并爆发性地向全球扩张。伴随着新技术革命浪潮的层层推进和经济结构的不断变化,即使发展非常迅速的信息管理领域,毕业生就业态势也日趋严峻,竞争异常激烈,综合素质和社会适应能力已逐渐成为信息管理人才需求与竞争的焦点[1]。在这种形势下,具有完备的知识结构、敏锐的创新意识与精神、完善的人格与较强社会适应能力的信息管理与信息系统专业综合性人才,才能胜任相应的岗位,并必然会得到市场的青睐。因此,财经类院校在教学实践中,应关注经济发展前沿、把握市场需求导向,根据社会对人才的多样化和层次化需求,着力构建与完善既符合当代经济社会实际需要,又体现各自培养特色的需求导向型信息管理与信息系统人才培养模式,努力为经济社会发展培养更多的实用型信息管理与信息系统人才。

1　国内外研究现状

目前国内外有关于人才培养模式的探讨与相关研究已有很多[2-3],总体来说,人才培养模式主要包含3个要素:教学制度、教学模式和人文环境,大部分的研究内容主张高等院校的人才培养应该在以下方面努力:面向社会实际、强调学科交叉、重视能力培养、加强实践环节、培养团队精神、训练系统思考和创新能力等。

当前针对信息管理与信息系统专业人才培养模式的研究主要问题表现在以下方面。

1.1　专业定位模糊

国家教育部《普通高等学校本科专业目录和专业介绍》[4]中对信息管理与信息系统专业的培养目标做了明确规定,但其表述具有高度概括性且较宽泛。很多学校的专业教师在对专业培养方案以及教学大纲的制定过程中,就会由于理解的模糊而造成一定偏差;从而致使该专业的学生,特别是刚刚踏入校门的新生对其所学专业的发展方向和将来的就业方向感到更加迷茫。很多高校的信息管理与信息系统专业教师是原来从事管理专业或者计算机专业教学的,就很容易从自己专业的角度出发,简单机械地把该专业分为管理发展方向和计算机发展方向。而实际上,信息管理类专业除了要开设计算机专业的信息技术类课程外,还要注重管理信息系统的设计与开发能力的培养。

从专业人才培养过程来看,很多高校的培养方案和课程体系上存在缺陷。一是专业课程的设置,没有按照知识获取行为的习惯来安排先导课程和后续课程。二是不注重实践教学环节,忽视了本专业作为交叉学科的特点,缺乏让学生应用所学知识,进行综合能力锻炼的必要手段。三是专业课程之间的必要联系体现不够深入,信息管理相关的基础理论与信息技术类课程衔接不紧密,使得学生学完相应课程后主动灵活地应用所学技术进行设计和开发较难,限制了学生能力的提高。

从现实的角度分析,信息技术已广泛应用在现代企业管理中,企业的管理理念、管理思想和管理方法发生了根本变化。信息技术同样深刻地影响着当代经济社会的各个方面。如何培养能够快速适应科学技术的发展,符合社会实际需要的学生,是信息管理类专业人才培养的又一重要课题。

1.2　培养模式混乱

目前信息管理类专业的定位体现在3类课程上:第一类是通识类课程,如高等数学、外语、思政类等;第二类是经济管理类课程,如管理学、经济学、会计学、财务管理等;第三类是信息技术类课程,如编程开发、操作系统、网络通信、数据库等。该培养模式没有形成有效的交叉学科专业课程体系,仅仅是把多个学科的课程简单拼凑,课程衔接不紧密,知识体系不健全。另外,许

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多院校的信息管理与信息系统专业培养方案不尽相同，观点上也存在着很大的分歧。教育部 1998 年的《普通高等学校本科专业目录和专业介绍》中确定的课程包括：经济学、会计学、市场营销学、生产运作管理、组织战略与行为学、管理学原理、应用数理统计、运筹学、计算机系统与系统软件、数据结构与数据库、计算机网络、信息管理学、信息组织、信息存储与检索、管理信息系统分析与设计等[4]。以上课程若要按照模块划分，则应该有：经济学知识模块、管理学知识模块、计算机知识模块和信息管理知识模块等，针对这一方案，各高校意见不统一，表 1 是几种典型的课程模块化方案对比。

以上方案中，各校普遍达成共识的是包括基础素质知识模块、现代信息技术模块、信息管理与信息系统专业知识模块和专业学科背景知识模块。由此可见，专业培养的首要目标是要解决专业知识结构的系统性。

2.3 实验室基础条件差，实验和实训环节薄弱

信息管理与信息系统专业具有理论与实践结合紧密的特点，特别要求专业教师具有工程实践经验。但是当前很多新教师硕士或博士毕业后直接走上讲台，缺乏具体信息化工程实施的经验。由于教师无法从实践中领会信息化实施方法的本质，只能照本宣科进行理论传教，使得学生更加无法切身感受到信息技术对企业现代化建设的重要性和关键性。因此，专业教师的知识更新和工程实践经验是当前存在的严峻问题。另外大家误认为信息管理类专业属于管理科学，存在对管理类专业实验室认识的误区：相对于理工类实验室，管理类专业实验室需要大量投入，但是产出较少，甚至为零。因此，各高校宁愿大量投入资金建设理工类实验室，也不愿将资金投向管理类专业实验室。另外，部分高校对理论教学人员和实验教学人员在待遇等方面不同等对待，严重损害了实验教学人员的工作积极性。由于以上存在的问题，导致信息管理类实验室的建设明显滞后于社会对于人才培养的需求，使之无法发挥其在人才培养中的重要作用。

2 改革方案设计和解决问题的方法

2.1 改革方案设计

表 1 几种典型的课程模块化方案对比

	课程模块				
方案一	基础素质知识模块	文献信息科学知识模块	计算机与数据库知识模块	专业学科知识与相关学科知识模块	
方案二	科学文化知识基础和语言工具知识模块	经济学知识模块	现代信息技术模块	专业化课与专门化课模块	学科背景知识模块
方案三	政治课基础课	专业基础课	专业技术课	专业延伸课	背景知识课
方案四	数学物理基础模块	信息技术基础及应用模块	信息管理理论与方法模块	经济与人文社会科学知识模块	
方案五	信息管理理论及技能知识模块	现代信息技术及应用能力知识模块	应用领域知识信息开发技能层的知识模块		

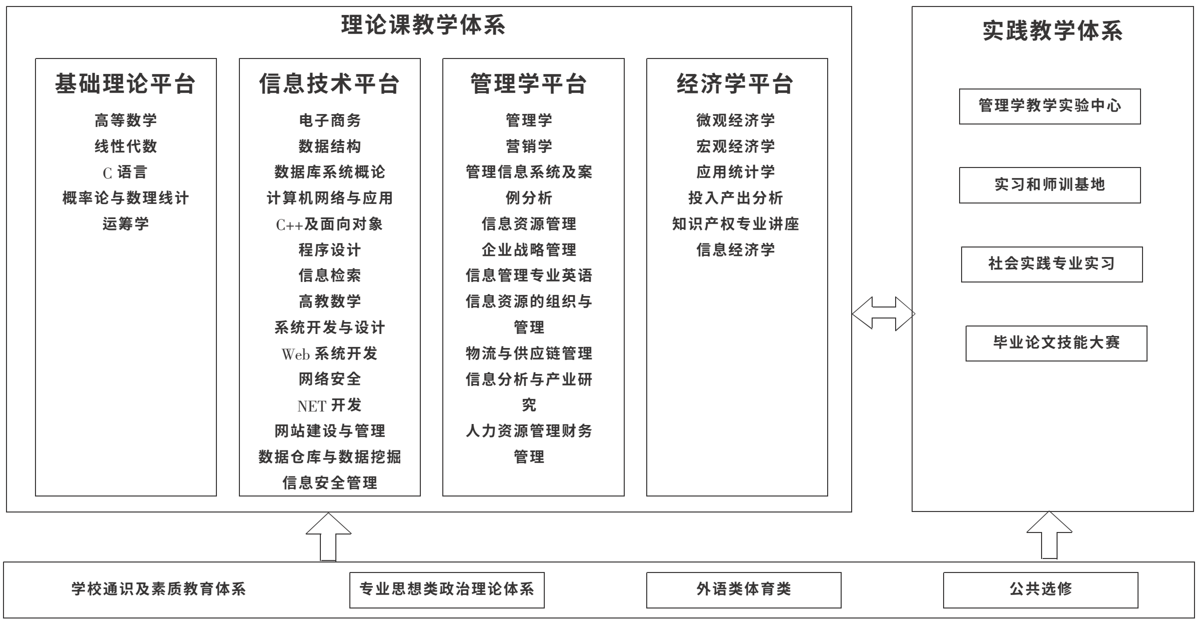

图 1 信息管理与信息系统课程体系

由图 1 可以看出信息管理与信息系统专业涉及的专业知识范围较为广泛，由于信息技术发展更新速度快，课程教学任务和工作量繁重，而专业学时有限，因此，创新专业教学改革和建设尤为重要。

(1)改革信息技术模块类课程。对信息技术模块类课程进行相应改革，使学生能够有效利用信息技术，把管理类课程中学习到的反映企业各项工作的运行状况的指标、管理与决策问题，结合在数学课程中学习到的各种定量方法，分析问题和解决问题。

(2)改革实践教学环节。围绕行业背景和专业培养目标来构建各种实践教学环节，形成环环相扣的实践教学链，以提高学生的基本实践能力、专业胜任能力和创新能力为目标，完善和改革现行的信息管理与信息系统专业实践教学目标体系、实践教学内容体系、实践教学管理体系以及实践教学质量评价体系，构建出本专业“四位一体”的闭环实践教学体系(见图 2)。

(3)改革教学方式，创新教学手段。更新教学理念，鼓励学生勤思考、多分析，并加强学生动手能力、实践能力的训练。利用现

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经管类专业Java语言程序设计课程教学改革与实践*

吴修国，陈 洁

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摘 要：经管类专业与理工类等专业在学习Java语言程序设计课程时，不论是在教学方法还是教学内容上，都存在诸多不同。针对目前教学中存在的授课对象不明确、教学内容、重理论轻实践、考核形式单一等问题，以山东财经大学经管类专业为例，从认识课程学习意义、合理安排教学内容、增加案例教学、加强实验教学等方面，总结了近年来Java语言程序设计课程在教学方面的改革与实践经验，以期提高经管类专业计算机编程类课程的教学效果。从学生反馈和考试结果来看，改革成效明显。

关键词：Java语言；程序设计；经管类专业；应用

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Reform and practice of Java programming language for economics & management specialties

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Abstract: There are great differences from methods to content between economic & management specialties and science & technology specialties in java program language teaching. Aiming at problems such as unclear teaching objects, over-professional teaching contents, focusing on theory rather than practice and single form of assessment, strategies including understanding the meaning of curriculum, arranging content reasonably, adding case teaching, and improving the teaching experiments are proposed, in order to enhance the quality of teaching effect in Shandong University of Financial and Economics (SDUFE). The student's feedbacks and score show that learning interest and effect have greatly improved in the past five years.

Key words: Java language; programming; economic & management specialties; application

0 引言

参照教育部学科分类办法，经管类专业主要包括经济学与管理学两个大的一级学科下设的各专业。在经管类各专业的教学中教授面向对象程序设计语言类的课程，一方面可以让学生掌握一门计算机编程语言，为其解决管理类问题提供有力的工具基础；另一方面，可以增强其逻辑思维能力，进一步提升其管理水平[1]。Java语言作为面向对象程序设计语言的典型代表，自推出以来即被看作最具生命力的计算机编程语言，特别是其“一次编程，各处运行”的特点，使其成为网络时代的重要编程工具之一。我国经管类高校的相关专业也大多开设了程序设计课程，如：上海财经大学、南京财经大学、东北财经大学、西南财经大学以及南京审计学院等[2]。

目前，在经管类专业中开设Java程序设计课程存在一定的难度，特别是随着面向对象概念的引入，不论是教师还是学生均对这门课程产生了诸多怀疑，传统的教学模式亟需要改革以适应课程和学生发展变化的需要。

1 经管类专业Java语言程序设计课程教学现状及存在的问题

目前，多数经管类专业的计算机课程的教学是以计算机应用为基础进行的，该课程的主要目的是让所有学生掌握计算机的基本操作，学会使用计算机；而Java语言程序设计是在掌握该课程的基础上要求学生能利用计算机解决问题。在目前的教学过程中，尚存在以下问题。

1.1 授课对象不明确

教授Java语言程序设计的教师大多是计算机或相关专业的专业人员，在授课时往往采用的是针对计算机专业的教学形式，重点讲程序设计的理论知识，课下让学生自主去完成练习。然而，经管类学生认为财经管理类专业的学生今后不会从事程序设计工作，学习程序设计没有用处，所以课下自主练习根本不可能完成，逐渐地对该课程失去兴趣，在教学的效果上将大打折扣[3]。

1.2 教学内容太专业

如果纯粹从Java语言程序设计本身而言，面向对象的设计

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方法包括类、封装、继承、多态、异常处理、多线程等，这些是课程的重点，也是难点。对于经管类专业的学生，对该课程普遍感到课程枯燥、难理解、难记忆，如果按部就班地讲解，很容易让学生产生厌烦情绪。

1.3 重理论轻实践

对于程序设计类课程来说，实践是检验学习效果的重要手段。尤其是对经管类的学生而言，实践显得非常重要。一方面可以加深巩固对理论知识的理解；另一方面，可以提高学生学习的兴趣。而经管类学生常常把学习Java语言程序设计当成文科课程来学习，只注重理论，不注重实践[4]。

1.4 考核形式单一

考核是检验教学成果的重要形式，同时也是教学的一个“指挥棒”，考试的内容、形式从另一方面决定了教学的效果。传统的笔试形式会使很多经管类的学生宁可去“背”程序也不去思考程序的编写过程[5]。

2 教学改革与实践的探讨

针对以上问题，如何让经管类专业学生对Java程序课程提高学习兴趣，改善学习效果，提高教学质量，近年来我们做了一些尝试。

2.1 充分认识学习本课程的意义

需要让学生充分认识学习本课程的意义，从思想上重视课程的学习。可从以下几个方面考虑。

⑴ 对大多数经管类专业的学生而言，将来从事的职业与金卡、金关、金税、金财等一批重大的信息系统工程相关，其就业的单位信息化程度都很高，要能够胜任该领域工作，需要具备一定的程序设计基础知识。比如审计专业的学生而言，目前尚无也不可能设计出统一的审计软件，这要求审计工作者必须掌握简单的编程技能才能在工作中针对不同的行业进行审计。

⑵ 经管类专业培养的是高级管理人才，这要求他们不仅要具备良好的专业知识，同时还应具备与信息技术人员良好的沟通能力，通过该课程的学习，可以有效提高学生对计算机原理与方法的理解。

⑶ 对现代大学生而言，掌握计算机编程的基础知识对培养学生良好的信息素养具有重要意义。

2.2 合理安排教学内容

学生对Java语言程序设计不感兴趣的一个主要原因是：传统的大而全的教学内容极大地削弱了学生学习的热情。学习Java不仅是为了多学习一门更为流行的编程语言，更是学习面向对象的开发技术。为此，我们列出了各章节学习内容，如表1所示，其中分为必学和选学两种形式，前7章为必学内容，最后一章为选学。

表1 Java语言程序设计教学内容

章	章标题	主要内容	类型	案例
1	初识Java语言	了解Java程序；Java程序的种类、特点；Java程序的开发工具NetBean等。	必学	案例1：一个简单的Java应用程序 案例2：一个简单的Java Applet程序
2	Java语言编程基础	数据类型，变量和常量表达式和运算符，Java输入与输出等。	必学	案例3：约瑟夫环问题(josephus) 案例4：随机生成学生数据
3	流程控制语句	分支结构语句、算法以及描述方法、if语句、switch语句。	必学	案例5：“拍卖”流程设计(1) 案例6 ：判断一个数是否为回文数程序
4	数组和字符串	数组的声明与使用；字符串类的使用方法。	必学	案例7：“议价”流程设计 案例8：“博弈”程序设计
5	面向对象程序设计方法	对象的概念；类的概念；封装、继承、多态的概念。	必学	案例9：股票类的设计与实现
6	图形用户界面设计与实现	JApplet；委托事件处理模型；Java图形类的实现方法等。	必学	案例10：“拍卖”流程设计(2)
7	数据库编程	数据库访问方法；记录的的查询、插入、删除、更新等。	必学	案例11：社保审计设计 案例12：银行循环担保问题设计
8	Java高级程序设计	多线程；异常处理；网络编程等。	选学	案例13：网络聊天室设计

2.3 以案例教学为主

一般而言，案例教学是提高学生学习兴趣、激发学习热情的重要手段之一。目前教材上的例题大多测试对语法知识的应用，内容比较枯燥，形式单一，不能有效吸引学生的注意力。如果在教学过程中结合经管类专业的特色，使学生能明白Java语言在他们专业工作中的作用，将极大地提高学生学习兴趣。例如：在学习流程控制语句时，以“拍卖”过程作为案例讲解，代码篇幅不是很长，复杂程度不高，但可以清晰地描述程序的执行流程；同时，引导学生在此基础上进一步的扩展。代码如图1所示。再如，数据库编程部分可结合审计工作中经常用到的数据采集方法。这些方法都能有效调动学生的学习兴趣，使他们对一些新的技术产生学习激情，起到事半功倍的效果。在教学过程中，我们一共设计了13个案例，见表1。

```
…
while(AuctionTimes<=3)
{  highest_price=gethighest_price();
   if (cur_price<Highest_price)
   {  Cur_price= Highest_price;
      AuctionTimes=0; }
   else
      AuctionTimes=AuctionTimes+1;
}
…
```

图1 “拍卖”案例的代码设计

2.4 加强实验教学

把编程当成文科的课程学习，不重视实践，这是大多数经管类专业的学生学不好Java语言的一个重要原因。Java语言作为一门实践性很强的课程，一定要让学生深入到实践中去，深刻认识到编程是“练”出来的，而不是“背”出来的。Java语言的实践包括课堂练习、上机实践和课程设计等，最重要的是上机实践。在实验内容的安排上应该针对相关知识点出题，并注意题目之间的难度，循序渐进，把握验证类与设计类上机题目之间的比例；在选题来源上也可以从认证考试、计算机等级考试或企业招聘试题中选题。

3 教学改革与实践情况

山东财经大学是一所经管类高等院校，目前拥有56个本科专业，其中绝大多数为会计、工商管理等管理与经济类专业。在新修订的本科教学计划中，有多个专业选择将Java语言程序设计作为其程序设计教学的内容，比如工商管理、旅游管理、人力资源管理、房地产管理、市场营销等。为了促进教学质量的提高，促进学生理论水平和实践能力的发展，我们一直就课程的教学内容、教学方法、教学模式等进行探索。每学期末都要对学生从教学方法、教学内容、教学效果等方面进行问卷调查。通过对近五年（2008-2012）的教学来看，教学取得了不错的成效。学生满意度调查如图2所示。

在探索经管类专业计算机编程类课程的教学过程中，无论是对教学方式的思考，还是对实验环节的思考，都是为了激发学生学习的兴趣，提高学生编程能力，培养出适应社会需求的经管类人才。我们尽管取得了一些成绩，但还远远不够，下一步将继续探索一条适合经管类专业的Java语言程序设计教学模式。

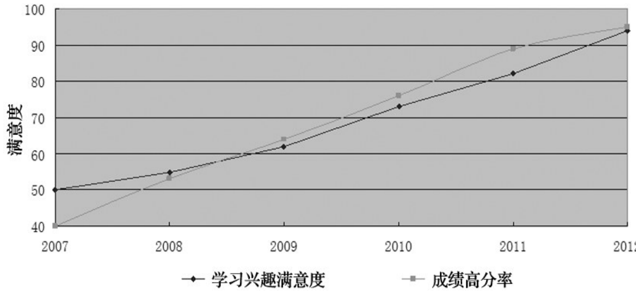

图2 各年教学效果评价图

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（上接第48页）

能型人才的培养质量，随着校企合作的层次不断深化，实践教学内涵建设成效将逐步显现。

4.5 鼓励学生获取专业网络资格认证

学生在完成学业的同时，教师应该鼓励学生获取专业网络资格认证，为毕业生提高就业竞争力，比如全国计算机等级考试网络工程师、数据库工程师、Cisco公司的网络技术认证、MCSE微软认证系统工程师等。通过这些专业资格认证的考试的准备和资格的获得，可以帮助学生明确自己的专业方向，提高专业兴趣和专业自信心。另外，要鼓励学生积极参与各级各类的专业网络竞赛，如H3C杯竞赛、ITAT竞赛以及其他竞赛。通过参与竞赛，拔高学生的网络技术运用的能力、拓展视野、培养创新精神和团队合作能力。

5 结束语

计算机网络课程实践教学的改革是一项长期的、复杂的系统工程，需要学校、教师、学生、社会共同不断的探索和努力才能获得更好的效果。包括实践教学计划的合理制定、实践教学的目标定位，以及改革和实施创新实践教学方法等各个方面。需要分层解决、稳步推进，才能达到把学生培养成应用型、创新性、复合型计算机网络人才的目标，让教育回报社会。

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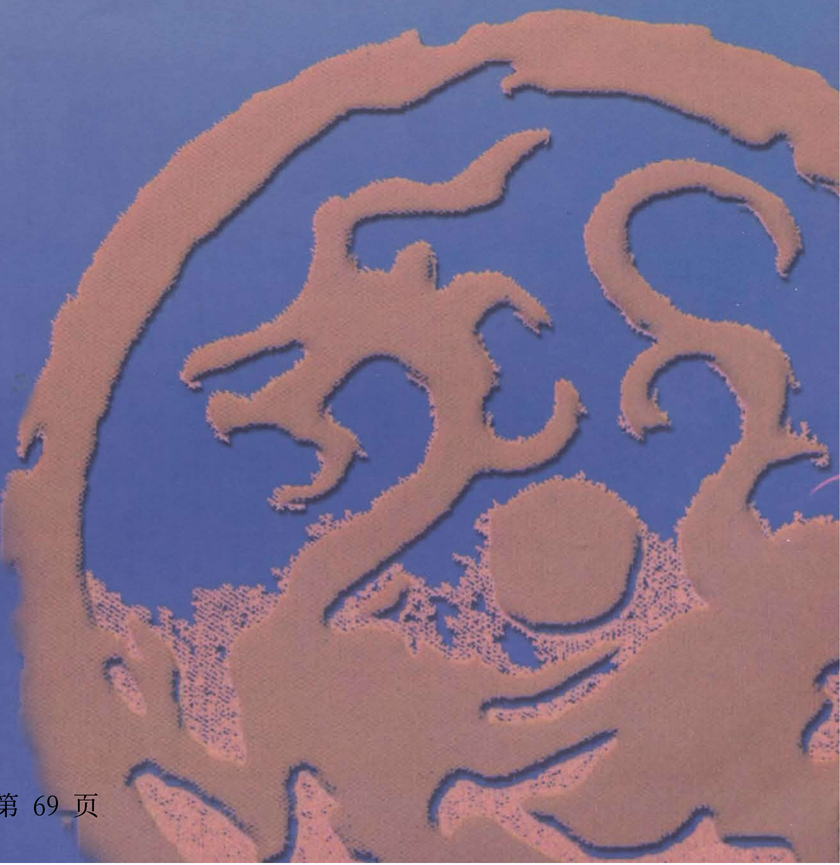

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财经院校电子商务专业人才培养模式研究

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摘 要:电子商务是一门新兴的交叉性学科,本科专业建设正在不断完善的过程中,专业人才与社会需求还存在较大差距。以山东经济学院电子商务专业为例,提出了“加强信息技术与商务融合,以实践能力培养为主线”的电子商务专业复合型高级应用人才培养目标,并在课程体系整合、实践教学、师资队伍建设和培养模式探索等方面进行了论述。

关键词:电子商务专业;人才培养模式;实践教学
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引言

电子商务是一门以经济学、管理学、计算机科学、法学为基础,以基于互联网的商业贸易为核心的电子事务应用作为研究对象,为机关、企事业单位输送电子商务应用人才的综合性、边缘性学科。进一步明确电子商务专业的培养目标、建立和优化符合教育部要求的、科学合理的人才培养计划和教学计划,设置和优化符合实际需要的理论教学体系和实践环节,是电子商务专业的当务之急。作为向社会培养和输送专业人才的高等院校,如何在新的教学理念指导下,改革传统的教学模式,构建有利于培养电子商务专业创新人才的教学模式,培养大量的电子商务创新人才,这既是当今时代对高等教育提出的改革与发展要求,也是时代赋予高等院校教学的新任务。

本文从适应社会发展需要出发,在实现信息技术与商务融合的基础上,对我校电子商务专业的人才培养模式方面做一些研究和探索,在电子商务专业的学科建设、专业方向调整方面做出适应社会形势发展需要的改革与创新,以培养适合工业化和现代化建设的复合型高级应用人才。

一、我校电子商务专业人才培养目标

我校提出了“强基础、宽专业、重能力、高素质、求创新、创特色”的本科教育原则,把更新教育理念、优化课程体系、压缩课堂理论教学课时、拓宽专业口径、增加实践教学课时作为重点,使教学内容能够更好地反映学科专业的最新研究方向与发展趋势,以切实增强学生的学习兴趣,完善学生的知识结构,促进学生个性全面发展。

电子商务是基于经济学、管理学、计算机科学以及法学等多个学科的交叉学科,也是一个跨专业、面向技术、管理和经济等多个层面、注重将工程化的方法和人的主观分析方法进行结合的一个学科,因此,课程设置、课程内容以及实践教学需要体现在信息技术应用中体现管理思想和商业模式,在解决管理和经济问题时应用先进信息技术。

鉴于以上分析,我们在对我校电子商务专业人才的培养现状、培养目标进行分析的基础上,对电子商务专业人才培养模式进行了深入研究,分析了电子商务专业实践教学的意义,提出“加强信息技术与商务融合,以实践能力培养为主线”的电子商务专业复合型高级应用人才的培养目标,并将电子商务专业分为两个培养方向:电子商务开发技术和电子商务运营管理。

二、整合课程体系

1.确定核心课程。我校在充分调研的基础上,确定了数据结构、网络数据库设计、计算机网络、电子商务分析与设计、管理学原理、会计学原理、西方经济学、运筹学、网络营销、管理信息系统、电子商务物流管理、电子商务运营管理和电子商务案例分析 13 门核心课程。这些课程体现了电子商务专业具有“信息技术与商务融合”的特色。

2.依据培养方向,整合模块选修课程。两个培养方向在公共基础课、学科基础课以及学科必修课方面没有差别,不同之处体现在专业模块选修方面。电子商务开发技术方向开设的模块选修课程为:J2EE 原理与开发、网页设计与制作、网络数据库设计、电子商务安全技术、嵌入式技术、多媒体技术、IT 项目管理、网络支付与结算等。电子商务运营管理方向开设的模块选修课程为:网页设计与制作、网络营销、电子商务运营管理、网络经济概论、电子商务案例分析、电子商务法规、电子商务安全技术、电子商务物流管理、网络支付与结算等。学生在进行模块选修的时候根据兴趣可以选择两个方向的课程,使教学内容能够更好地反映学科专业的最新研究方向与发展趋势,以切实增强学生的学习兴趣,完善学生的知识结构,促进学生个性全面发展。

三、以实践能力培养为主线,加强实践教学

实践教学是让学生通过一定的实践活动将理论与实际相结合,从而使专业人才培养目标得以实现。实践教学具有深化知识的作用,是教学过程的重要环节。理论教学只能使学生达到理性认识阶段,它必须经过转化,才能将知识转化

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为智慧和真正的内在力量。实践教学具有强有力的整合知识的作用，可以将专业知识和信息资源按照系统化与有序协调的原则进行整理融合，以达到最优化的效果。

围绕我校在“十一五”发展规划中提出的培养应用型高级专门人才的目标和要求，在电子商务专业的培养模式中大力加强实践教学，切实提高大学生的实践能力，具体表现在：

1.提高实践教学的学分、学时比例。在整合后的课程体系中，实践教学的学分达到 38 个学分，专业必修课和模块选修课中实验学时比例达到 30%以上。

2.改革实践教学内容。在主要课程中启动开放性实践教学环节的改革，设置较多的开放性、设计性、综合性的实验，培养学生实践应用能力。主要课程设计性、综合性实验占 60％。例如，在《电子商务分析与设计》专业课程中，参考国外经典原版教材，课程详细介绍电子商务系统开发的主流方法和每一个步骤，并设计了这门课程的实验指导书。

3.改进实践教学方法。增加学生开放性实验的内容和时间，以专业实验室为依托，组建学生专业教学创新基地，充分利用专业实验室的人员、场地、设备等现有条件，为学有所长的学生开展科学研究创造良好的环境；教学采用国外流行的学生分组的方式，模仿软件项目开发团队开发软件的过程来进行实验，学生在实验过程中锻炼其系统分析和实际设计实现的能力。

4.改进毕业实习（设计）流程。在电子商务专业方向实习中，通过组织学生观摩企业电子商务系统和运作流程，鼓励学生自主选题，在教师的引导下，自己动手，创造性地开发中小型系统，培养了创新意识和吃苦耐劳的作风。有的学生毕业后未出试用期就委任为项目小组负责人，受益匪浅。通过种种措施提高培养的质量，使得我院的毕业生在社会上得到认可，具有比较好的口碑。

5.加强实践基地的建设。学生实践能力的培养要有实践基地作保证。我们采用两种方式建设实践基地：第一种方式是建设校内实验室，加大投入，保证基本实践技能训练，通过教学内容和教学方法（如开设设计性、综合性、创新性实验、沙盘实验或实习项目）的改革，使其具备创新内涵。第二种方式是建立校外实践基地。这种方式为学生走出学校，体验真实的社会环境建立了良好的基础。组织学生参加科研课题，激励学生的创新精神，教给学生分析问题和解决问题的能力，培养了学生创造性的学习方法。

四、加强师资队伍建设

1.提高教师的业务水平。通过鼓励教师参加学术会议、国内外进修或攻读博士学位等方式培养在校青年教师；大力引进电子商务相关专业毕业的研究生，在补充教师队伍时，尽量吸收不同高校的毕业生，使教师队伍具有良好的学缘结构。

2.进行广泛的学术交流。邀请国内外名校、名师及优秀的企业家和相关专业的专家到校讲学，把国内外最新的信息及时传递给教师和学生。每个学校具有不同的办学特色和创新理念，通过组织相互学习、专题研讨等各种方式，提高教师的业务水平、更新思想观念。

3.课程主讲教师参与项目实施工作。每门主要课程至少重点培养二至三名教师，其中，一名教师为主讲教师（课程负责人）。新教师到校后，明确其今后的教学与科研方向，部分课程聘任兼职教师授课，尽量创造条件鼓励教师参加工程实践，如参加纵向课题或企业委托课题的研究，作为技术人员参加相关项目实施工作，实现学校与社会的有机结合。

五、积极探索新的培养模式

1. 211 培养模式。以开放式、走出去办学为指导思想，积极探索与科研单位、企业联合培养学生的新模式，争取确定“211”的培养模式。“211”模式是指学生四年本科教育期间，两年的管理科学与工程学科背景下的宽口径专业通识教育，培养“厚基础、宽口径”、具有自主学习能力的高素质创新型人才；一年的电子商务专业课程教育，根据学生兴趣分方向培养电子商务开发技术或电子商务运营管理两个方向的专业人才；一年的电子商务专业课外实践教育，通过“产学研结合”和“校外实践基地建设”，使电子商务专业的学生在大学四年级能够参与本专业教师的横向和纵向科研课题的研究或到校外实践基地实习，为学生提供实践和锻炼机会；最后通过毕业设计或毕业论文环节的学习和实践来巩固和检验本专业的学习成果。

2.企业培训考核与学校学分互认模式。我校积极探索与企业合作办学新模式，该模式由企业针对企业需求制订教学计划和教学目标，充分发挥高校理论水平和授课技巧上的优势，由高校讲师讲授理论基础知识，为学生打下坚实的理论基础；实战课程由企业的项目经理带领学生完成，讲授一系列企业所需的知识以及进入企业项目组进行实际开发，熟悉企业开发流程、实用技术、工作方法和企业文化等，并使学生养成良好的工作习惯和心态。经过培训，学生在毕业后整体素质将得到极大的提升，可以立即进入企业工作。这样的合作模式，不仅可以解决学生的就业困难，也为学校教学改革和开放式办学积累了经验，同时也为企业提供了一批优秀的高素质人才，实现了学校、企业、学生的三方共赢。

总结

随着信息技术在中国传统行业和领域的不断渗透，信息技术和电子商务在各级政府和企事业单位得到广泛的应用，社会需要大量的既懂商务运营管理又懂信息技术的复合型人才。因此，在新的教学理念指导下，探讨电子商务专业人才的培养模式，培养大量的复合型创新人才，是时代赋予高等院校的职责。本文从适应社会需要出发，在实现信息技术与商务融合的基础上，对我校电子商务专业的人才培养模式作一些研究和探索，在专业的学科建设、方向调整和培养模式等方面做出适应社会发展需要的改革与创新，以培养适合社会主义现代化建设的复合型高级应用人才。

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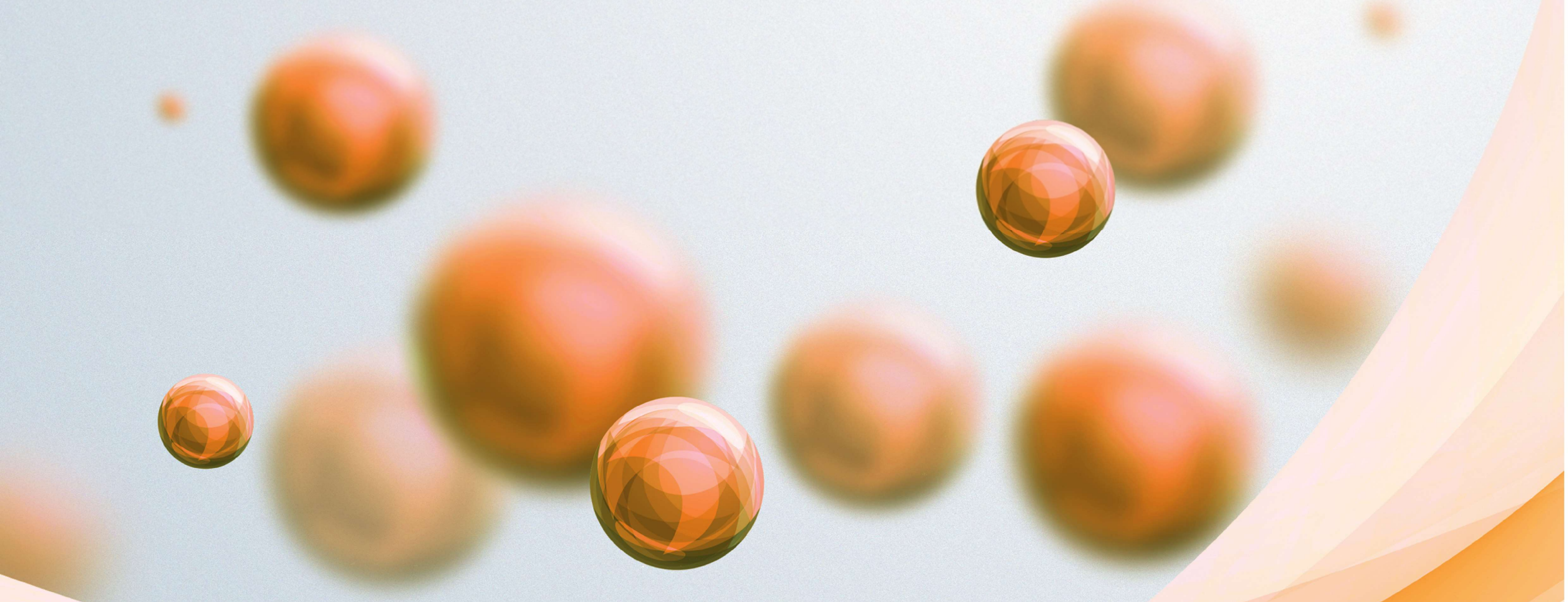

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计算机相关专业的IT基础教学的困境、思考与探索*

陈 洁，吴修国

(山东财经大学，山东 济南 250014)

摘 要：在各专业对信息技术需求不断提高的背景下，文章分析了当前计算机基础教学普遍存在的困境和原因，通过一个省级精品课程群的建设和研究成果，介绍了将信息技术与专业知识融合的基于案例驱动的计算机基础课程教学模式的建设经验和心得，并对在计算机基础教学框架中引入计算思维的意义进行了初步探讨。

关键词：课程建设；计算机基础教学；教学改革；计算思维

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The predicament, thinking and exploration on IT fundamental teaching of computer related specialties

Chen Jie, Wu Xiuguo

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Abstract: In the context of increasing demand for information technology in various professions, this article analyzes the current predicament and its causes in basic computer education. Through the construction and research results of a provincial-quality course group, the experience of building a case-driven computer-based curriculum teaching mode that integrates information technology and professional knowledge is introduced. The significance of introducing computing thinking in the basic computer teaching framework is discussed.

Key words: course construction; basic computer teaching; teaching reform; computational thinking

0 引言

信息技术与各专业不断融合是当今时代的发展趋势，各专业对于计算机基础教学的内容和深度要求越来越高。自本世纪初开始国内外高校都存在两个变革趋势，一是将更多的计算机理论引入到计算机相关专业和非计算机专业的培养方案中，二是将计算机基础教学与专业教学融合[4]。

目前高校的理工、经管、社科、人文等几乎全部的专业都对计算机基础教育有一定的要求，但在内容和程度方面存在很大差别。理工和经管类专业对信息技术的要求越来越高，培养方案和教学理念都在不断变革。计算机相关专业的计算机基础教学，大致经历了三个阶段：从开始的面向操作技能培养到逐步引入计算机基础理论，从重视理论教学到重视"计算思维"的培养[1,7-9]。

笔者在财经类普通高等院校从事计算机基础教学近三十年，开设过十几门计算机基础课和专业课，曾经担任八年信息管理学院教学院长，负责制定全校50多个不同专业的计算机基础教学培养方案和课程建设（其中多数为经管类专业，少数为人文社科类专业，个别为理工类专业）。为了追赶信息技术的知识更新速度，我们的教学团队每二年对培养方案进行一次微调，每四年进行一次大调整，而某些具体课程的教学大纲几乎是年年更新。正如何钦铭教授所说："如何在有限的教学时间内完成内容宽广的大学计算机基础教学目标，仍然是近年来困扰广大从事大学计算机基础教学的教师的核心问题"[2,5]。我们教学团队面对全校4万多不同专业的本科生，多年来一直进行着

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计算机基础教学的教研与教改，希望通过本文与同行分享我们的心得和困惑，共同思考和探索解决之道。

1 困境和思考

我校的信息管理与信息系统专业有一个软件外包培养方向，按照校企合作的要求，在4年的培养方案中设置了大量的计算机基础课程，开设了程序设计语言、数据结构、计算机网络和数据库等课程。3年前我们对该专业首届毕业班进行了一次调研，结果只有22%的学生对今后从事专业对口的软件外包工作感兴趣，大部分学生将从事与计算机相关性很小的工作。还有一个工程管理专业，在我们进行了国内高校的调研之后，确定规划两个培养方向，一个是以土木工程为背景的工程管理方向，另一个是以软件工程为背景的工程管理方向。由于人才市场和师资因素，我们本希望有更多的学生选择后者，并且专门对学生进行了动员（在大二的下学期要求每个同学根据自己的兴趣选择专业学习的方向）。结果该专业全体学生选择了前者。

信息技术无疑对各学科各专业越来越重要，也越来越受到重视。计算机基础教学可以分为四个层次。首先受众最多的是通识教育，几乎全部专业都需要。其次是那些应用信息技术较多的专业，需要学习一些专业的数据处理软件和编程语言（这类专业将越来越多，如上述的工程管理专业）。再次是计算机相关专业的计算机基础教学，在深度和广度上都有较高的要求（包括许多理工类专业，如上述信息管理与信息系统专业）。最高层次是计算机学科各专业的计算机教学。在培养方案设计中，根据不同层次的要求，将计算机基础课设置为通识、选修、辅修、主修等课程类别，同时根据专业差异对各课程内容和难度也进行适当调整。

在过去的三十年中，计算机科学技术是所有学科中发展最快、影响最广的学科，没有之一。计算机基础教学一直处于与时俱进的发展和演进中。尽管如此，教学内容还是会或多或少地滞后于学科发展和社会需求。教材教学内容和教学改革一直在教师、学生和社会之间的互动过程中不断更新和进行，期间经历了许多的纠结和困境。

有些课程是入门比较容易，但深入理解却比较困难（如当下最热门的python程序设计语言）。而有些课程入门较难，但是一旦入门就比较容易进行自主学习（如互联网技术）。多数人文社科课程、经济管理课程属于前者，即使学生有不少难点暂时不理解，通过死记硬背也可以初步掌握基本知识。但多数计算机基础课程属于后者，如C++、JAVA程序设计语言，即使背过所有的定义和语法，死记硬背各种程序，如果不能理解，还是没有学懂没有入门。理工类课程的特点是知识之间的关联度高，往往一步跟不上处于被动地位，追赶起来非常困难，而一旦理解领会了精髓，后续的学习比较容易自主进行。也就是说，在学习的初期，计算机基础课程较一般的经管类课程的入门难、门槛高、学习曲线陡。对于理工类专业或计算机专业不存在这类问题。我们的信息管理与信息系统、物流管理、电子商务等专业，都需要较强的信息技术的支持，我们的培养目标是既懂管理又懂信息技术的高级专业技术人才。但是几届学生普遍的结果是，大多数学生基本放弃了信息技术的学习，转向了管理方向。究其原因，是学习信息技术的门槛比学习管理专业课的门槛高，多数同学知难而退，选择在相对容易的领域发展。我们必须承认不同专业在思维方式上是存在差异的。

面对全校各专业的计算机基础教学，我们首先要根据各专业培养目标确定开设哪些计算机基础课程以及这些课程的性质（通识、选修、必修等），其次是修订各课程的教学大纲，再次是课堂教学、实验教学、课程设计、题库等各个教学环节的课程建设工作。通识课和对信息技术要求不高的专业开设的计算机基础课程是比较容易处理的，已经有相当多的经验和模式可供借鉴。问题主要集中在信息技术相关专业的计算机基础课程的教学上。

很多信息技术相关专业是学校新上专业，有些是国务院学位委员会新设专业，如电子商务、物流管理等，这些专业通常是经济管理和信息技术的结合，培养相关领域的技术管理人才。这些专业需要开设大量的经管类课程和信息技术课程。各专业对计算机基础课程的重视程度不同，兴趣点和精力投入的差异也很大。在课时量和教学内容的深度上不容易把握平衡。存在着两个极端的认识，一是计算机“狭隘工具论”，认为计算机不过是一个高效率的工具，对本专业的基本框架没有本质影响。另一个“泛计算机化”，过度迷信信息技术对专业的影响。

从学生层面看，计算机相关专业的总课时量一般都比较多，他们既要学习本专业的知识又要学习计算

机知识。如会计电算化专业,他们学习会计专业课程的深度不如会计专业,开设的计算机课程更不如计算机软件专业,但是他们的总课时量却高于这两个专业。人的精力是有限的,该专业的普通同学会有这样一种挫败感,会计方面不如专业学会计的,信息技术方面不如学计算机的。

对于非理工类学生,计算机基础课程难度相对较大。加之压缩课时量,减少实验课,师生比小(一个自然班约50人)等因素,导致多数学生的计算机学习不仅没有入门,反而增添了畏惧感。不敢做题、不敢大胆编程,没有求知欲,只是在死记硬背的恶性循环中勉强应对考试。

2 一个成功的探索

计算机相关专业的计算机教学不能等同于计算机专业的计算机教学,也不是通识教育层面的教学。我们的切入点是如何让信息技术能够真正为专业工作服务。“经管类IT支撑课程群”便是在上述背景下立项的一个省级精品课程项目[6]。教育部高校电子商务专业教学指导委员会副主任李琪教授认为,类似信息管理与信息系统、电子商务等经管类专业,IT课程量应占总课程量1/3左右[3]。以此为依据。我们将JAVA,C++(C#),数据结构,数据库,WEB应用与开发等5门各专业共同的专业基础课组织在一起,由教学团队进行统一的课程建设,通过系统地学习这组IT基础课程,基本能够支撑经管类各专业对于信息技术的需求。

原本上述课程都有自己的课程大纲、教案、课件、实验教程,甚至题库等,但课程之间的衔接存在一些缝隙,不同课程存在不少重复介绍的知识。如程序设计语言课程重复介绍面向对象程序设计方法论,不同课程课后练习题类似和相同等。为此,教学团队决心将这一课程群打造成为一个有机整体,支撑经管类各专业的IT培养需求。对课程群进行统一建设可以系统地解决一些问题,可以更高效地利用课堂教学和实验教学的时间。

该项目的亮点之一是精心选择课程的教学案例,尽可能为不同的专业选择与专业相关的信息技术案例,这些由浅入深的案例便于学生的理解,提高学生的学习兴趣,同时在专业学习上也有一定的获得。多数经管类专业属于文理交叉学科,许多学生的动手能力不强。我们设计的基于案例驱动的教学模式,是建立在建构主义学习理论基础上的,同时也有利于培养自学能力和自主解决问题的能力。

为了适应被压缩的课时(如数据结构只有54学时课堂教学,36学时实验教学),我需要减少教学内容,降低难度。以课程群为单位优化课程体系,在一定程度上可以补偿教学内容的不足。为了实现课程群中各门课程间的无缝连接。我们将整个课程群的教学内容当作一门课程看待,进行系统和统一的设计。裁剪掉重复的教学内容,对于相近的教学内容采取前详后略的原则。设计统一的教学案例系列,教学案例尽可能融入各种经济管理中的模型和方法,以适合经管类学生的特点。每个教学案例具有独立性,前后案例之间具有连续性和过渡性。某些教学案例之间具有一定的关联,若干教学案例组合在一起能够形成一个相对完整的小系统,这些小系统可以进一步作为课程设计和学年论文的内容。

总之,对于计算机相关专业的计算机基础课程的教学,我们的观点是应当尽可能早地将专业知识与信息技术进行融合。让学生深刻体会信息技术对于专业工作的重要价值。

3 依然存在的问题

信息技术与专业知识融合式教学改革,需要占用更多的教学资源。除了需要对教学内容进行重新梳理和调整,还需要进行师资队伍建设。我们要求讲授计算机基础课程的老师也要掌握学生所学的专业知识,尤其是对于一些新上专业,这个要求是有一定难度的。其次是学生的学习资源问题。计算机基础课程教学一般包含课堂教学和实验教学,一个班的人数是50人左右,每个同学的学习都有一些特殊性,课堂教学中的互动和实验室个别问题的辅导都需要每个学生独占老师的时间。操作性很强的计算机课程就像英语课一样,只有小班上课(20人左右)才能取得较好的教学效果。如果计算机基础课程采取以专业案例为驱动的教学模式,在师资队伍和师生比方面都需要大幅度改进。

计算机相关专业的学生,实际上是在同样的学习周期内需要面对两个专业的学习,一个是本专业,另一个是计算机科学。两个专业的跨度越大,学生对于计算机科学的学习难度就越大,两个专业的教学融合就非常困难。我们发现很多高年级同学会直接放弃计算机课程的学习,对学习信息技术完全失去了信心。

计算机相关专业的学生对于计算机课程的学习,两级分化情况非常严重。那些成绩优异的学生对学习信息技术投入的精力和热情甚至远远超过了对专业课的学习,这个极端同样也偏离了我们的培养目标。

4 新的教改目标

我们对于计算机基础课程的教改目标,就是将信息技术与每个具体的专业教育融合、融合、再融合。信息技术发展迅速,程序设计语言在发展,新架构、新范式不断涌现。计算机基础课教学不但要适应不同专业的要求,也需要不断更新教学内容,介绍社会上流行的新技术和新模式。另一方面,我们也迫切需要计算机基础课程的教学内容、教学方法具有相对的稳定性,对各个专业教学的核心内容具有一定的不变性。我们需要寻找一个以不变应万变的原则。

教育部高等学校大学计算机课程教学指导委员会认为:"系统地将计算思维落实到大学计算机基础教学中,应当尽快地建立计算思维的表述体系"[8-10]。计算思维(Computational Thinking)由美国卡内基·梅隆大学计算机科学系主任周以真(Jeannette M. Wing)教授2006年3月在美国计算机权威期刊《Communications of the ACM》杂志上首次给出[7],周教授认为:计算思维是运用计算机科学的基础概念进行问题求解、系统设计、以及人类行为理解等涵盖计算机科学之广度的一系列思维活动。

我们认为计算思维是一种不同于数学思维、工程思维、逻辑思维的思维模式,具有其独有的特征。计算思维本质上是一种机器思维,即机器如何自动解决问题的方法和过程。以往的人类更多的是与自然打交道。下一代人类必将越来越多地与机器打交道,特别是与具有智能的机器打交道。无论是对客观世界的理解、问题求解,还是知识创造等方面,计算思维都具有重要作用。所以建立和培养计算思维是计算机基础教育的一个重要使命。

我们下一步的教改目标,就是建立以培养计算思维为核心理念的面向非计算机专业的计算机基础教学体系,建立"以抽象、自动化、设计、通信、协作、记忆、评估为基本概念的带有层次结构的计算思维表述体系框架"[8],并逐步向新的教学体系过渡。

5 结束语

计算机相关专业对计算机学科的教学需求正在不断提升,这需要在有限的课时分配条件下完成越来越多的教学任务,同时还要保障教学质量。对此困境我们采用了基于任务驱动的案例教学法,整合了经管类各专业的经典案例,以专业为基础有针对性地组织教学内容,通过建设经管类IT课程群,有意识地培养非计算机专业学生的计算思维,在提高教学质量的同时缓解了教师和学生的教学和学习压力,经过几年的努力,收效显著。

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封二简介

肖汉斌博士现任武汉理工大学物流工程学院院长、教授、博士生导师，兼任交通部港口装卸技术重点实验室主任、教育部港口物流技术与装备工程研究中心副主任、中国工程机械学会全国港口机械专业委员会常务理事、湖北省物流协会副会长。

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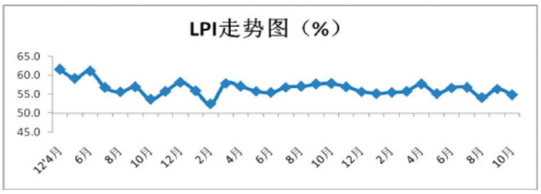
简　讯

2017年10月 中国物流业景气指数为54%

中国物流与采购联合会发布的2017年10月份中国物流业景气指数为54%较上月回落0.3个百分点；中国仓储指数为55.1%，较上月回升4.2个百分点；中国公路物流运价指数为104.08点，比上月回升0.18%；中国电商物流运行指数同比指数为122.3点，比上月回升1.3点。



中国物流信息中心副主任何辉认为：10月份，物流业景气指数有所回落，但仍位于较高水平，显示出物流业经济活动整体运行态势良好、保持适度增长。从品种上看，大宗商品类受需求趋旺，价格上涨等因素影响，钢铁、有色、木材、机械设备等仓储活动活跃。

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基于智能物流实验室的物流专业实验教学探讨

Research on Experiment Teaching System of Logistics Management Education Based on Smart Logistics Lab

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摘 要：为了满足社会对物流人才的需求，加强物流专业学生在实践方面的能力，文章首先探讨了实验课程的内容体系和课时安排，其次分析了理论课程和实验课程的衔接问题，最后提出了实验课教学中可能遇到的问题以及解决方法。

关键词：物流管理；实验教学；智能物流实验室
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Abstract: In order to meet the needs of the society for logistics talents, strengthen the ability of logistics students in practice. First the content system and class scheduling of experiment course are discussed in this paper. Secondly, the paper analyzes the cohesion of theoretical courses and experimental courses. Finally, this paper presents some problems and solutions which may be encountered in the teaching of experimental class.

Key words: logistics management; experimental teaching; smart logistics lab

0 引 言

随着物流行业的快速发展，物流人才需求巨大，虽然物流管理专业每年本科毕业生人数约为 28 000~30 000 人，其中：物流工程专业每年的毕业生人数约为 4 000~4 500 人；物流管理专业高职（专科）毕业生人数约为 65 000~70 000 人①，合计物流专业本专科毕业生人数在 10 万人左右。但社会每年新增 180 万人左右的物流岗位，导致物流人才缺口很大。但是由于高校培养的物流人才偏重于理论知识，导致近几年社会上出现了物流专业毕业学生“就业难”的问题，导致部分学生转行进入其他行业。

究其原因，是由于高等院校物流类专业的教育与社会需求脱节，与社会需要的理论与实践并重的人才不符。为了适应社会的需求，许多高校纷纷强化实践教学，为了满足实践教学的要求和提高实践教学，各高校不但加强校企合作，建立实训基地，而且斥巨资建立物流实验室，以满足课堂教学的需要。山东财经大学也于 2013 开始建设物流实验室，目前已将物联网与智能物流实验室建设成为了现代化的智能物流中心，该中心以模拟第三方物流公司配送中心的物流活动为背景，集包装、装卸、仓储、流通加工、配送于一体，并结合了计算机及其网络通信、自动控制与识别、自动导航、无线射频识别（RFID）等最新科学技术，实现物流配送的全过程智能控制。

实验室的硬件设施主要有三大块，分别是自动化立体仓库模块、智慧物流模块运输与配送模块。其中自动化立体仓库模块的主要设备有立体货架、全电动堆垛机、出入库分拣滚筒输送链、出入货台、条码阅读器、电磁引导的 AGV 小车、电子拣货系统以及流利式货架。智慧物流模块的主要设备有 RFID 阅读器、RFID 写卡器、电子标签、手持终端和条形码打印机。另外，还有其他物流设备，如包装机、手推液压托盘车、周转笼、托盘，等等；与该物流设备配套的软件资源主要有综合物流软件系统、智慧物流管理软件、运输与配送软件。

另外，实验室还有物流中心经营模拟软件、快递物流 3D 模拟的仿真教学软件、物流仿真软件和 3D 国际物流软件等。这些软硬件资源几乎囊括了所有物流课程的实践环节。那么如何利用好物流实验室的各种设施设备和物

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流软件，提高教学效果，就是本文要探讨的问题。

1 物流专业的课程体系

1.1 物流管理专业的培养目标

为了适应物流行业快速发展的需求，要求学生具有一定的管理学、经济学的知识，掌握现代物流的基本理论并具备一定的分析、规划设计、仿真和运营的基本能力；能熟练运用物流与供应链的知识从事供应链设计与管理、物流系统优化与运营管理、电子商务的物流配送、物流信息管理和物流软件开发等工作的应用型高级专门人才[1]。

1.2 物流管理专业理论课程体系

本专业的课程体系分为学科基础课、专业必修课、方向模块课和专业任选课。其中学科基础课不涉及物流实践课。专业课是物流专业的基础和主干课程，主要包括《物流学导论》、《采购与仓储管理》、《运输与配送》、《物流设施与设备》、《供应链管理》、《国际物流学》、《物联网与智能物流》、《国际货运代理实务》、《电商物流配送实务》、《物流系统分析与设计》、《供应链设计与运营》和《物流配送中心规划与管理》等课程，涉及到从采购、包装、运输、仓储、物流系统、供应链和配送及规划等物流知识。这些课程既需要学生掌握一定的理论知识，又需要学生掌握一定的操作能力。这就需要设计一定的物流实验课程，让学生通过实验理解物流知识并掌握一定的技能，培养学生的动手能力。独立实验课需要学生综合运用所学物流知识，模拟现实中的物流活动，完成实验内容。这类课程主要有物流管理综合模拟实验、物流规划设计工具和物流系统建模与仿真。

2 基于智能物流实验室的物流管理专业实验教学设计

物流课程主要分为三大类：偏重理论性的课程、偏重实践性的课程和独立实验课程。针对理论性强的物流专业课程，过去的教学方法一般采用多媒体教学，但是在教学过程中发现，许多问题即使老师讲解的很深入，但教学效果依然不佳。因此，需要利用物流实验室，将一系列物流活动：如包装、打托盘、装车等物流活动设计成几个模块完成，包括物流学导论、仓储管理、运输与配送中的很多物流知识，要求学生利用物流实验室的设施设备，根据实验内容和教师要求，完成实验，巩固课堂中学习的物流知识。比如包装模块，要求学生理解并掌握包装技术、包装材料，如何贴标签以及储运标志，如何码托盘，如何集装，如何选择装卸搬运设备以及如何配载等物流知识，可以通过实验将这些知识融会贯通（见表1）。这类课程包括物流学导论、采购与仓储管理、物联网与智能物流等，其中《物流学导论》和《物流设施与设备》等课程属于专业基础课程。物流实验侧重于实践能力的培养，对于这类课程，可以采用模块教学法，在课堂上让学生掌握相关物流知识并写出实验要实现的目的以及需要哪些物流设备，然后让学生到物流实验室完成实验并巩固相关知识，最后写出实验总结。

对于偏重于实践性的课程，可以采用课堂教学和实践教学相结合的方法。这类课程主要涉及到应用模块的课程，有国际物流学、供应链管理、运输与配送、电商物流配送实务和国际货运代理实务（见表1）。针对这几门课程的教学，一般采用 2+2 教学模式，任课教师要针对物流软件合理安排教学内容，提出实验目的及学生要掌握的内容，以便理论和实际相结合。针对这个模块的课程，学院实验室有国际物流软件、快递物流软件、配送与运输综合实训软件以及国际货代软件。其中国际货代软件支持远程教学，任课教师可以在上课时给学生演示，并根据课程内容，每两个星期安排一次实验课。

最后是综合模块，这类课程是对前面所学知识的综合运用，目的是培养学生的综合能力，包括利用物流实验室的设施设备设计物流实验并实现，属于综合实践课程[2]。要求安排在物流实验室上课，如配送与运输管理软件模拟供应商、客户和第三方物流公司的仓储部、客户服务部、采购部、运输部、信息部的运作。学生需要掌握采购、运输和仓储的整个流程，包括订单处理环节、拣货环节以及托运、车辆调度、运输监控、收货及车辆回车登记等整个流程。这个实验涉及到采购、仓储、拣货、出入库、车辆配载、运输、和路线规划等知识。这就要求任课教师即要掌握理论知识，又要掌握软件的应用及相关的物流设施设备操作方法，提出合理的实验目的和实验内容，掌握实验进度。

针对综合模拟实验，学院针对这门课程需要连续上课的特点，把该课程安排在第 7 学期，每天 8 个课时，连续 4 天完成教学任务。

3 物流专业在实验教学中存在的问题及解决方法

在制定培养方案和教学过程中，遇到很多问题：一是基础模块的实验课安排，由于实验与课程进度有关，课程大纲无法统一，实验室上课时间不好确定，导致实验室难以统一统筹安排。二是应用模块的实验课程，对任课教师要求较高，要求教师既要掌握课堂理论教学，又要掌握实验室的软件教学，对教师压力较大。三是物流实验

表 1　物流专业实验模块一览表

实验模块		课程名称	实验内容	设施设备及软件	课时
基础模块	实验 1：包装、打托盘及电子沙盘	物流学导论	1. 掌握自动打包机和标签打印机的使用 2. 掌握码托盘的方法 3. 掌握叉车的使用 4. 掌握 AGV 小车和堆垛机的工作原理 5. 掌握物流的各个功能模块	打包机 标签打印机 托盘 叉车 AGV 小车 堆垛机 电子沙盘	6
		物流设施与设备			
	实验 2：立体货架、流利式货架	仓储管理	1. 货位编码 2. 掌握拣货的方式和电子标签拣货	立体货架 周转笼 电子标签	6
应用模块	实验 3：供应链管理	供应链管理	供应商的选择与采购、生产管理、销售管理、库存管理、财务管理等知识点	供应链模拟教学软件	16
		采购管理			
		供应链设计与运营			
	实验 4：国际物流	国际物流	单证、报关报检、堆场管理、港口码头等业务	3D 国际物流软件	16
	实验 5：国际货运代理	国际货运代理实务	货代公司海运、空运的业务流程，包括业务制单或审单的方法、业务流转程序等	国际货运代理软件	16
	实验 6：配送	电商物流配送实务	1. 配送流程 2. 配送中心规划	配送与运输管理软件 Flexsim 软件	17
综合模块	实验 7：物流仿真	物流系统建模与仿真	1. 掌握 Flexsim 软件的应用 2. 利用 Flexsim 规划配送中心	Flexsim 软件	34
		物流配送中心规划与管理			34
	实验 8：综合模拟实验	物流管理综合模拟实验	1. 综合物流实训 2. 运输与配送 3. 智慧物流	物流设施设备：标签打印机、托盘、AGV 小车、堆垛机、输送机、手持终端、写卡器和电子标签阅读器物流软件： 1. 智能物流实训 2. 配送与运输管理软件 3. RFID 智慧型存储系统	34

室中的设施设备，有的需要提前充电，如 AGV 小车和手持终端；有的需要提前调试，如出入库的流程，以免在上课时发生问题。即使这样，在上课过程中，也经常有物流设施设备出现问题，影响教学效果。四是综合模拟实验课，要提前和其他任课教师协调好上课时间。

为了解决这些问题，最好的方法是设置专门负责实验教学的教师岗位，有了专门的实验教学岗，该教师不但可以维护物流实验室的设施设备，统一协调上课时间，而且可以随时关注物流设施设备和相关物流软件的更新换代，并根据课堂教学内容设计实验教学内容，强化学生的动手能力和创新能力，跟上物流行业的发展。最后要强化校企合作，建立校外实践基地，将校外的参观实习和校内的实验教学结合起来，让学生带着问题去企业参观、实习，并引导学生利用所学知识去解决问题。

自学院实验室成立以来，已有 3 届学生在实验室完成学习内容，教学效果显著。

注：①阳光高考 http://gaokao.chsi.com.cn/。

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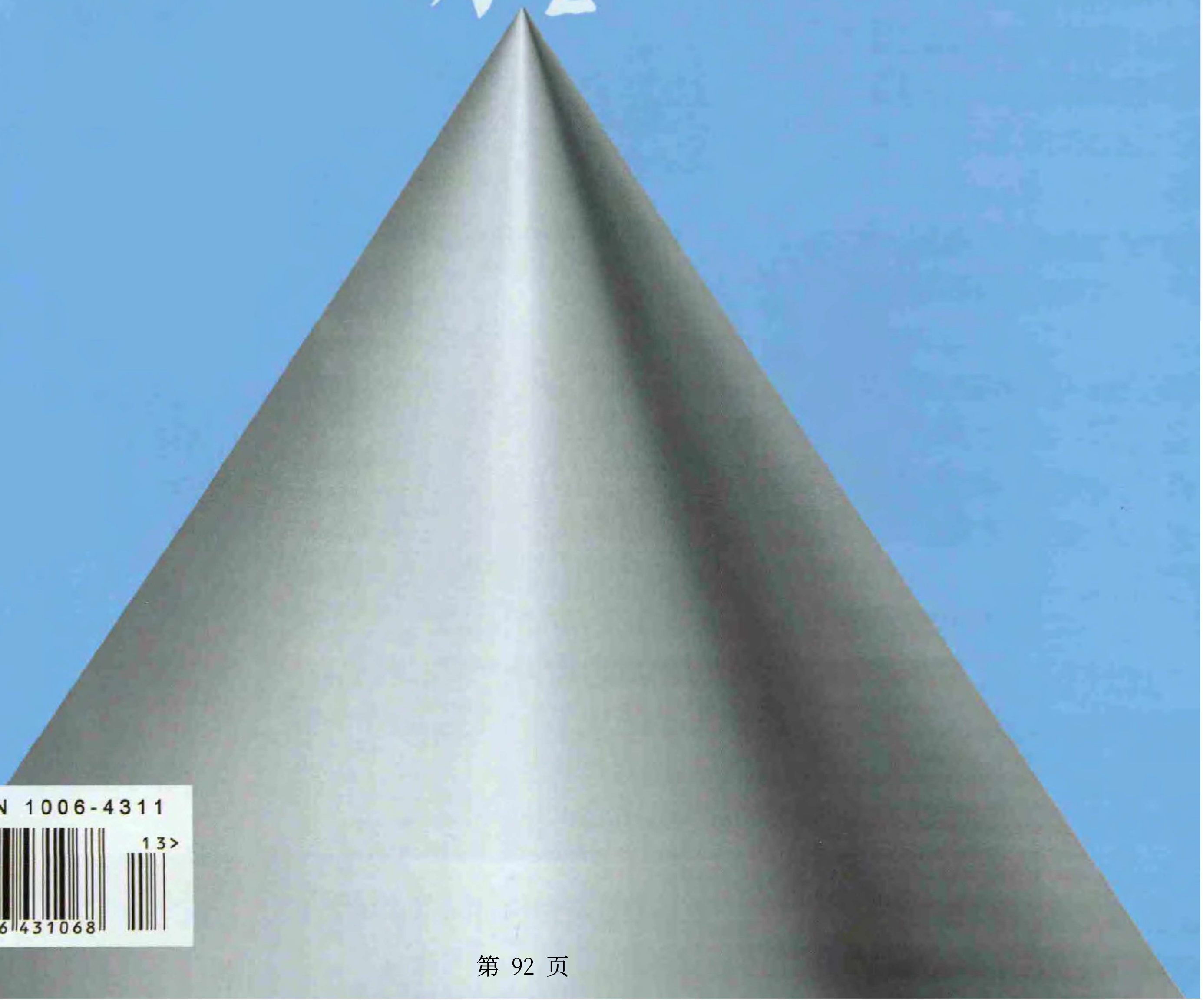

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以专业大赛探索电子商务专业实践教学改革

E-commerce Major Practice Teaching Reform Based on Professional Competition

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摘要：本文提出以专业大赛为平台，进行电子商务专业实践教学改革，培养学生对电子商务的兴趣，提高学生对电子商务知识的综合应用能力，调整电子商务专业实践教学适应电子商务市场环境，培养满足社会需求的专业人才。

Abstract: This paper presents that taking professional competition as a platform to carry on e-commerce major practice teaching reform, cultivate students′ interest in e-commerce, improve students′ ability to apply comprehensive knowledge of e-commerce, adjustment e-commerce major practice teaching to adapt to e-commerce market environment, train professionals to meet the needs of the community.

关键词：专业大赛；电子商务专业；实践教学改革

Key words: professional competition；e-commerce major；practice teaching reform

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0 引言

经济全球化的不断深入以及信息技术的突飞猛进，引发了商务模式的变革，电子商务已成为当今重要的经济形式之一，并以迅猛的态势飞速发展。因此对电子商务教学提出了更高的要求。这就要求电子商务专业教学必须适应电子商务的发展，紧随电子商务创新脚步，不断改革教学方式和教学内容才能真正培养符合时代需求的电商人才。

电子商务专业实践教学是让学生通过参与模拟或真实的电子商务运作过程，了解电子商务运营原理，培养电子商务综合能力。那么，如何才能使实践教学更加贴合电子商务发展，怎样才能建立教学与实际的集合，就成为电子商务专业实践教学中亟需解决的问题。而电子商务大赛正是一个拓展实践环境，结合实际需求的很好的平台，可通过这一平台，持续改进实践教学，提高学生的实践能力，并为学生提供与实际的电商运营商的交互，提高学生的综合实践能力。

1 电子商务大赛为电子商务专业实践教学提供平台

电子商务大赛为电子商务专业实践教学提供了更为宽广的实践平台。此类大赛比赛类别和项目的设置都与高校专业教学密切相关，并与相关电子商务产业紧密结合，很多比赛项目的设置甚至直接针对行业企业的实际需求。这就使得参赛学生能够在比赛过程中不但提高了电子商务相关知识的运用水平，同时也了解到电子商务企业最新的动向和未来发展，很好地提高了学生的专业素养。大赛往往邀请业内专家以及行业企业代表参加对参赛项目的

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要的工作能力和学习方法，以行动为导向的教学方法培养学生的创新能力、解决问题的能力和实践能力。

4 应用型大学的道路

应用型大学讲究的是学生的动手能力和解决问题的能力，在教学过程中要全程贯穿学习能力的培养，提高学生的社会实践能力。教师结合本门课程对学生进行引导和启发，通过不断的调试很好的培养了学生的团队合作精神和解决问题的能力。

校企合作不但检验一个专业是否适合社会的发展需要，也是检验一门课程是否合适专业需要的一个重要标志，实训室的摸拟与仿真，与真正的生产现场还是有很大差距的，因此，针对此课程实践性强的特点组织学生参观生产现场。

学校还可以组织举办相关的 PLC 技能大赛，比赛主要以实际应用为核心，重点考察学生理论知识与实际应用有机结合的能力，促进学生的技术技能，提高学生实际操作和运用先进科技设备水平能力。另外还可以组织学生参加亚龙的自动生产线安装与调试大赛，比赛与教学结合，以赛促进学生的积极性。

此外，毕业设计能够检验一个学生大学过程的综合能力，PLC 课程作为电气和机电等专业的核心课程，其一些综合控制系统的设计可以作为相关专业学生的毕业设计题目。例如：“十字路口交通灯控制系统设计”，“机械手控制系统设计”，“多层电梯系统的控制设计”等。本校每年都有很多学生选择这类型的题目。

5 总结

总之，采用 PLC 实训教学能够让学生快速适应现代化企业发展的需要，从而成为具有专业知识以及操作技能的专业人才，同时也才符合建设应用型大学的课程实践的要求。从实验室到生产线这才是应用型技术大学的真正发展道路。相信在不久的将来我们将发展成为一所符合社会发展需要的应用技术型大学。

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评审，使得项目更加贴近电子商务市场环境，提高了学生对行业最新发展方向的了解。各种电子商务大赛非常侧重学生实践能力的检验，参赛项目往往是通过实际运作效果进行评比，从而提高了学生的电子商务实际运作能力，解决了高校专业教育与电子商务市场需求相脱节的问题。

以电子商务“创新、创意及创业”挑战赛为例，该大赛是教育部高教司电子商务专业教学指导委员会主办的全国各个高等院校参加的全国规模的电子商务大赛。大赛从创新，创意及创业三个角度考察学生电子商务的综合能力。大赛评委既有高校电子商务专业教师，也有相关企业运营高管，项目评价不光考察学生电子商务专业知识的掌握和实际电子商务运营能力的高低，更侧重学生对电子商务模式的创新和对电子商务未来发展方向的把握。全面考查了各个高校电子商务专业实践教学的综合水平和质量。大赛促进学生对电子商务专业学习的积极性和主动性，每一届大赛都有一批高水平、高素质的创新型人才脱颖而出，他们在学校中也起到了一定的示范和带动作用，提高了学生参与电子商务实践的积极性与主动性。

1.1 培养学生对电子商务的整体认知和兴趣　电子商务大赛的项目设置往往需要参赛团队完成一个电子商务商业项目的全过程，即从项目规划立项，实施，商业运营等全部电商流程。在此过程中，学生需要对电子商务的各个环节都了若指掌，并且能够将各环节有机结合，合理规划电子商务，才能取得较好的效果。在此过程中，学生对电子商务就建立了一个形象的整体认知，使得学生对电子商务的认知不止停留在课本中的定义之中，而是一个立体的模型。

电子商务大赛项目的设置还与电商企业的需求，电子商务的最新发展相适应，鼓励学生发挥创造性和发散性思维，鼓励学生提出一些全新的探索性的电子商务解决方案，这种开放的比赛模式，可以很好的调动学生的积极性，培养学生对电子商务的兴趣，提高学生在后续学习中的主动性。

1.2 提高学生对专业课程的综合应用能力　电子商务大赛考察的是参赛学生的电子商务综合能力，学生仅仅掌握书本知识是远远不够的。如上文所述，电子商务大赛需要参赛学生完成一个电子商务项目的全过程，这就要求学生要对课堂中所学的各个电子商务专业知识进行综合运用才能获得一个比较好的整体效果。如果仅仅是各种专业知识的堆砌是不可能取得较好结果的。所以电子商务大赛能够很好的提高学生对专业课程的综合应用能力。

1.3 提高电子商务专业实践教学与电子商务市场环境的结合　各类电子商务大赛的特点都是与电子商务实际环境紧密结合，很多大赛的参赛项目就直接来源于企业的实际需求。在参赛过程中，通过解决各类实际问题，提高了学生对电子商务市场环境的了解。同时参赛学校也可以通过大赛交流，及时了解电子商务最新的发展和问题，并以此为依据，及时调整电子商务的实践教学环节，使其能够与电子商务市场环境紧密结合，适应电子商务发展的需求。

综上所述，电子商务大赛对高校的电子商务专业实践教学有很高的推动作用，通过参加大赛可以检验高校电子商务专业实践教学水平，促进其不断完善向前发展。

2 利用电子商务大赛促进电子商务专业实践教学改革的途径

2.1 调动学生参加电子商务竞赛的积极性　开展校企的交流活动，邀请大赛主办方或电商企业到学校开展一系列的学生座谈，让学生了解大赛的具体情况，增加学生对大赛的了解，从而培养参赛的积极性。通过开展专业教育讲座，请往届获奖同学做报告等各种形式宣传电子商务大赛，培养学生的兴趣和参赛积极性。开展学生交流活动，邀请以往参加过大赛的同学，为同学讲述大赛经历，分享大赛所得，提高学生的参赛兴趣。并可将参加大赛与学生在校的实践课程考核相结合，鼓励学生参赛。

遵循由易到难、由简单到复杂的基本规律，首先通过专业教育等途径培养学生对电子商务兴趣与参赛热情。

2.2 引导学生综合利用电子商务专业知识　首先通过模拟训练，依托相关教学软件和设备，为学生提供了一个仿真“电子商务平台”，供学生模拟实践。为学生提供电子商务三大模式 B2B、B2C、C2C 流程的前后台全程仿真环境。学生可分别扮演电子商务环节中各角色，适时变化身份分组进行交互式操作，充分考虑各种实际运营情况进行模拟演练。后期逐渐增加自主创新内容，并开展实际的电子商务综合运作，逐渐培养学生的电子商务综合能力。真正做到理论与实践相结合，加强运用电子商务的能力。

通过参加大赛，根据比赛过程由专任教师布置任务，安排项目逐步开展实训任务。开展设计、开发、建网站，进行网上购物、开网店，从调研、沟通、采购、销售、广告、公关等环节完全由学生独立完成，提高学生电子商务的综合应用能力和实际运作能力。

2.3 合理设置电子商务专业实践教学与电子商务发展相适应　有针对性的进行电子商务竞赛的选题。在校内实践的基础上，鼓励学生到电子商务企业实习，做些和专业有关的工作，将参赛项目实际运营起来。在参赛结束后，积极总结经验对照实践教学课程，对已有课程进行适当调整。充分总结参赛经验，灵活开展实践教学，对实践教学的内容和形式根据电子商务发展适时调整。

3 总结

以电子商务大赛带动电子商务专业实践教学，提高学生对专业课程的综合应用能力，培养学生对电子商务专业的兴趣和认知水平，培养学生的创新性和对电子商务市场的敏锐性，针对电子商务市场需求培养创新型人才。可在电子商务专业在校 1-4 年级学生中广泛开展，学生通过设计实施电子商务项目，使学生可以综合运用所学的专业知识。加深学生对电子商务专业的认知，提高学生电子商务的实战能力，提高学生的创新性，从而培养具有较高实践能力的创新型电子商务专业人才。

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Distance education quality evaluation based on multigranularity probabilistic linguistic term sets and disappointment theory

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ABSTRACT

Distance education quality evaluation is extremely important in improving the quality of education under COVID-19. As traditional teaching-quality evaluation methods are no longer applicable, it is crucial to construct effective evaluation methods. In the evaluation of distance education quality, decision-makers have different linguistic expression preferences, and the evaluation information may be biased due to an improper grasp of the problem. In addition, the correlation between the criteria of distance education quality evaluation is common, and the results of existing evaluation methods are quite different. In this paper, to compensate for these deficiencies, we utilize the multi-granularity probabilistic linguistic term set (MGPLTS), which can reflect the linguistic expression preference of decision-makers and the importance of linguistic terms, and propose a multi-criteria group decision-making (MCGDM) method. First, the dispersion and concentration degrees are proposed as the theoretical basis for judging the hesitancy of decision-makers' evaluation information, and the decision-maker weight adjustment model is constructed. To reflect the importance and correlation of criteria, the SWARA method and the CRITIC method are constructed as criteria weight methods. To obtain reliable decision results, decision-makers' psychological expectations are taken into account, the MULTIMOORA method is improved upon, and a new integration theory is proposed to improve its robustness. Finally, through an example case of distance education quality evaluation and comparison with other methods, the effectiveness, practicability and superiority of this method are verified.

1. Introduction

Education plays an important role in technological innovation and economic growth, but modern education differs from traditional, offline education. Schools, students, and educational institutions are looking for more efficient learning methods, and distance education based on technological innovation has received widespread attention. Distance education, also known as distance learning, e-learning and online learning, provides regular and substantive learning interactions for students who are separated from teachers [21,25]. Due to COVID-19, schools in many countries have replaced offline education

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with distance education, which has greatly promoted the development of distance education methods. However, during this period, there have been obvious differences and gaps in the quality of distance education among different institutions and platforms, which is not conducive to the realization of the original intention, which is improving education quality. Pozzi et al. [22] determined the criteria and indicators that reflect the particularity of distance education through participation, indicating that distance education quality evaluation is a typical multi-criteria group decision-making (MCGDM) problem. MCGDM is a process by which multiple decision-makers select the optimal alternative from the perspective of multiple criteria [19,35]. Some studies have established MCGDM models for distance education quality evaluation, including VIKOR [23], hybrid MCDM [24], TODIM [25], and the aggregation operator method [26]. However, the applicability and consistency of the criterion weighting methods used need to be improved. In addition, these decision-making methods rarely take into account the psychology of decision-makers. Therefore, it is essential to evaluate distance education quality with effective and reasonable methods to determine the problems in the teaching process and improve them.

Many qualitative criteria in the process of distance education quality evaluation are fuzzy and imprecise. It is inconvenient for decision-makers to provide evaluation information with accurate numbers but prefer linguistic information that conforms to human expression habits, such as linguistic term sets (LTSs, also known as linguistic evaluation scales) [32]. However, a single linguistic term is not enough to express the hesitancy and uncertainty of decision-makers [33]. The probabilistic linguistic term set (PLTS) overcomes this disadvantage by displaying multiple linguistic terms and corresponding probabilities (or importance or trust level) [3,27,34,39]. There may be decision-makers in teaching, training, and other fields involved in the distance education quality evaluation, and their different linguistic preferences are unlikely to be accommodated by an LTS. As an ideal choice, multi-granularity probabilistic linguistic term set (MGPLTS) includes the advantages of PLTSs and takes into account the choice of different granularities (cardinality) of LTSs due to the linguistic preferences of different decision-makers [26]. Although the applicability of MGPLTS is strong, different decision-makers have different thinking about and masteries in specific problems. This means that the evaluation information given by decision-makers has different degrees of hesitancy, uncertainty and credibility. Lin et al. [6] proposed the deviation degree, which can measure the hesitancy degree of evaluation information, but it cannot be used for MGPLTS. Therefore, there are deficiencies in the existing research: (i) Existing research on MGPLTS lacks the identification of dispersion and credibility of evaluation information, and the measurement of credibility is related to the effectiveness of subsequent decision-making results.

The decision-makers involved in distance education quality evaluation include teachers, technicians and other professionals. In the existing distance education quality evaluation methods [23,25,26], the weight of the decision-maker is directly assigned to the decision-maker according to his or her authority, and there is no subsequent adjustment. However, the existence of authority does not mean that the evaluation process is free of bias [41]. When the evaluation information of decision-makers is biased, adjusting the weight of decision-makers has a positive contribution to the decision-making results. Additionally, the weight of each criterion has a crucial impact on the final result of a decision. The commonly used subjective weight methods in distance education quality evaluation include Delphi [23], analytic hierarchy process (AHP) [24], and fuzzy measures [26]. The correlation between the criteria involved in decision-making is widespread, such as teaching design and teaching interaction. The existing methods for calculating the correlation between PLTSs are based on the Pearson correlation coefficient [5,11]. The existing weight model has some deficiencies: (ii) a lack of methods to adjust the weight of decision-makers based on evaluation information; (iii) the subjective weight method requires high consistency, but the methods [23,24,26] have low consistency, a large amount of calculation, and poor applicability; (iv) Methods [5,11] omit testing the linear relationship between PLTSs, which may lead to deviations in the results. In addition, the Pearson correlation coefficient is greatly affected by the outliers.

Distance education is an organic product of the combination of traditional education methods and the internet, whose evaluation process is complex and whose content is varied; thus, a reasonable MCGDM method is essential. By incorporating three aggregation tools, MULTIMOORA is considered a powerful method since it satisfies the six robustness conditions [19,40]. Therefore, the MULTIMOORA method is widely combined with other methods and applied in practice [42–45]. To address the results of the three aggregation tools, many types of integration theories have been proposed. Dominance theory [37] does have some theoretical support, such as from the factors of dominance, transitivity, and equality [38]. However, it also has some weaknesses, for example, not considering the utility value of the alternatives. Furthermore, integration theory includes Borda theory [30], improved Borda theory [5], Euclidean distance [29], the compromise measure [28], and the arithmetic and geometric mean [36]. Traditional MULTIMOORA, existing aggregation tools and integration theory have some deficiencies: (v) The reference point method, one of the three aggregation tools, is the max tool, which is based on partial evaluative information, which results in information loss. Also, if there are outliers in the evaluation information then the results cannot be trusted. Therefore, the reference point method needs to be improved; (vi) There are few existing strategies that address the importance of aggregation tools in the existing integration theories, and combining the ranking values and ranking results can exaggerate the advantages and disadvantages of alternatives; (vii) In the traditional MULTIMOORA method and the current distance education quality evaluation, the influence of decision-makers' psychological expectations on decision-making results is not considered.

In light of the above research analysis, the existing information forms selected for distance education quality evaluation cannot function properly in a complex decision-making environment, and there are certain deficiencies in the related theories of MGPLTS. To reasonably judge the reliability of the evaluation information, reflect the correlation between the criteria, consider the influence of the decision-makers' psychological expectations on the decision, and output a reasonable and effective decision result, this paper uses a combination of different methods and then proposes an MCGDM method. The main contributions of this paper are summarized as follows:

(1) Propose the dispersion degree and concentration degree of MGPLTS. As a means to rate credibility, these degrees can be used to express the dispersion of evaluation information in distance education quality evaluations, such as MGPLTSs, and can address research deficiency (i).
(2) Construct decision-maker weight and criterion weight models. The decision-maker weight adjustment model based on the dispersion and concentration degrees is established, which can address research deficiency (ii); Construct MGPL-SWARA method to obtain criteria subjective weight; introduce Spearman correlation coefficient to calculate correlation value and combine it with CRITIC to obtain criteria objective weight, which addresses deficiencies (iii) and (iv).
(3) Propose the MGPL-DT-MULTIMOORA method. Combining disappointment theory with the MULTIMOORA method to consider the impact of decision-makers' expected emotions on decision-making results can compensate for deficiency (v). The reference point method in the traditional MULTIMOORA is improved to avoid information loss and address deficiency (vi). Then, a new integration theory is proposed, which effectively considers the importance of each aggregation tool and the deviation and consistency of calculation results, which can compensate for deficiency (vii).
(4) The proposed MGPL-DT-MULTIMOORA method is applied to the distance education quality evaluation and compared with other existing methods to verify the practicability and superiority of the proposed method.

The remainder of this paper is organized as follows: Section 2 reviews the concepts of PLTS and MGPLTS and defines the dispersion and concentration degrees of MGPLTSs. Section 3 constructs an MCGDM method for distance education quality evaluation, including some weight determination methods, improved ranking methods and integration theory, and details the specific steps to be taken. Section 4 illustrates the practicality and superiority of the proposed method by applying it to the distance education quality evaluation case and comparing it with other methods and gives some suggestions according to the case results. Section 5 summarizes the advantages of the proposed method and the research directions that can be further explored in the future.

2. Preliminaries

This section reviews the basic concepts of PLTS and MGPLTS and proposes the dispersion degree and the concentration degree to measure the credibility of MGPLTSs.

2.1. Multi-granularity probabilistic linguistic term sets

The LTS [1], also named the linguistic evaluation scale, contains an odd number of linguistic terms. There are two forms of LTS: subscript-asymmetric LTS $S_1 = \{\ell_\alpha | \alpha = 0, ..., 2g, g \in N^+\}$ [1] and subscript-symmetric LTS $S_2 = \{\ell_\alpha | \alpha = -g, ..., 0, ..., g, g \in N^+\}$[2], where $2g + 1$ is the granularity of the LTS. In practical applications, if the value of g is too large, then the meaning of two adjacent linguistic terms will be too close to be distinguished, so the value of g is usually no more than 4.

MGLTSs are a combination of LTSs with different granularity levels, i.e., $S_t^{n(t)} = \{\ell_\alpha^{n(t)} | \alpha = -g_t, ..., 0, ..., g_t\}(t = 1, 2..., T)$, $S_t^{n(t)}$ represents the t-th LTS, $n(t)$ is the granularity of$S_t^{n(t)}$, and$n(t) = 2g_t + 1$. For MGLTSs, the equivalent translation functions proposed by Gou and Xu [4] can realize the equivalent transformation between linguistic terms and values.

Definition 1 (*[4].*). Assuming that $S = \{\ell_\alpha | \alpha = -g, ..., 0, ..., g, g \in N^+\}$ is an LTS, the linguistic terms ℓ_α can be transformed into equivalent information to the membership degree β by the φ function:

$$\varphi : [\ell_{-g}, \ell_g] \to [0, 1], \ \varphi(\ell_\alpha) = \frac{1}{2}\left(\frac{\alpha}{g} + 1\right) = \beta \tag{1}$$

Similarly, the membership degree β can also be transformed into equivalent information linguistic terms ℓ_α through the φ^{-1} function:

$$\varphi^{-1} : [0, 1] \to [\ell_{-g}, \ell_g], \ \varphi^{-1}(\gamma) = \ell_{(2\beta-1)g} = \ell_\alpha \tag{2}$$

A single linguistic term cannot usually accurately express the hesitancy and uncertainty of decision-makers. Therefore, Pang et al. [3] proposed PLTS, which contains information on importance, frequency, or probability about multiple linguistic terms.

Definition 2 (*[3].*). Assuming that $S = \{\ell_\alpha | \alpha = -g, ..., 0, ..., g, g \in N^+\}$ is an LTS, a PLTS is defined as.

$$L(p) = \left\{ \ell_k(p_k) \middle| \ell_k \in S, p_k \geqslant 0, k = 1, 2, ..., K, \sum_{k=1}^{K} p_k \leqslant 1 \right\} \tag{3}$$

where $\ell_k(p_k)$ represents the k-th linguistic term and its corresponding probability value p_k, K represents the number of linguistic terms in PLTS and $\ell_k(k = 1, 2, ..., K)$ in $L(p)$ are arranged in ascending order of subscripts of linguistic terms.

In some situations, the sum of the probability values in a PLTS is less than 1. Therefore, the corresponding probability values of the linguistic terms need to be normalized.

Definition 3 (*[3].*). Assuming that $L(p)$ is a PLTS with $\sum_{k=1}^{K} p_k < 1$, the normalized PLTS is:

$$\bar{L}(p) = \left\{ \ell_k\left(\bar{p}_k\right) \middle| k = 1, 2, ..., K, \sum_{k=1}^{K} \bar{p}_k = 1 \right\} \tag{4}$$

where $\bar{p}_k = p_k / \sum_{k=1}^{K} p_k, k = 1, 2, ..., K$.

To compare different PLTSs, scholars have studied the score function [3,5,6].

Definition 4 (*[3].*). Assuming that $\bar{L}(p) = \{\ell_k(\bar{p}_k) | k = 1, 2, ..., K\}$ is a PLTS, the score function value of $\bar{L}(p)$ is $E(\bar{L}(p)) = \ell_\eta$, where $\eta = \sum_{k=1}^{K} \varsigma(\ell_k)\bar{p}_k / \sum_{k=1}^{K} \bar{p}_k$ and $\varsigma(\ell_k)$ represents the subscript of ℓ_k. The deviation degree of $\bar{L}(p)$ is$\sigma(L(p)) = \sqrt{\sum_{k=1}^{K} \left(\bar{p}_k(\varsigma(\ell_k) - \eta)\right)^2} / \sum_{k=1}^{K} \bar{p}_k$.

On the basis of this score function, Wu et al. [5] proposed an expected value function for PLTSs.

Definition 5 (*[5].*). Assuming that $L(p) = \{\ell_k(p_k) | k = 1, 2, ..., K\}$ is a PLTS, the expected value is:

$$Z(L(p)) = \frac{\sum_{k=1}^{K} (\varphi(\ell_k) \times p_k)}{\sum_{k=1}^{K} p_k} \tag{5}$$

Due to the low distinguishing ability of the score function [3 5], Lin et al. [6] proposed a new score function.

Definition 6 (*[6].*). Assuming that $\bar{L}(p) = \{\ell_k(\bar{p}_k) | k = 1, 2, ..., K\}$ is a PLTS on$S = \{\ell_\alpha | \alpha = -g, ..., 0, ..., g, g \in N^+\}$, the deviation degree of $\bar{L}(p)$ is:

$$dd(L(p)) = -\sum_{k=1}^{K} \bar{p}_k \log_2 \left(1 - \frac{|\varsigma(\ell_k) - \varsigma(E(L(p)))|}{2g} \right) \tag{6}$$

then the ScoreC-PLTS is:

$$S(L(p)) = \ell_{\eta \times (1 - dd(L(p)))} \tag{7}$$

where $\eta = \sum_{k=1}^{K} \varsigma(\ell_k)\bar{p}_k / \sum_{k=1}^{K} \bar{p}_k$.

Definition 7 (*[26].*). Assuming that $S_t^{n(t)} (t = 1, 2..., T)$ are MGLTSs: $L_{n(t),\gamma}(p) = \left\{ \ell_k^{n(t),\gamma}(p_k) \middle| \ell_k^{n(t),\gamma} \in S_t^{n(t)}, k = 1, 2, ..., K_{n(t),\gamma}, \gamma = 1, 2, ... \right\}$ is the γ-th PLTS with $n(t)$ granularity level based on $S_t^{n(t)}$, then $L_1(P) = L_{n(t_1),\gamma_1}(p) \cup L_{n(t_2),\gamma_2}(p) \cup L_{n(t_3),\gamma_3}(p) \cup \cdots$ is an MGPLTS.

Remark 1. If all linguistic terms in $L_1(p)$ are at the same granularity level, then $L_1(p)$ remains a PLTS. In$L_1(p)$, the probabilities of linguistic terms with the same subscript at the same granularity levels are added together, and $L_1(p)$ is normalized according to Definition 3. Linguistic terms in $L_1(p)$ are arranged in ascending order of the equivalent information in Eq. (1). If the equivalent information for linguistic terms belonging to different granularity levels is the same, the one with the larger granularity is ranked behind.

2.2. The dispersion degree and concentration degree of MGPLTSs

Before further processing the evaluation, if there are multiple linguistic terms in the MGPLTS provided by the decision-maker, the credibility of the evaluation information needs to be considered. Obviously, scattered information means that decision-makers cannot accurately make judgments. Therefore, inspired by the deviation degree [6] and entropy formulas

[7], we propose the dispersion and concentration degrees based on the expected score function [5] to measure the credibility and hesitancy of MGPLTSs.

Definition 8. Assuming that $S_t^{n(t)} = \left\{\ell_\alpha^{n(t)} \middle| \alpha = -g_t, ..., 0, ..., g_t\right\}(t = 1, 2..., T)$ is an MGLTS and $\bar{L}_t(p) = \left\{\ell_k^{n(t)}\left(\bar{p}_k^{n(t)}\right) | k = 1, 2, ..., K_t\right\}(t = 1, 2..., T)$ are T MGPLTSs on $S_t^{n(t)}(t = 1, 2..., T)$, where $S_t^{n(t)}$ represents the t-th LTS and $n(t)$ is the granularity of$S_t^{n(t)}$, then, based on Definition 7, $L_{t+1}(p) = \bar{L}_1(p) \cup \bar{L}_2(p) \cup \cdots \cup \bar{L}_t(p)$ is an MGPLTS, and $\bar{L}_{t+1}(p)$ is a normalized MGPLTS based on Remark 1. The dispersion degree of $\bar{L}_{t+1}(p)$ is:

$$f\left(\bar{L}_{t+1}(p)\right) = \frac{1}{\sqrt{2}} \sum_{k=1}^{K_1 + \cdots + K_T} p_k^{n(t)} \sin\left(\frac{\pi}{2}\left|\varphi\left(\ell_k^{n(t)}\right) - \sum_{k=1}^{K_1 + \cdots + K_T} p_k^{n(t)} \times \varphi\left(\ell_k^{n(t)}\right)\right|\right) \tag{8}$$

Property 1. Assuming that $\bar{L}_{t+1}(p)$ is a normalized MGPLTS, the dispersion degree of $\bar{L}_{t+1}(p)$ satisfies.$f(\bar{L}_{t+1}(p)) \in [0, 1/2]$.

Definition 9. Assuming that $\bar{L}_{t+1}(p)$ is a normalized MGPLTS. Then, the concentration degree of $\bar{L}_{t+1}(p)$ is:

$$c\left(\bar{L}_{t+1}(p)\right) = 1 - f\left(\bar{L}_{t+1}(p)\right) \tag{9}$$

where $c(\bar{L}_{t+1}(p)) \in [1/2, 1]$.

Example 1. Given three PLTSs with different granularity levels, $L_1 = \{\ell_{-1}^3(0.7), \ell_0^3(0.3)\}$ $L_2 = \{\ell_0^5(0.7), \ell_1^5(0.3)\}$, $L_3 = \{\ell_{-1}^9(0.2), \ell_0^9(0.8)\}$, their dispersion degrees are $f(L_1) = 0.2264$, $f(L_2) = 0.1158$, $f(L_3) = 0.0443$ and their concentration degrees are $c(L_1) = 0.7736$,$c(L_2) = 0.8842$, $c(L_3) = 0.9557$.

3. The proposed MGPL-DT-MULTIMOORA method for distance education quality evaluation

This section proposes a complete MCGDM method for distance education quality evaluation. It first introduces the various stages of distance education quality evaluation and then introduces the detailed process of the MCGDM method in detail, including the decision-maker weight adjustment model. The criterion weight is obtained by combining the results of SWARA and CRITIC based on the correlation coefficient by the combination weights method. Then, disappointment theory is combined with MULTIMOORA. The max tool is further improved, and a new integration theory is proposed.

3.1. Decision-making solution framework for distance education quality evaluation

This section constructs an MCGDM framework to solve the problem of distance education quality evaluation, which is divided into four stages.

Stage 1: Preparation

In this stage, teachers, technicians and related experts are invited to participate in the distance education quality evaluation. The initial weight of each decision-maker is determined, and the evaluation information provided by each decision-maker is collected and standardized. This stage provides the basis and data support of the decision-making method.

Stage 2: Design decision-maker weight adjustment method

In this stage, the degree of dispersion of evaluation information is measured according to the dispersion degree and concentration degree to determine its credibility. If the credibility is relatively low, the adjusted decision-maker weight is lower than the original weight.

Stage 3: Construct the calculation model of criterion weight

The purpose of this stage is to calculate the criteria subjective weight more reasonably and establish the MGPL-SWARA method; the correlation between the criteria is obtained through the Spearman correlation coefficient, and the criteria objective weight is obtained by combining with the CRITIC method; Through the combination weight method based on game theory, the subjective and objective weights are effectively combined.

Stage 4: Construct an improved MULTIMOORA method based on disappointment theory

This stage introduces the MGPL-DT-MULTIMOORA method considering the disappointment of decision-makers. The purpose of this stage is to obtain ranking results through reasonable and effective MCGDM methods.

3.2. Description of the multi-granularity probabilistic linguistic MCGDM problem

Suppose that there are m distance education institutions $X = \{ x_u | u = 1, 2, ..., m\}$, n criteria $A = \{ a_v | v = 1, 2, ..., n\}$, and τ decision-makers $D = \{d_i | i = 1, 2, ..., \tau\}$. The decision-makers weights are $W = (w_1, w_2, .., w_\tau)^T$, with $0 \leqslant w_i \leqslant 1, (i = 1, 2, ..., \tau)$, $\sum_{i=1}^{\tau} w_i = 1$. The criteria subjective weight is $\lambda = (\lambda_1, ..., \lambda_v, ..., \lambda_n)^T$, criteria objective weight is $\theta = (\theta_1, ..., \theta_v, ..., \theta_n)^T$, and combination weight is $\omega = (\omega_1, ..., \omega_v, ..., \omega_n)^T$. $U_i = [L_{i,uv}^{n(t)}(p)], (i = 1, 2, ..., \tau)$ is the evaluation information matrix of the i-th decision-maker, where $L_{i,uv}^{n(t)}(p) = \{\ell_k^{n(t)}(p_k^{n(t)}) | k = 1, 2, ..., K\}$ is a PLTS.

3.3. Decision-maker weight adjustment method based on the dispersion degree

In the distance education quality evaluation, the preassigned decision-maker weight may be biased. By using the dispersion degree and concentration degree, the credibility of the evaluation information given by the decision-maker can be judged. If the concentration degree is larger, it means that the decision-maker is more confident in grasping, judging and understanding the current problem. Therefore, the preassigned decision-maker weight should be further tweaked in accordance with the dispersion degree, concentration degree, and score function of the MGPLTS.

Step 1. Calculate the score $Z_{i,uv}$ and dispersion degree $f_{i,uv}$ of each $L_{i,uv}^{t,n(t)}(p)$ by Eqs. (5) and (8), respectively.

Step 2. Average the score of each alternative under each criterion:

$$\bar{Z}_{uv} = \sum_{i=1}^{\tau} \frac{Z_{i,uv}}{\tau} \tag{10}$$

Step 3. Calculate the average dispersion degree of the evaluation information matrix U_i:

$$\bar{f}_i = \frac{\sum_{v=1}^{n} \sum_{u=1}^{m} f_{i,uv}}{mn} \tag{11}$$

Obviously, the smaller the average dispersion degree $\bar{f}_i$ is, the higher the credibility of the evaluation information is.

Step 4. Compute the score function deviation $\hat{Z}_{i,uv}$, the score function matrix deviation TZ_i, the total score function deviation TZ, and the score function matrix deviation ratio DTZ_i:

$$\hat{Z}_{i,uv} = \left| Z_{i,uv} - \bar{Z}_{uv} \right|, (u = 1, 2, ..., m; v = 1, 2, ..., n; i = 1, 2, ..., \tau) \tag{12}$$

$$TZ_i = \sum_{v=1}^{n} \sum_{u=1}^{m} \hat{Z}_{i,uv}. \tag{13}$$

$$TZ = \sum_{i=1}^{\tau} TZ_i. \tag{14}$$

$$DTZ_i = \frac{TZ_i}{TZ}. \tag{15}$$

Evidently, the lower the score function matrix deviation ratio DTZ_i is, the more reliable the evaluation information of the decision-maker is.

Step 5. Compute the adjusted weight $\hat{w}_i$ of decision-makers:

$$\hat{w}_i = \frac{(1 - DTZ_i)\left(1 - \bar{f}_i\right) w_i}{\sum_{i=1}^{\tau} (1 - DTZ_i)\left(1 - \bar{f}_i\right) w_i}. \tag{16}$$

3.4. Criteria weight model

3.4.1. Subjective weights MGPL-SWARA method

Decision-makers in different professional fields have different perceptions of the importance of teaching, interaction, technology and other distance education quality evaluation criteria. The subjective weighting method fully considers a decision-maker's experience, professional knowledge and grasp of the particular problem. The SWARA method [8] is widely used, which is less complicated and more straightforward than AHP and BWM [9]. Moreover, the SWARA method can determine the priority process according to the current policies and decision-making environment.

Since MGPLTSs are constructed with linguistic terms, the classic SWARA method cannot be applied, so the MGPL-SWARA method is constructed.

Step 1: Each decision-maker gives a vector $Y_i = (y_1^i, ..., y_v^i ... , y_n^i), (i = 1, 2, ..., \tau)$ for the importance of the criteria, where y_v^i is the PLTS given by the i-th decision-maker regarding the importance of criteria a_v.

Step 2: Calculate the score Z_v^i and concentration degree c_v^i of each y_v^i by Eqs. (5) and (9).

Step 3: Calculate the mean of the criteria scores $Z = (Z_1, ..., Z_v, ..., Z_n)$ by:

$$Z_v = \frac{\sum_{i=1}^{\tau} w_i c_v^i Z_v^i}{\sum_{i=1}^{\tau} w_i c_v^i} \tag{17}$$

Step 4: Sort in descending order according to the mean of criteria scoresZ_v, and obtain a new vector $\bar{Z} = (\bar{Z}_1, ..., \bar{Z}_j, ..., \bar{Z}_n)$, where $\bar{Z}_j \geqslant \bar{Z}_{j+1}$, and the coefficient F_j is computed as:

$$F_j = \begin{cases} \bar{Z}_1 & j = 1 \\ \bar{Z}_j + 1 & j > 1 \end{cases} \tag{18}$$

Step 5: The recomputed weight r_v is obtained as follows:

$$r_j = \begin{cases} 1 & j = 1 \\ \frac{r_{j-1}}{F_j} & j > 1 \end{cases} \tag{19}$$

Step 6: The relative weights λ_j of the criteria are determined as follows:

$$\lambda_j = \frac{r_j}{\sum_{j=1}^{n} r_j} \tag{20}$$

where $\lambda = (\lambda_1, ..., \lambda_j, ..., \lambda_n)$ represents the criteria subjective weights.

3.4.2. Objective weights MGPL-CRITIC method based on the Spearman correlation coefficient

In the distance education quality evaluation problem, the criteria cannot be completely independent, such as teaching interaction, faculty support and learner support. The CRITIC method proposed by Diakoulaki et al. [10] can solve this problem by calculating the correlation coefficient between the criteria. In the PLTS method, the currently available correlation coefficients are based on Pearson correlation coefficients [11,5]. However, before calculating these correlation coefficients, the linear relationship between PLTSs is not verified, which may lead to deviation in the results. In addition, the Pearson correlation coefficient is sensitive to outliers, which is not conducive to subsequent calculation. Compared with the Pearson correlation coefficient, the Spearman correlation coefficient is more suitable for obtaining the correlation coefficient of MGPLTS and PLTS. Therefore, the MGPL-CRITIC method is constructed according to the Spearman correlation coefficient to obtain the criterion objective weight.

Definition 12. Assume that $H_1 = (L_1^1(p), ..., L_m^1(p))$ and $H_2 = (L_1^2(p), ..., L_m^2(p))$ are two MGPLTSs vectors. Compute the score of each MGPLTS by Eq. (5), then record the ranking of the MGPLTS score by vectors $M_1 = (M(L_1^1(p)), ..., M(L_m^1(p)))$ and$M_2 = (M(L_1^2(p)), ..., M(L_m^2(p)))$. Then, the correlation coefficient between H_1 and H_2 is:

$$\rho_{12} = 1 - \frac{6 \times \sum_{u=1}^{m} \left(M\left(L_u^1(p)\right) - M\left(L_u^2(p)\right) \right)^2}{m^3 - m} \tag{21}$$

where $\rho \in [-1, 1]$.

Assuming that $U = [L_{uv}(p)], (u = 1, 2, ..., m; v = 1, 2, ..., n)$ is an MGPLTS matrix, then the calculation of the MGPL-CRITIC method is described in detail.

Step 1: Compute the score Z_{uv} of each MGPLTS by Eq. (5), and record the ranking by vectors $M_{v_1} = (M(L_{1v_1}(p)), ..., M(L_{mv_1}(p))), (v_1 = 1, 2, ..., n)$.

Step 2: Construct the correlation coefficient matrix $N = \left[\rho_{v_1 v_2}\right]_{n \times n}$ by Eq. (21).

Step 3: Obtain the standard deviation of the criteria:

$$R_{v_1} = \sqrt{\frac{1}{m-1} \sum_{u=1}^{m} \left(Z(L_{uv}(p)) - \frac{1}{m} \sum_{u=1}^{m} Z(L_{uv}(p)) \right)^2} \tag{22}$$

Step 4: Calculate the criteria objective weights:

$$\theta_{v_1} = \frac{R_{v_1} \sum_{v_2=1}^{n} \left(1 - \rho_{v_1 v_2}\right)}{\sum_{v_1=1}^{n} \left(R_{v_1} \sum_{v_2=1}^{n} \left(1 - \rho_{v_1 v_2}\right) \right)} \tag{23}$$

where $0 < \theta_{v_1} < 1$, and $\sum_{v_1=1}^{n} \theta_{v_1} = 1$.

3.4.3. Combination weight method based on the game theory method

Subjective weights and objective weights both have their advantages and limitations. Subjective weights are subjective and arbitrary and may contain subjective biases of the decision-makers; objective weights cannot fully reflect the significance of the criteria in a particular problem. Therefore, combination weights play an important role. However, the multiplicative model may lead to a multiplicative effect, overestimating large weights and underestimating small weights [46]. Although the additive model does not have this problem, it is still insufficient in effectively determining the weighting coefficient. Chen regards subjective and objective weights as two participants in a game, and the combination weight is the result of this "weight" game [48]. Therefore, Chen [47] proposed a combination weight method according to the idea of game theory. The combination weight method based on game theory seeks the consistency or compromise between different weights, that is, minimizing the deviation between possible weights and each weight to make the combination weight more reasonable. Then, we can establish the target model [12]:

$$\min \| e_1 Y_1 + e_2 Y_2 - Y_q \|_2; (e_q > 0, q = 1, 2) \tag{24}$$

where Y_1 is the subjective weight vector, Y_2 is the objective weight vector and $e_1 Y_1 + e_2 Y_2$ represents a linear combination of Y_1 and Y_2.

According to the differentiation property of the matrix, the first derivative condition that satisfies optimality can be expressed as:

$$\sum_{f=1}^{2} e_f Y_q Y_f^T = Y_q Y_q^T (q = 1, 2) \tag{25}$$

And the corresponding linear equation is:

$$\begin{bmatrix} Y_1 Y_1^T & Y_1 Y_2^T \\ Y_2 Y_1^T & Y_2 Y_2^T \end{bmatrix} \begin{bmatrix} e_1 \\ e_2 \end{bmatrix} = \begin{bmatrix} Y_1 Y_1^T \\ Y_2 Y_2^T \end{bmatrix} \tag{26}$$

Solving Eq. (26) may result in negative numbers, and the values of e_1 and e_2 should be normalized:

$$\begin{cases} e_1^* = \frac{|e_1^*|}{|e_1^*| + |e_2^*|} \\ e_2^* = \frac{|e_2^*|}{|e_1^*| + |e_2^*|} \end{cases} \tag{27}$$

Finally, we can derive the combination weights:

$$\omega = e_1^* Y_1 + e_2^* Y_2 = (\omega_1, \omega_2, ..., \omega_n)^T \tag{28}$$

3.5. The MGPL-DT-MULTIMOORA method

3.5.1. The disappointment theory

Disappointment theory is the results of Bell's further study of the influence of risk aversion factors on decision-making after he proposed regret theory [13]. Disappointment is a psychological response to results that are not in line with expectations. The greater the gap, the greater the disappointment. Carver and Scheier [14] believe that disappointment represents the relationship between the actual progress toward achieving goals and the expected rate. The feeling of powerlessness caused by disappointment causes people to think that no decision would lead to a different outcome, leading to inertia and risk aversion, which ultimately causes them to terminate the action or abandon the current goal [15].

The disappointment-elation function describes the idea of disappointment theory in more detail. Assume that x is an alternative, the evaluation information for x is y, R is the reference point associated with x, and $T(\Delta y)$ is the disappointment-elation value. The disappointment-elation function is [16]:

$$T(\Delta y) = 1 - \delta^{\Delta y} = 1 - \delta^{y-R} \tag{29}$$

where Δy represents the deviation of consequences between y and R, $0 < \delta < 1$ represents the disappointment aversion parameter, and the higher the δ value, and the higher the disappointment aversion degree of the decision-maker. Different disappointment aversion parameter δ has different effects on the result of the disappointment-elation function, as illustrated in Fig. 1.

3.5.2. The MGPL-DT-MULTIMOORA method based on combination weight and IDC method

The MULTIMOORA method was improved by Brauers and Zavadskas [17] by adding the full multiplicative form (FMF) method on the basis of MOORA (including the ratio system (RS) method and the reference point method (RP)) [18]. However, the traditional MULTIMOORA method does not consider the expectations of decision-makers. In fact, disappointment can

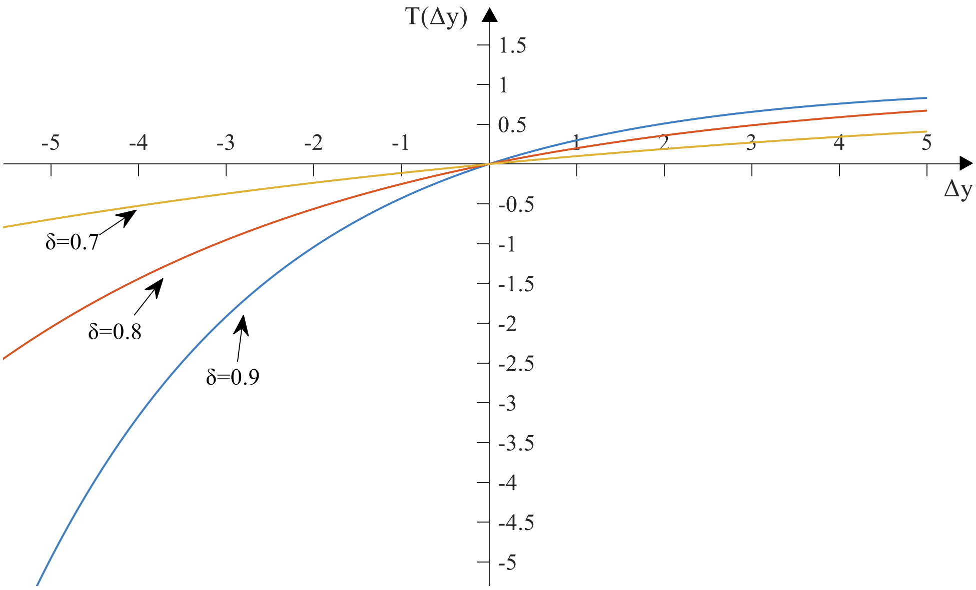

Fig. 1. The disappointment-elation function $T(\Delta y)$.

lead to avoidance behavior by decision-makers, which adversely affects decision-making. Therefore, we combine disappointment theory with the MULTIMOORA method.

The reference point method in MULTIMOORA only considers the closeness of partial evaluation information to the optimal value. Although traditional reference point methods, such as the TOPSIS method, consider the closeness to the optimal value and to the worst value, the ranking result is inaccurate if these extreme values (the optimal value and the worst value) are not given or cannot be calculated correctly. To address this case, this paper proposes an improved reference point method in MULTIMOORA based on the EDAS method.

According to Eqs. (1) and (9), the MGPLTS standardization in the i-th matrix can be transformed into the disappointment-elation value:

$$T_{uv}^{i} = \sum_{k=1}^{K}\left(1 - \delta^{\varphi\left(\ell_k^{n(t)}\right)-R}\right) \times p_k^{n(t)} \tag{30}$$

The weighted result of the decision-makers is:

$$DT_{uv} = \sum_{i=1}^{\tau} w_i T_{uv}^{i} \tag{31}$$

Then, the disappointment-elation value is normalized:

$$G_{uv} = \frac{DT_{uv}}{\sqrt{\sum_{u=1}^{m}(DT_{uv})^2}} \tag{32}$$

(1) The MGPL-DT-ratio system method (MGPL-DT-RS).

The MGPL-DT-ratio system method can be expressed as follows:

$$J_1(x_u) = \sum_{v=1}^{s}\omega_v G_{uv} - \sum_{v=s+1}^{n}\omega_v G_{uv} \tag{33}$$

where s represents the number of beneficial criteria, $n - s$ represents the number of cost criteria, and $J_1(x_u)$ is the ranking value of x_u in the ratio system method. The first ranking $B_1 = \{b_1(x_1), b_1(x_2), \ldots, b_1(x_m)\}$ for the alternatives is determined in descending order of $J_1(x_u)$.

(2) The MGPL-DT-extended reference point method (MGPL-DT-ERP).

The average value under each criterion is:

$$AV_v = \frac{\sum_{u=1}^{m} G_{uv}}{m} \tag{34}$$

First, distinguish between beneficial criteria and cost criteria. Then, determine positive distances and negative distances according to the distance between the normalized disappointment-elation value and the average value under different criteria. Then, obtain the sum of the positive distances from the average (SP) and the sum of negative distances from the average (SN) by Eqs. (35) and (36), respectively:

$$SP_u = \sum_{v=1}^{s} \omega_v \max(0, (G_{uv} - AV_v)) + \sum_{v=s+1}^{n} \omega_v \max(0, (AV_v - G_{uv})) \tag{35}$$

$$SN_u = \sum_{v=1}^{s} \omega_v \min(0, (G_{uv} - AV_v)) + \sum_{v=s+1}^{n} \omega_v \min(0, (AV_v - G_{uv})) \tag{36}$$

Normalize the values of SP and SN:

$$NSP_u = \frac{SP_u}{\max_u (SP_u)} \tag{37}$$

$$NSN_u = \frac{SN_u}{\min_u (SN_u)} \tag{38}$$

The comprehensive value $J_2(x_u)$ of x_u in the reference point method for each alternative is:

$$J_2(x_u) = \frac{1}{2}(NSP_u + (1 - NSN_u)) \tag{39}$$

The second ranking $B_2 = \{b_2(x_1), b_2(x_2), ..., b_2(x_m)\}$ for the alternatives is determined in descending order of $J_2(x_u)$.

(3) The MGPL-DT-full multiplicative form method (MGPL-DT-FMF).

The full multiplicative form method can be expressed as:

$$J_3(x_u) = \frac{\sqrt[s]{\prod_{v=1}^{s}\left(1 - \left(1 - \frac{G_{uv}+1}{2}\right)^{\omega_v}\right)}}{\sqrt[n-s]{\prod_{v=s+1}^{n}\left(1 - \left(1 - \frac{G_{uv}+1}{2}\right)^{\omega_v}\right)}} \tag{40}$$

where $J_3(x_u)$ is the ranking value of x_u in the full multiplicative form method. The third ranking $B_3 = \{b_3(x_1), b_3(x_2), ..., b_3(x_m)\}$ for the alternatives is determined in descending order of $J_3(x_u)$.

(4) Final ranking result determination method.

The above three methods yield three ranking results and three ranking values. According to dominance theory [20], the traditional MULTIMOORA method can obtain the final ranking.

Wu et al. [5] pointed out that dominance theory does not consider the ranking value of each alternative for each method, and the operation is complicated, so they proposed an improved Borda rule method. However, Liu and Li [19] pointed out that it is unreasonable for the improved Borda rule method to take only the ranking result to be the weight of the ranking values. In addition, the importance of these three methods should also be considered. Therefore, the final ranking should comprehensively take into account the importance of the method, the deviation degree of the ranking value, and the consistency of the ranking results. The IDC (importance, deviation, consistency) final ranking steps are described below.

Step 1. Ranking value standardization.

$$\bar{J}_\kappa(x_u) = \frac{J_\kappa(x_u)}{\sqrt{\sum_{u=1}^{m} (J_\kappa(x_u))^2}} (\kappa = 1, 2, 3; u = 1, 2, ..., m) \tag{41}$$

Step 2. Determine the importance of the method.

Decision-makers use MGPLTSs to provide evaluation information according to the importance of each method and obtain τ vectors $C_\alpha = (L_1^\alpha(p), L_2^\alpha(p), L_3^\alpha(p))$. Multiply the probability value in each vector by the corresponding decision-maker weight, and finally integrate the τ vectors into one vector $C = (L_1(p), L_2(p), L_3(p))$. Then, calculate the score value vector $(Z(L_1(p)), Z(L_2(p)), Z(L_3(p)))$ by Eq. (5). Inspired by the BWM [9], the importance (I_1^1, I_2^1, I_3^1) of the three methods was obtained by constructing the following model:

$$\min \xi$$
$$s.t.\begin{cases} \left| I_1^1/I_2^1 - Z(L_1(p))/Z(L_2(p)) \right| \leqslant \xi, \\ \left| I_1^1/I_3^1 - Z(L_1(p))/Z(L_3(p)) \right| \leqslant \xi, \\ \left| I_2^1/I_3^1 - Z(L_2(p))/Z(L_3(p)) \right| \leqslant \xi, \\ I_1^1 + I_2^1 + I_3^1 = 1 \\ I_1^1 \geqslant 0, I_2^1 \geqslant 0, I_3^1 \geqslant 0 \end{cases} \tag{42}$$

Then, we obtain the importance results:

$$I_\alpha^1 = \frac{Z(L_\alpha(p))}{Z(L_1(p)) + Z(L_2(p)) + Z(L_3(p))}; (\alpha = 1, 2, 3) \tag{43}$$

Step 3. Determine the deviation degree of the ranking value.
According to the above three methods, the ranking value matrix is:

$$\begin{bmatrix} \bar{J}_1(x_1) & \bar{J}_2(x_1) & \bar{J}_3(x_1) \\ \bar{J}_1(x_2) & \bar{J}_2(x_2) & \bar{J}_3(x_2) \\ \cdots & \cdots & \cdots \\ \bar{J}_1(x_m) & \bar{J}_2(x_m) & \bar{J}_3(x_m) \end{bmatrix} \tag{44}$$

Inspired by maximizing the optimal deviation model [19], the deviation degree model is as follows:

$$I_\alpha^2 = \frac{\sum_{u_1=1}^m \sum_{u_2=1}^m \left| \bar{J}_\alpha(x_{u_1}) - \bar{J}_\alpha(x_{u_2}) \right|}{\sqrt{\sum\limits_{\alpha}^{3} \sum\limits_{u_1=1}^{m} \sum\limits_{u_2=1}^{m} \left| \bar{J}_\alpha(x_{u_1}) - \bar{J}_\alpha(x_{u_2}) \right|}}; (\alpha = 1, 2, 3) \tag{45}$$

Step 4. Determine the consistency of the ranking results.
According to the above three methods, the ranking result matrix can be obtained as:

$$\begin{bmatrix} b_1(x_1) & b_2(x_1) & b_3(x_1) \\ b_1(x_2) & b_2(x_2) & b_3(x_2) \\ \cdots & \cdots & \cdots \\ b_1(x_m) & b_2(x_m) & b_3(x_m) \end{bmatrix} \tag{46}$$

Compute the average ranking of each alternative:

$$Ab(x_u) = \frac{b_1(x_u) + b_2(x_u) + b_3(x_u)}{3} \tag{47}$$

Calculate the inconsistency degree of each method:

$$IC_\alpha = m - 1 - \sum_{u=1}^{m} |b_\alpha(x_u) - Ab(x_u)| \tag{48}$$

The consistency degree model is as follows:

$$I_\alpha^3 = \frac{IC_\alpha}{\sum_{\alpha=1}^3 IC_\alpha}; (\alpha = 1, 2, 3)$$

Thus, we can obtain the final ranking value:

$$J(x_u) = I_1^1 \times \bar{J}_1(x_u) \times \left(I_1^2 + I_1^3\right) + I_2^1 \times \bar{J}_2(x_u) \times \left(I_2^2 + I_2^3\right) + I_3^1 \times \bar{J}_3(x_u) \times \left(I_3^2 + I_3^3\right) \tag{50}$$

The final ranking result for the alternatives is determined in descending order of $J(x_u)$.

3.6. The specific decision procedures for the MGPL-DT-MULTIMOORA method

The specific steps are described below. The corresponding relationship between the MGPL-DT-MULTIMOORA method and the various stages of the distance education quality evaluation decision-making framework is shown in Fig. 2.

***Step 1*:** Collect evaluation information $U_i = [L_{i,uv}^{n(t)}(p)](i = 1, 2, ..., \tau)$ given by decision-makers and normalize MGPLTSs according to Eq. (5).

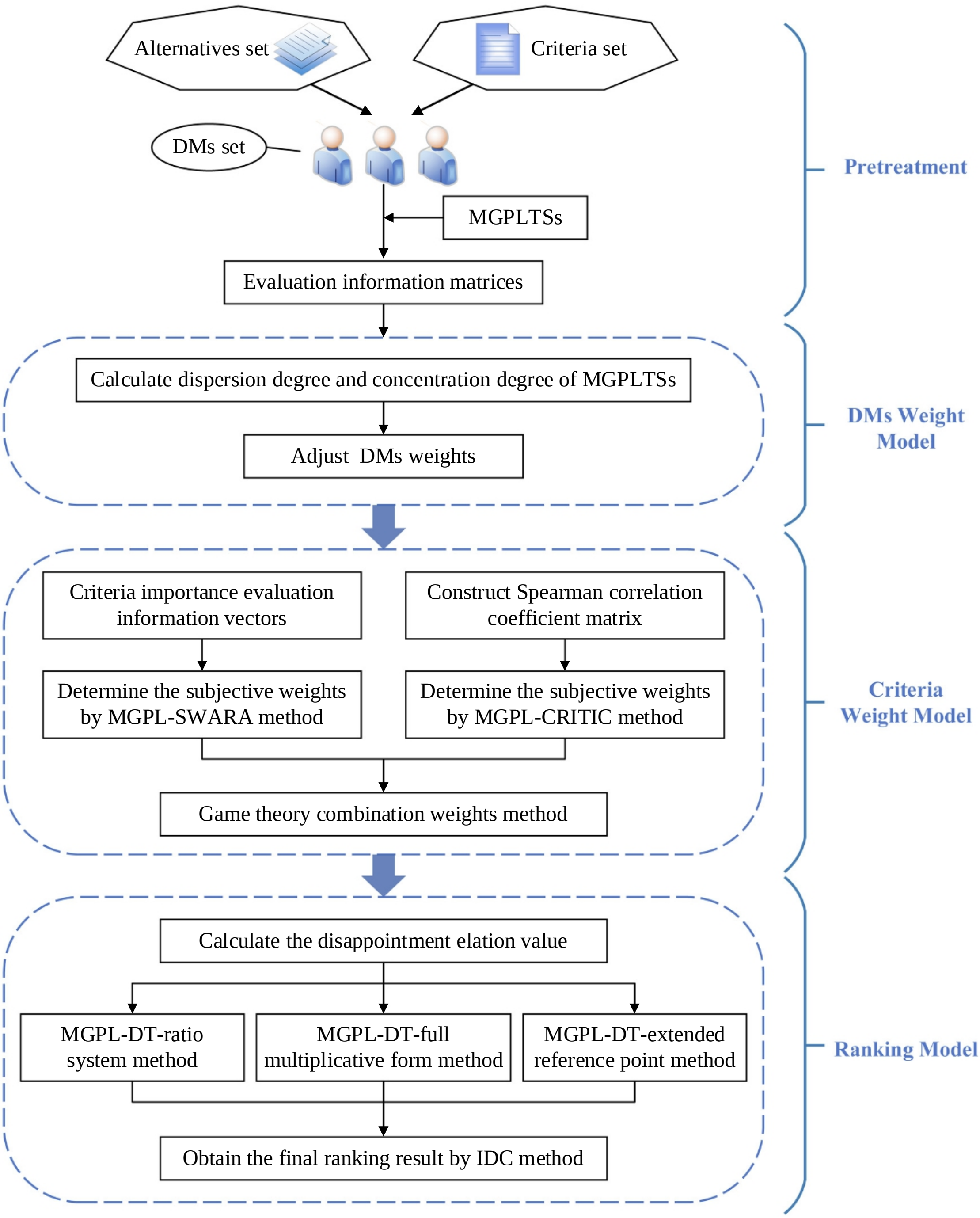

Fig. 2. The whole framework created MCGDM method.

***Step 2*:** Compute the dispersion and concentration degrees of each evaluation information matrix by Eqs. (8) and (9).

***Step 3*:** Based on the dispersion and concentration degrees, the adjusted weight $W = (w_1, w_2, .., w_\tau)^T$ of the decision-makers is calculated by Eqs. (10)–(16).

***Step 4*:** Determine criteria weights.

***Step 4.1*:** Calculate the subjective weights with the MGPL-SWARA method. Compute the criteria weights $(\lambda_1, \lambda_2, ..., \lambda_n)$ according to Eqs. (17)–(20).

***Step 4.2*:** Calculate the objective weights with the MGPL-CRITIC method. Compute the criteria weights $(\theta_1, \theta_2, ..., \theta_n)$ according to Eqs. (21)–(23).

***Step 4.3*:** Determine the combination weights with the combination weights method. Compute the criteria weights $(\omega_1, \omega_2, ..., \omega_n)$ according to Eqs. (30)–(32).

***Step 5*:** Determine the ranking result with the MGPL-DT-MULTIMOORA method.

***Step 5.1*:** Calculate the normalized disappointment elation value according to Eqs. (30)–(32).

***Step 5.2*:** Obtain the ranking value $J_1(x_u)$ and ranking result $B_1 = \{b_1(x_1), b_1(x_2), ..., b_1(x_m)\}$ of $x_u(u = 1, 2, ..., m)$ in the MGPL-DT-ratio system method by Eq. (33).

***Step 5.3*:** Obtain the ranking value $J_2(x_u)$ and ranking result $B_2 = \{b_2(x_1), b_2(x_2), ..., b_2(x_m)\}$ of $x_u(u = 1, 2, ..., m)$ in the MGPL-DT-extended reference point method by Eqs. (34)–(39).

***Step 5.4*:** Derive the ranking value $J_3(x_u)$ and ranking result $B_3 = \{b_3(x_1), b_3(x_2), ..., b_3(x_m)\}$ of $x_u(u = 1, 2, ..., m)$ in the MGPL-DT-full multiplicative form method by Eq. (40).

***Step 5.5*:** Obtain the final ranking value $J(x_u)$ and final ranking result $B = \{b(x_1), b(x_2), ..., b(x_m)\}$ of $x_u(u = 1, 2, ..., m)$ with the IDC method based on Eqs. (41)–(50).

4. A case study

In this section, a distance education quality evaluation case is addressed by the MGPL-DT-MULTIMOORA method, and the influence of the parameters in the disappointment-elation function on the decision result is analyzed. Finally, the effectiveness of the proposed method is illustrated by comparing it with other methods.

Distance education is a new method of education and plays an important role in modern education systems. Regarding the characteristics of distance education, there are significant differences between distance education and traditional education. The evaluation criteria of traditional education are not suitable for the evaluation of distance education quality. Under the new developing environment, distance education quality evaluation has added new criteria, and many new problems have followed. Evaluation criteria are the basis of distance education quality evaluation. In view of the new problems, targeted evaluation criteria should be formulated to provide a basis for distance education quality evaluation. This paper considers 8 distance education criteria frameworks in Table 1: Quality Scorecard (QS, from the Online Learning Consortium of USA), Excellence (from the European Association of Distance Teaching Universities), Quality Assurance Framework (QAF, from the Asian Association of Open University), Cyber Universities Criteria (CUC, from the Ministry of Education, Science and Technology of South Korea), CELTS-22 (the Ministry of Education of China), [22,23,25].

4.1. Application of the proposed MCGDM method to a distance education quality evaluation

Case. The development of distance education in China has gone through three generations: The first generation was correspondence education; The second generation was radio and television education; In the 1990s, with the development of information and network technology, the third generation of modern distance education based on information and network technology came into being. Especially under the influence of COVID-19, distance education has played a great role in education. At present, there are three institutions in China using modern distance education public service systems. In this case, we evaluate these three institutions and one other, smaller institution. The potential distance education institutions ($X = \{x_1, x_2, x_3, x_4\}$) and brief information are as follows:

- x_1: Founded in 2001, it has established more than 1,800 learning centers and more than 400 training centers to provide education services for 400 majors in 8 categories.
- x_2: Founded in 2005, it covers more than 30 cities and has established more than 40 service centers to provide teaching and examination services for 20 colleges and universities.
- x_3: Founded in 2007, it has cooperated with more than 10 colleges and universities, and its business covers network higher education, adult education informatization and other fields.

Table 1
Criteria framework of distance education quality evaluation.

Framework	Criteria
QS	System, Technology, Course and teaching design, Course structure, Teaching and learning; Teacher support, Learner support, Evaluation and review
Excellence	Strategic management, Professional design, Course design, Course delivery, Faculty support, Learner support
QAF	Policy and planning; Internal management, Learners and their characteristics, Facilities, Media and learning resources, Student assessment, Research and social services, Human resources, Student support, Professional design and course system, Course design
CUC	Teaching planning, governance and management, Teaching design, Course delivery and development, Teachers and administrators, Infrastructure, Educational results
CELTS-22	Course content, teaching design, interface design, technology, professional design
[22]	Teaching quality, Learner support, Teacher support, Reputation/Impact, Quality of research, Organization quality, Sustainability of institution, Quality of the technological infrastructure
[23]	Accurate and easy-to-understand content, Systematic content, Personalized design, Security, Navigation, Interactivity, Application interface
[25]	User interface, Personalization, Interactivity, Security, Complete content, Navigation, Right and understandable content

- x_4: Founded in 2003, it has been entrusted by more than 50 key universities and more than 300 training institutions to provide educational services to 10 million students.

By summarizing the framework in Table 1, five criteria $A = \{a_1, a_2, a_3, a_4, a_5\}$ are selected in this case, their meanings are explained in Table 2, and they are all shown to be beneficial.

First, invite three decision-makers: The first decision-maker d_1 is an expert in distance education, who has been engaged in the study of traditional education evaluation and distance education quality evaluation for many years; The second decision-maker d_2 is a technician, who is proficient in human–computer interaction design, live course transmission, software development and other technologies; The third decision-maker d_3 is a distance education teacher. He was engaged in traditional offline teaching before switching to the distance education industry and engaged in distance education for 5 years. Their initial weights are $W = (0.3, 0.3, 0.4)^T$. Depending on their preferences, they select three LTSs with different granularity levels.

$$S^3 = \{\ell^3_{-1} = bad, \ell^3_0 = medium, \ell^3_1 = good\}$$

$$S^5 = \{\ell^5_{-2} = very\ bad, \ell^5_{-1} = bad, \ell^5_0 = medium, \ell^5_1 = good, \ell^5_2 = very\ good\}$$

$$S^9 = \left\{ \begin{array}{c} \ell^9_{-4} = extremely\ bad, \ell^9_{-3} = very\ bad, \ell^9_{-2} = bad, \ell^9_{-1} = slightly\ bad, \ell^9_0 = medium, \\ \ell^9_1 = slightly\ good, \ell^9_2 = good, \ell^9_3 = very\ good, \ell^9_4 = extremely\ good \end{array} \right\}$$

Step 1: Collect the evaluation information U_1, U_2, U_3 provided by the decision-makers d_1, d_2, d_3, as shown in Tables 3–5 (Appendix 1). Since the sum of the probability values of each PLTS is 1, there is no need for normalization (see Table 6).

Step 2: Obtain dispersion degree $(f(U_1), f(U_2), f(U_3)) = (0.1482, 0.0852, 0.0498)$ by Eqs. (8) and (11), and obtain the concentration degree $(c(U_1), c(U_2), c(U_3)) = (0.8518, 0.9148, 0.9502)$ by Eq. (9).

Step 3: The adjusted weights $W = (0.24, 0.27, 0.49)^T$ of the decision-makers are calculated by Eqs. (10)–(16).

Step 4: Determine the criteria weights.

Step 4.1: Each decision-maker gives an evaluation vector according to the importance of the criteria:

$$Y_1 = (\{\ell^3_{-1}(0.2), \ell^3_0(0.8)\}, \{\ell^3_0(0.5), \ell^3_1(0.5)\}, \{\ell^3_0(0.8), \ell^3_1(0.2)\}, \{\ell^3_{-1}(0.2), \ell^3_0(0.8)\}, \{\ell^3_0(1)\})$$

$$Y_2 = (\{\ell^5_{-2}(0.3), \ell^5_{-1}(0.7)\}, \{\ell^5_1(0.6), \ell^5_2(0.4)\}, \{\ell^5_0(0.3), \ell^5_1(0.7)\}, \{\ell^5_{-1}(0.6), \ell^5_0(0.4)\}, \{\ell^5_0(0.8), \ell^5_1(0.2)\})$$

$$Y_3 = (\{\ell^9_{-3}(0.3), \ell^9_{-2}(0.7)\}, \{\ell^9_2(0.2), \ell^9_3(0.8)\}, \{\ell^9_1(0.3), \ell^9_2(0.7)\}, \{\ell^9_{-2}(0.5), \ell^9_{-1}(0.5)\}, \{\ell^9_0(0.8), \ell^9_1(0.2)\})$$

Subjective weights $(0.0963, 0.3967, 0.2365, 0.1155, 0.1550)$ is obtained by Eqs. (17)–(20).

Step 4.2: Objective weights $(0.1322, 0.2519, 0.2480, 0.1508, 0.2171)$ are obtained by Eqs. (21)–(23).

Step 4.3: Combination weights $(0.1052, 0.3608, 0.2393, 0.1243, 0.1704)$ are obtained by Eqs. (24)–(28).

Step 5: Obtain the ranking result.

Set the parameters in Eq. (30) as $R = 0.5,\ \delta = 0.7$.

Each decision-maker provides an evaluation vector according to the importance of each method:

$$C_1 = (\{\ell^3_0(0.4), \ell^3_1(0.6)\}, \{\ell^3_0(0.6), \ell^3_1(0.4)\}, \{\ell^3_0(0.8), \ell^3_1(0.2)\})$$

$$C_2 = (\{\ell^5_1(0.8), \ell^5_2(0.2)\}, \{\ell^5_1(1)\}, \{\ell^5_0(0.6), \ell^5_1(0.4)\})$$

$$C_3 = (\{\ell^9_2(0.5), \ell^9_3(0.5)\}, \{\ell^9_2(1)\}, \{\ell^9_1(0.5), \ell^9_2(0.5)\})$$

Table 2
Distance education quality evaluation criteria and illustrations.

Criteria	Illustrations	References
Strategic Management (a_1)	Strategy and management are management measures at the strategic level of distance education institutions, covering policies to maintain a high-quality distance education environment.	QS; Excellence; QAF; CUC
Teaching design and course development (a_2)	Including professional design goals, course goals and resources required for design and development. The development process should involve subject experts, faculty and stakeholders.	QS; Excellence; QAF; CUC; [22,23,25]
Teaching interaction (a_3)	Teaching interaction refers to the guarantee of the course communication process. Including course transmission, and the interactivity and collaboration of the teaching process involved.	QS; Excellence; QAF; CUC; [22,23,25]
Faculty support (a_4)	Faculty support is human resource, teaching support and innovation rewards for faculty, but also support for self-development.	QS; Excellence; QAF; CUC; [22]
Learner support (a_5)	Learner support is the support provided to students by distance education institutions to ensure that learners obtain high-quality education services.	QS; Excellence; QAF; CUC; [22,23,25]

Table 6
Ranking value and ranking result of aggregation tools.

	MGPL-DT-RS		MGPL-DT-ERP		MGPL-DT-FMF	
	$J_1(x_u)$	$b_1(x_u)$	$J_2(x_u)$	$b_2(x_u)$	$J_3(x_u)$	$b_3(x_u)$
x_1	0.5092	2	0.9497	2	0.2259	2
x_2	−0.2094	3	0.2184	3	0.0853	3
x_3	−0.4502	4	0.0000	4	0.0571	4
x_4	0.5548	1	1.0000	1	0.2495	1

IDC results $I^1 = (0.37, 0.34, 0.29)$, $I^2 = (0.46, 0.31, 0.23)$, $I^3 = (1/3, 1/3, 1/3)$ is obtained by Eqs. (42)–(49).

Then, obtain final ranking value of $J = (0.4189, 0.0051, -0.1205, 0.4526)$ by Eq. (50), and final ranking result of $x_4 \succ x_1 \succ x_2 \succ x_3$.

4.2. Sensitivity analysis

In ***Step 5***, we set the parameters in the disappointment-elation function as $R = 0.5$ and $\delta = 0.7$. However, for different decision-making environments, the disappointment aversion and expectations of decision-makers may also differ, which may lead the ranking results to vary with the parameters. Thus, it is necessary to perform a sensitivity analysis of parameters R andδ. The corresponding ranking results presented for different R and δ are shown in Fig. 3, Fig. 4 and Table 7.

As seen in Fig. 3**,** Fig. 4 and Table 7 (Appendix 2), for different parameters, the ranking values are not the same, but the ranking results are unchanged, which means that the ranking of the alternatives is insensitive to the parameters R and δ to changes in parameters A and B.

4.3. Comparison of existing MCGDM methods based on the case

To illustrate the advantages of the proposed MCGDM method compared with the improved PL-VIKOR method [28], PL-DNMA method [29], PL-GLDS method [30], and PL-MULTIMOORA method [30], the results of the comparison are shown in Table 8. Each method is composed of a combination of several aggregation tools, and the integration theory of each method is classified. The results in Table 8 show that the proposed MCGDM method, PL-DNMA method [29], PL-GLDS method [30], and PL-MULTIMOORA method [30] all presented the same final ranking results, while the PL-VIKOR method [28] presented a different optimal alternative.

It can be seen from Table 8 that in different methods, the results of the aggregation tool and the final results are not completely consistent. We show their differences in Fig. 5. It should be noted that the original ranking results of the PLGU, PLIR, final method [28], UCM, DS_2, and PLRP are arranged in ascending order, but in Fig. 5, we change to descending order (take the reciprocal). Fig. 6 shows the difference in the final results of different methods.

Comparison with aggregation tools and integration theory: The aggregation tools in Table 8 and Table 9 include three categories, arithmetic tools, max tools and geometry tools, but different methods also have different specific manifestations.

(1) Arithmetic tools. PL-VIKOR's arithmetic tool is a comparison based on distance [28]; the PL-GLDS method [30] arithmetic tool is based on the arithmetic weighting of dominance flow; and in the PL-DNMA method [29], PL-MULTIMOORA method [5] and MGPL-DT-MULTIMOORA method are based on the arithmetic weighting of evaluation information. The effects of these treatments are similar.

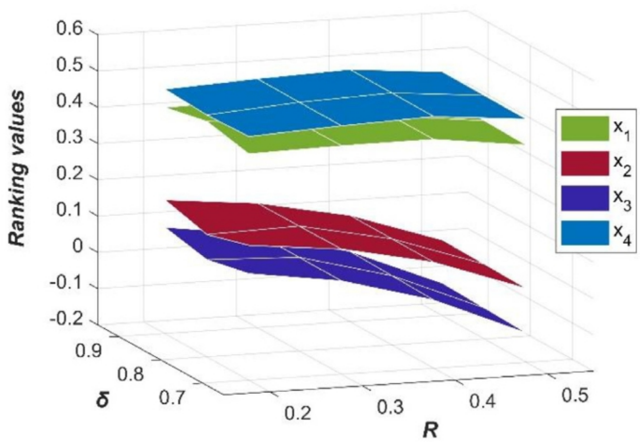

Fig. 3. Ranking values with different R and δ.

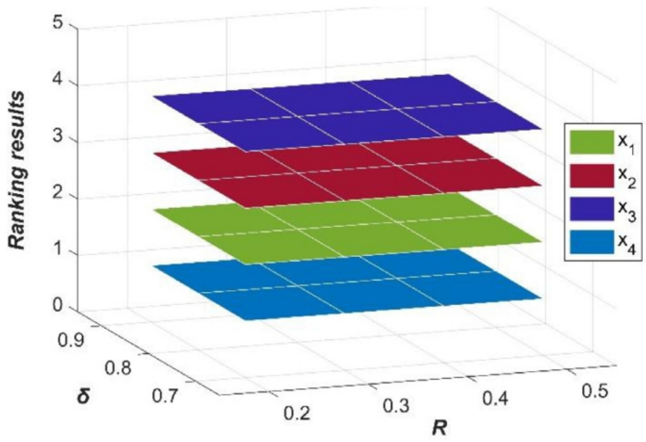

Fig. 4. Ranking results with different R and δ.

Table 8
The ranking results of the Case obtained by different methods.

Methods	Tools	Ranking values				Ranking results
		x_1	x_2	x_3	x_4	
Improved PL-VIKOR method [28]	PLGU	−0.5653	0.6161	1.0000	−0.6568	$x_4 \succ x_1 \succ x_2 \succ x_3$
$\lambda = 1, \theta = 0.5$	PLIR	−0.0117	0.2556	0.3608	0.0269	$x_1 \succ x_4 \succ x_2 \succ x_3$
	Final	0.0276	0.7429	1.0000	0.0518	$x_1 \succ x_4 \succ x_2 \succ x_3$
PL-DNMA method [29]	CCM	0.7826	0.1794	0.0000	0.8284	$x_4 \succ x_1 \succ x_2 \succ x_3$
$\varphi = 0.5$	UCM	0.1294	0.3096	0.3608	0.1331	$x_1 \succ x_4 \succ x_2 \succ x_3$
	ICM	0.7531	0.3559	0.2782	0.8418	$x_4 \succ x_1 \succ x_2 \succ x_3$
	Final	0.0448	−0.2582	−0.4064	0.1420	$x_4 \succ x_1 \succ x_2 \succ x_3$
PL-GLDS method [30]	DS_1	0.6814	0.0862	0.0052	0.7268	$x_4 \succ x_1 \succ x_2 \succ x_3$
	DS_2	0.2516	0.6018	0.7013	0.2878	$x_1 \succ x_4 \succ x_2 \succ x_3$
	Final	0.1793	−0.1633	−0.2800	0.2331	$x_4 \succ x_1 \succ x_2 \succ x_3$
PL-MULTIMOORA method [5]	PLRS	0.6068	0.3602	0.2838	0.6492	$x_4 \succ x_1 \succ x_2 \succ x_3$
	PLRP	−0.0264	0.5767	0.8142	0.0606	$x_1 \succ x_4 \succ x_2 \succ x_3$
	PLFMF	0.6131	0.3261	0.2554	0.6727	$x_4 \succ x_1 \succ x_2 \succ x_3$
	Final	0.3686	−0.0358	−0.2718	0.5166	$x_4 \succ x_1 \succ x_2 \succ x_3$
MGPL-DT-MULTIMOORA method	RS	0.5092	−0.2094	−0.4502	0.5548	$x_4 \succ x_1 \succ x_2 \succ x_3$
	ERP	0.9497	0.2184	0.0000	1.0000	$x_4 \succ x_1 \succ x_2 \succ x_3$
	FMF	0.2259	0.0853	0.0571	0.2495	$x_4 \succ x_1 \succ x_2 \succ x_3$
	Final	0.4189	0.0051	−0.1205	0.4526	$x_4 \succ x_1 \succ x_2 \succ x_3$

(2) Max tools. All these tools have one thing in common: After processing the original evaluation information, the maximum value is selected for comparison. However, the maximum value may be one of the outliers caused by the decision-maker's misjudgment or by other reasons, and the ranking result from the outliers cannot reflect the actual situation of alternatives, or even the opposite of reality.
(3) Geometry tools. The geometry tool in the PL-DNMA method [29] is the traditional geometric weighted aggregation formula $\prod_{v=1}^{n} a_{uv}^{w_v}$, where a_{uv} is the evaluation value and w_v is the criteria weight. However, Wu et al. [5] pointed out that this method is contrary to the purpose of weighting. Therefore, MGPL-DT-MULTIMOORA chooses the improved aggregation formula $\prod_{v=1}^{n}(1-(1-a_{uv})^{w_v})$ that meets the purpose of weighting.
(4) Integration theory of final results. Integration theory in the PL-VIKOR method [28] is a compromise measure in which the parameter θ is given subjectively, and only the ranking value of the aggregation tools is considered without the ranking result. Integration theory in the PL-MULTIMOORA method [5] and PL-GLDS method [30] is Borda theory, which takes the ranking result as the weight information of the ranking value, but $(m-b(x)+1)/(m(m+1)/2)$ means that the higher the ranking, the higher the weight. In addition, Borda theory does not include the importance of the aggregation tools. In the PL-DNMA method [29], the integration theory is that the Euclidean distance is improved based on Borda theory. As a comprehensive integration theory, various aspects are considered, such as the importance of each aggregation tool in a particular problem, the ranking values and the ranking results of the aggregation tool. Hence, the IDC method has a broader application range and is more advanced than other integration theories.

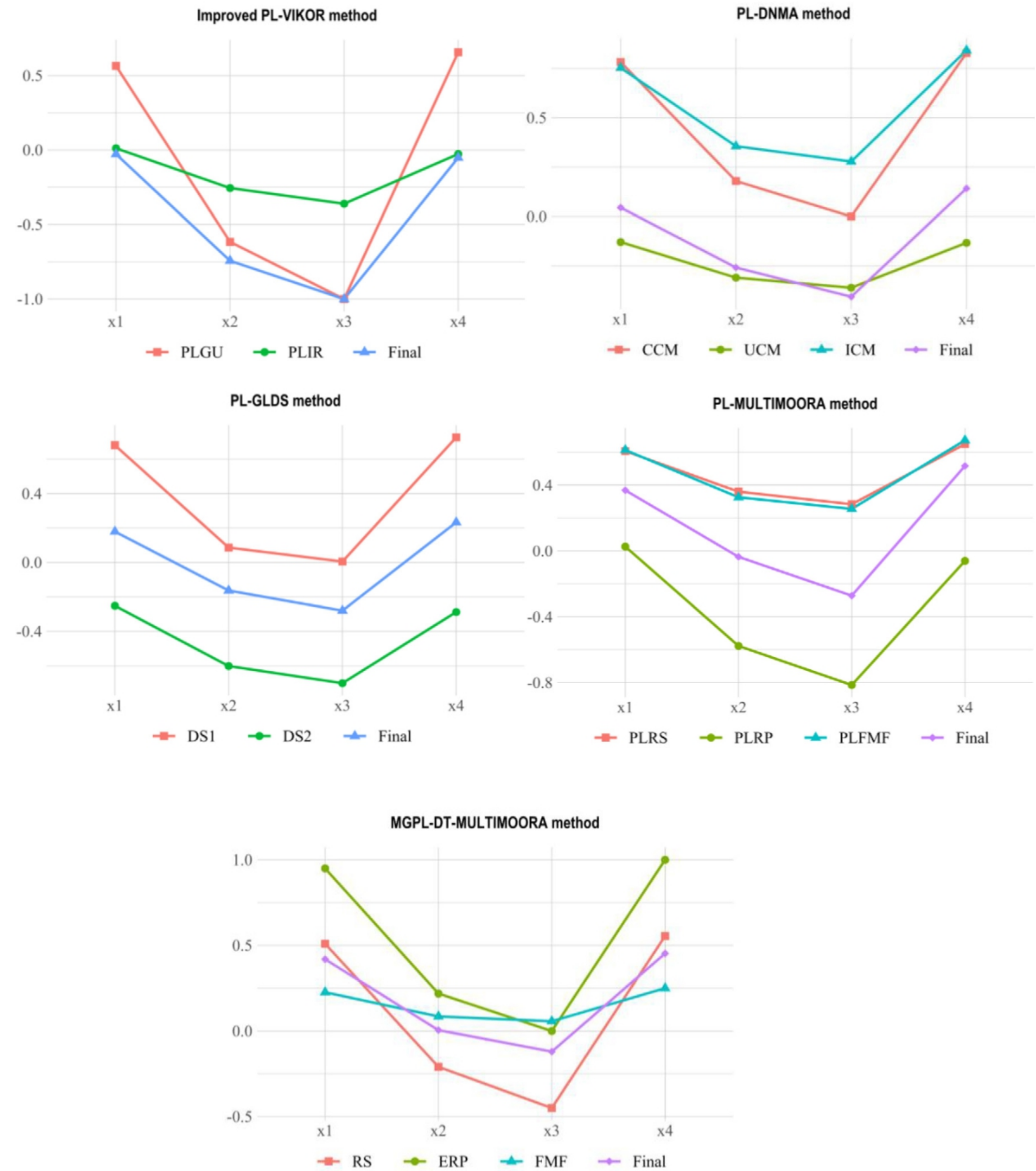

Fig. 5. Aggregation tool results and final results of different methods.

Table 10 shows the comprehensive comparison of these methods in multiple aspects.

Comparison with improved PL-VIKOR method [28]**:** The final ranking result of this method is different from other methods for two main reasons. (1) Among the aggregation tools, the PLGU tool is an arithmetic tool, and the PLIR tool is a max tool. Because PLIR and PLGU differ in the amount of evaluation information they contain (PLIR only contains partial evaluation information, while PLGU contains complete evaluation information), PLIR's rankings are different from PLGU's. This omission of evaluation information makes the results biased. (2) The final ranking result is the same as PLIR but different from PLGU, which is related to the choice of integration theory. A reasonable integration theory should be corrected in the final ranking when the results of the aggregation tools are biased, but the compromise measure does not implement this correction. In addition, this method has some shortcomings. The distance measure used to compare two PLTSs is compli-

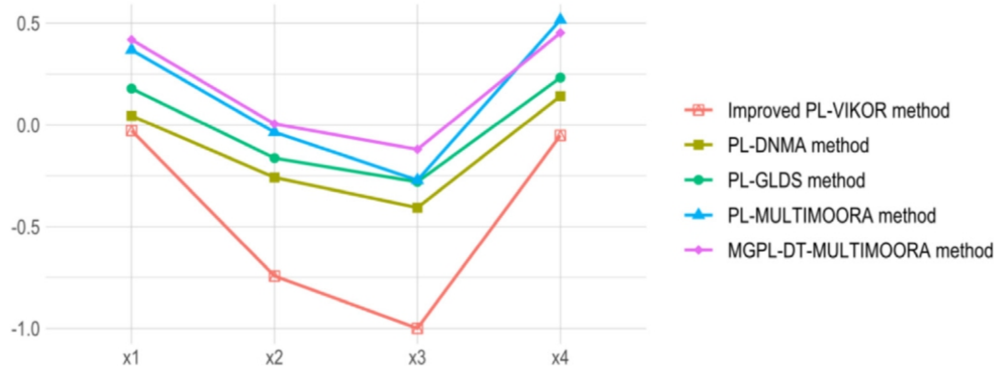

Fig. 6. Final results of different methods.

Table 9
The characteristics of aggregation tool and integration theory in final ranking.

Methods	Aggregation tools	Integration theory	Characteristics	
			Parameter	Illustration
Improved PL-VIKOR method [28]	PLGU	Arithmetic	$\theta = 0.5$	Subjective
	PLIR	Max	$\theta = 0.5$	Subjective
	Final	Compromise measure	Ranking values are added proportionally	
PL-DNMA method [29]	CCM	Arithmetic	$w = 1/3, \varphi = 0.5$, $(m - b(x) + 1)/m$	Subjective, Objective
	UCM	Max	$w = 1/3$, $\varphi = 0.5, b(x)/m$	Subjective, Objective
	ICM	Geometry	$w = 1/3, \varphi = 0.5$, $(m - b(x) + 1)/m$	Subjective, Objective
	Final	Euclidean distance	Ranking results as ranking value, and importance as weight	
PL-GLDS method [30]	DS_1	Arithmetic	$(m - b(x) + 1)/(m(m + 1)/2)$	Objective
	DS_2	Max	$b(x)/(m(m+1)/2)$	Objective
	Final	Borda theory	Ranking results as the weight	
PL-MULTIMOORA method [5]	PLRS	Arithmetic	$(m - b(x) + 1)/(m(m + 1)/2)$	Objective
	PLRP	Max	$b(x)/(m(m+1)/2)$	Objective
	PLFMF	Geometry	$(m - b(x) + 1)/(m(m + 1)/2)$	Objective
	Final	Borda theory	Ranking results as the weight	
MGPL-DT-MULTIMOORA method	RS	Arithmetic	$I_1^1 + I_1^2 + I_1^3$	Subjective, Objective
	ERP	Arithmetic	$I_2^1 + I_2^2 + I_2^3$	Subjective, Objective
	FMF	Geometry	$I_3^1 + I_3^2 + I_3^3$	Subjective, Objective
	Final	IDC	Importance, deviation, consistency as the weight	

where $b(x)$ is ranking result of alternative x, and m is the number of alternatives.

cated; the decision-maker weight is not adjusted in accordance with the performance of the decision-maker, and the criteria weight only includes the subjective weight AHP, which is complex and has low consistency.

Comparison with the PL-DNMA method [29]**:** (1) There are three types of aggregation tools in this method. Among them, the UCM tool is a max tool, and its ranking result differs from the final ranking result because of the deviation caused by information loss. When the difference in the ranking value of the alternatives in the UCM is too large, it will have a negative impact on the final ranking. (2) In this method, the ICM tool is a geometry tool and uses the traditional geometric weighted aggregation formula, which may violate the aggregation purpose. (3) The Euclidean distance is an integration theory in which the parameters w and φ are given subjectively. The ranking results and ranking values of aggregation tools play the same role, which exaggerates the advantages and disadvantages of the alternatives. Additionally, in this method, the decision-makers weight in particular problems is not adjusted; the criteria weight only includes the objective method.

Comparison with the PL-GLDS method [30]**:** This method contains 2 kinds of aggregation tools. (1) The DS_1 tool for calculating the dominance flow is an arithmetic tool, similar to the positive flows in the PROMETHEE method [31]. The PROMETHEE method also contains negative flows, but DS_1 does not, which means that the calculation in DS_1 only contains partial information. (2) The DS_2 tool in this method is max tool. Using two aggregation tools used to aggregate information in this method results in information loss, which is not conducive to calculating accurate final ranking results. (3) The feature in Borda theory is that the ranking result of aggregation tools is directly used as the weight information of the ranking value. However, the ranking result and importance are two different concepts, and it is unreasonable to regard the ranking result as weights.

Table 10
The characteristics of different methods.

	Improved PL-VIKOR [28]	PL-DNMA [29]	PL-GLDS [30]	PL-MULTIMOORA [5]	MGPL-DT-MULTIMOORA
Decision-makers' weight adjustment model	No	No	No	No	Yes
The correlation between criteria is considered	No	No	No	Yes	Yes
Combination weight	No	No	No	Yes	Yes
Whether the psychological expectations of decision-makers are considered	No	No	No	No	Yes
Aggregation tools avoid massive information loss	No	No	No	No	Yes
Whether integration theory considers the importance, deviation and consistency of aggregation tools	No	No	No	No	Yes

Comparison with PL-MULTIMOORA method [5]**:** (1) The PLRP tool is max tool, and the result is different from the final result. (2) Similar to the PL-GLDS method [30], the weight information given by the Borda theory is also unreasonable. Additionally, this method proposes a correlation coefficient based on the Pearson correlation coefficient to calculate the objective weights of the criteria, but the linear relationship between PLTSs is not tested, which may have led to deviations in the results. In contrast, the Spearman correlation coefficient used in this paper is more appropriate.

In summary, it can be seen from Table 10 that none of the above four methods include the influence of decision-makers' psychological expectations on decision-making results. It is critical for a reasonable MCGDM method to avoid using tools that lead to bias in the decision result, such as the max tool and traditional geometry tool. In the examined case, all max tools produced the same results, but they differed from the final ranking. In addition to the importance of aggregation tools, integration theory should incorporate deviation of the ranking results and ranking values of the aggregation tools. Decision-makers from different professional fields have different levels of mastery of different particular problems. The performance of the evaluation information reflects that the decision-maker weight is more reasonable than the original weight. The criterion weight should not only consider its importance in the current problem but also consider the correlation between them. Therefore, the proposed MCGDM method based on disappointment theory not only avoids mistakes in the selection of aggregation tools and integration theory but also chooses various weight models that are more appropriate for actual situations.

4.4. Distance education quality evaluation results analysis

Based on the evaluation information and results in Section 4.1, we give some management and development suggestions from the perspective of various criteria and evaluation methods.

(1) Strategic Management.

Institutions should clarify their mission and positioning, as well as determine their enrollment scale according to their current situation. When recruiting teachers, institutions should clarify these standards.

(2) Teaching design and course development.

There is a large variation among several institutions in regard to this criterion. Better distance teaching content should include theoretical courses, case analysis, and explanation of the latest practical process. Among the four institutions, only x_4 is outstanding, while x_3 is the most deficient. Furthermore, an increasing number of people in different industries want to engage in distance education, which requires institutions to establish more diversified professional structures.

(3) Teaching interaction.

Teaching interaction refers to a guarantee of the course transmission process in teaching. It is necessary to ensure that the whole teaching interaction process can be recorded, evaluated and traced. The interaction should be diversified and timely and the frequency and quality of interaction should be ensured.

(4) Faculty support.

The four institutions need to improve their implementation of this criterion. As a bridge connecting educational institutions and students, teachers' work needs the support of institutions. Teacher trainings and seminars should be carried out regularly to provide new ideas and directions for teaching and to provide a variety of office spaces and equipment.

(5) Learner support.

Institutions should issue corresponding policies to support students' learning in multiple dimensions; special organizations should be set up to supervise and support students, and to give them feedback regularly.

(6) Evaluation methods.

Only reasonable evaluation methods can reflect real situations. In the stage of determining the criteria weight, the weight method should not only consider the importance of the criteria but also consider the correlation between them. In addition, the importance of the reasonable ranking method is shown by comparison in Section 4.3.

5. Conclusions

The evaluation of distance education quality promotes the development of distance education institutions, open universities, and online teaching. This paper proposes a comprehensive MCGDM method based on MGPLTSs to improve distance education quality evaluation. Aiming at decision-makers from different fields in distance education quality evaluation, the dispersion and concentration degrees of MGPLTSs are proposed to measure the deviation of evaluation information, and a model for adjusting decision-maker weights is given. The combination weight model of the criteria subjective weight MGPL-SWARA method and criteria objective weight MGPL-CRITIC method considers the importance of criteria in specific problems and the correlation between criteria. The MGPL-DT-MULTIMOORA method considers the impact of psychological expectations on decision-making, including the extended reference point method in MULTIMOORA, which avoids the loss of evaluation information, and the IDC method, which effectively combines the results of aggregation tools. Finally, an example case of distance education quality evaluation shows that the proposed method is reasonable and effective, and the its advantages are improved compared with other methods.

However, there are some limitations in the proposed method: (1) It is unable to deal with incomplete decision-making information; (2) The method proposed in the paper deals with completely unknown weight information, however, it cannot deal with situations in which the weight information is only partially unknown. There are still some issues worth studying in the future. In this paper, the Spearman correlation coefficient is used to determine the correlation of the calculation criteria. There is, of course, the possibility of further exploring, comparing, and applying other correlation coefficients, such as the Jaccard similarity coefficient. In future research, the use conditions and information loss of aggregation tools should be studied, as should the application of IDC methods in different aggregation tools.

Author contribution

Peide Liu, the first author proposed concept, ideal, and model, provided guidance to the second author, and revised this paper.

Xiyu Wang, the second author proposed some concepts and models, verified the proposed method, and wrote the original manuscript, and revised it.

Fei Teng, the third author provided some proofs, investigated the data, compared the proposed method with some existing methods.

Yanwen Li, the fourth author provided criteria framework of distance education quality evaluation, obtained the data, calculated some results.

Fubin Wang, the fifth author provided some calculations, compared the proposed method with some existing methods.

Compliance with ethical standards

(1) Disclosure of potential conflicts of interest

We declare that we do have no commercial or associative interests that represent a conflict of interests in connection with this manuscript. There are no professional or other personal interests that can inappropriately influence our submitted work.

(2) Research involving human participants and/or animals

This article does not contain any studies with human participants or animals performed by any of the authors.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

Appendix 1

Table 3
Decision matrix U_1 provided by decision maker d_1.

	a_1	a_2	a_3	a_4	a_5
x_1	$\left\{\ell_0^3(1)\right\}$	$\left\{\ell_0^3(1)\right\}$	$\left\{\ell_0^3(0.3),\ell_1^3(0.7)\right\}$	$\left\{\ell_{-1}^3(0.2),\ell_0^3(0.8)\right\}$	$\left\{\ell_0^3(0.4),\ell_1^3(0.6)\right\}$
x_2	$\left\{\ell_{-1}^3(0.3),\ell_0^3(0.7)\right\}$	$\left\{\ell_{-1}^3(0.7),\ell_0^3(0.3)\right\}$	$\left\{\ell_0^3(1)\right\}$	$\left\{\ell_{-1}^3(0.5),\ell_0^3(0.5)\right\}$	$\left\{\ell_0^3(1)\right\}$
x_3	$\left\{\ell_0^3(1)\right\}$	$\left\{\ell_{-1}^3(0.5),\ell_0^3(0.5)\right\}$	$\left\{\ell_{-1}^3(0.7),\ell_0^3(0.3)\right\}$	$\left\{\ell_{-1}^3(0.5),\ell_0^3(0.5)\right\}$	$\left\{\ell_0^3(0.9),\ell_1^3(0.1)\right\}$
x_4	$\left\{\ell_0^3(0.8),\ell_1^3(0.2)\right\}$	$\left\{\ell_0^3(0.1),\ell_1^3(0.9)\right\}$	$\left\{\ell_0^3(1)\right\}$	$\left\{\ell_0^3(0.7),\ell_1^3(0.3)\right\}$	$\left\{\ell_0^3(0.7),\ell_1^3(0.3)\right\}$

Table 4
Decision matrix U_2 provided by decision maker d_2.

	a_1	a_2	a_3	a_4	a_5
x_1	$\{\ell_1^5(1)\}$	$\{\ell_0^5(0.2),\ell_1^5(0.8)\}$	$\{\ell_1^5(0.7),\ell_2^5(0.3)\}$	$\{\ell_0^5(0.3),\ell_1^5(0.7)\}$	$\{\ell_1^5(0.5),\ell_2^5(0.5)\}$
x_2	$\{\ell_0^5(0.7),\ell_1^5(0.3)\}$	$\{\ell_0^5(1)\}$	$\{\ell_{-1}^5(0.2),\ell_0^5(0.8)\}$	$\{\ell_0^5(1)\}$	$\{\ell_{-1}^5(0.5),\ell_0^5(0.5)\}$
x_3	$\{\ell_{-1}^5(1)\}$	$\{\ell_{-2}^5(0.1),\ell_{-1}^5(0.9)\}$	$\{\ell_{-1}^5(0.3),\ell_0^5(0.7)\}$	$\{\ell_{-1}^5(0.4),\ell_0^5(0.6)\}$	$\{\ell_{-1}^5(0.5),\ell_0^5(0.5)\}$
x_4	$\{\ell_1^5(0.7),\ell_2^5(0.3)\}$	$\{\ell_1^5(0.4),\ell_2^5(0.6)\}$	$\{\ell_0^5(0.6),\ell_1^5(0.4)\}$	$\{\ell_1^5(0.8),\ell_2^5(0.2)\}$	$\{\ell_1^5(1)\}$

Table 5
Decision matrix U_3 provided by decision maker d_3.

	a_1	a_2	a_3	a_4	a_5
x_1	$\left\{\ell_1^9(1)\right\}$	$\left\{\ell_1^9(0.4),\ell_2^9(0.6)\right\}$	$\left\{\ell_2^9(0.7),\ell_3^9(0.3)\right\}$	$\left\{\ell_0^9(0.3),\ell_1^9(0.7)\right\}$	$\left\{\ell_1^9(0.5),\ell_2^9(0.5)\right\}$
x_2	$\left\{\ell_0^9(1)\right\}$	$\left\{\ell_{-2}^9(0.5),\ell_1^9(0.5)\right\}$	$\left\{\ell_0^9(0.4),\ell_1^9(0.6)\right\}$	$\left\{\ell_{-2}^9(0.4),\ell_{-1}^9(0.6)\right\}$	$\left\{\ell_{-1}^9(0.3),\ell_0^9(0.7)\right\}$
x_3	$\left\{\ell_{-1}^9(0.2),\ell_0^9(0.8)\right\}$	$\left\{\ell_{-3}^9(0.2),\ell_{-2}^9(0.8)\right\}$	$\left\{\ell_{-1}^9(0.5),\ell_0^9(0.5)\right\}$	$\left\{\ell_{-2}^9(0.8),\ell_{-1}^9(0.2)\right\}$	$\left\{\ell_{-1}^9(0.8),\ell_0^9(0.2)\right\}$
x_4	$\left\{\ell_3^9(1)\right\}$	$\left\{\ell_2^9(0.2),\ell_3^9(0.8)\right\}$	$\left\{\ell_0^9(0.4),\ell_1^9(0.6)\right\}$	$\left\{\ell_1^9(0.7),\ell_2^9(0.3)\right\}$	$\left\{\ell_1^9(0.6),\ell_2^9(0.4)\right\}$

Appendix 2

Table 7
Ranking with different values of parameters R andδ.

R	δ	Ranking values				Ranking results
		x_1	x_2	x_3	x_4	
0.2	0.7	0.4262	0.1721	0.0937	0.4695	$x_4 \succ x_1 \succ x_2 \succ x_3$
	0.8	0.4260	0.1704	0.0933	0.4705	$x_4 \succ x_1 \succ x_2 \succ x_3$
	0.9	0.4258	0.1689	0.0928	0.4713	$x_4 \succ x_1 \succ x_2 \succ x_3$
0.3	0.7	0.4339	0.1456	0.0573	0.4813	$x_4 \succ x_1 \succ x_2 \succ x_3$
	0.8	0.4334	0.1445	0.0580	0.4819	$x_4 \succ x_1 \succ x_2 \succ x_3$
	0.9	0.4330	0.1436	0.0585	0.4825	$x_4 \succ x_1 \succ x_2 \succ x_3$
0.4	0.7	0.4389	0.0930	−0.0122	0.4867	$x_4 \succ x_1 \succ x_2 \succ x_3$
	0.8	0.4384	0.0934	−0.0092	0.4876	$x_4 \succ x_1 \succ x_2 \succ x_3$
	0.9	0.4380	0.0937	−0.0066	0.4885	$x_4 \succ x_1 \succ x_2 \succ x_3$
0.5	0.7	0.4189	0.0051	−0.1205	0.4526	$x_4 \succ x_1 \succ x_2 \succ x_3$
	0.8	0.4199	0.0068	−0.1156	0.4558	$x_4 \succ x_1 \succ x_2 \succ x_3$
	0.9	0.4208	0.0083	−0.1114	0.4586	$x_4 \succ x_1 \succ x_2 \succ x_3$

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ORIGINAL RESEARCH

Abnormal video homework automatic detection system

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Abstract
Automatic abnormal detection of video homework is an effective method to improve the efficiency of homework marking. Based on the video homework review of "big data acquisition and processing project of actual combat" and other courses, this paper found some student upload their videos with poor images, face loss or abnormal video direction. However, it is time-consuming for teachers to pick out the abnormal video homework manually, which results in prompt feedback to students. This paper puts forward the AVHADS (Abnormal Video Homework Automatic Detection System). The system uses suffix and parameter identification, Open CV, and the audio classification model based on MFCC feature to realize the automatic detection and feedback of abnormal video homework. Experimental results show the AVHADS is feasible and effective.

Keywords Video homework · Open CV · Abnormal detection · Audio classification

1 Introduction

Today's rapid updating of knowledge expects a new learning mode that students shift from focusing on the acquisition of knowledge to skills of social adaptability (Jiang et al. 2016). Ways of evaluating students also shifted from the single knowledge to students' ability and comprehensive quality. Homework is an important way to evaluate students, and traditional homework are generally in the form of text, sound, pictures, which cannot convey student's status such as movement and expression etc. in a comprehensive way to teacher. Thus, video homework that combine text, pictures and audio to present more complete information has become the choice of more teachers. During the COVID-19 epidemic, there was a spatial distance between students and teachers, and some teachers chose to learn about students' learning status through video homework.

Video homework is a good way which integrated big data information acquisition and student autonomy project output (Wang 2019). Here, video homework refers to student's record videos of related experiments, operations, presentations, or performances according to homework requirements. In the form of video homework, students are expected to explain how the experiment or operation process, or express the assignment theme through speech or performance after certain organization and design. Video homework is one of the operational forms that can promote personalized and proactive learning (Zhu 2019). Here is the advantages that other form of assessment do not have:

1. Video homework can help teachers to evaluate students better. An experiment on the sources of human information by the experimental psychologist Treicher showed that 83% of human information comes from sight, 11% from hearing, 3.5% from smell, 1.5% from touch, and 1% from taste (Xu 2003). Video homework contains text, pictures, sound, video and other rich information and content, which is helpful for students to express their learning content and thinking results in a more comprehensive way. Teachers can accurately evaluate students' familiarity with knowledge through their tone, expres-

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sion, sight, action in the video. In addition, Professor Jiang Dayuan pointed out that the purpose of learning is not to memorize knowledge, but to apply it (Jiang 2020). Video homework is a good way for students to apply their knowledge when solving problems and teachers can quickly evaluate how students can apply their knowledge by video homework and detect the problems of each student. Therefore, video homework is a conductive way to improving teaching.

2. Video homework can help students to master knowledge at a higher level. A famous experiment on memory persistence by the experimental psychologist Treicher showed that people tend to remember 10% of what they read, 20% of what they hear, 30% of what they see, 50% of what they hear and see, 70% of what they say in the communication (Wang 2011). Students present knowledge in the form of communication through video homework. It is a process of knowledge output through which students can achieve the lasting memory in the process of application of knowledge. In terms of content, video homework usually focus on complex problem solving, solution design, debate and discrimination, etc. It also contains the concept introduction, case evidence, hierarchical analysis, summarizes conclusions, etc. To ensure the quality of video homework, students will organize their presentations logically and ponder on the theme of homework carefully. Students might also evaluate themselves in the course of a lecture or performance. While recording of video assignments, students learn related technologies of video production and cultivate their ability to use information technology. In a word, video homework might improve students' cognition on memorization, understanding and application, and might also promote students' higher-level abilities such as synthesis, evaluation and innovation, which will realize Bloom's educational goal system (Xiang 2009) in the field of cognition.

2 Practical application

Video homework can achieve better learning results than what traditional homework can (Tu et al. 2017). This paper adopts the form of video homework in courses of "Actual practice of Big Data Collection and Processing Project" in Shandong University of Finance and Economics. The homework requires students to record the entire operation process of python experiment and explain the relevant knowledge with a purpose of getting to know the level of the students' knowledge familiarity in the six-level comprehensive education objective of Bloom, evaluating the students' learning situation and adjusting the later teaching. The homework ask the students to upload videos need which contain both input and output process, successful run results and clear explanation. Students are supposed to show their faces in the videos instead of only recording audios and PPT.

There are 443 video homework in total, and 89 (nearly 21%) cannot satisfied the homework requirement. The unqualified videos are compressed files, no faces or unclear voices. Some cannot be reviewed online due to the direction of images. Teachers can only manually identify those problems while marking all the uploaded files, which is time consuming and hold back the homework correction cycle. As a result, students cannot receive feedback timely. When the unqualified homework are return to students, they are less motivated to resubmit video homework. Therefore, in order to improve the efficiency of review of video homework and save the labor of identifying the unqualified ones, Abnormal Video Homework Automatic Detection System (AVHADS) is proposed in this paper, which realizes the preliminary detection of uploaded video homework. Unqualified video homework is automatically sent back to students with sensible explanations of which students might see it as a prompt feedback. It might prevent students from academic pressure caused by long homework correction time.

3 Related work

Many scholars have been contributing research efforts on automatic homework detection and review. Some scholars focused on the automatic review of program homework. Martin et al. (2018) used the argument-based machine learning (ABML) to finish semiautomatic identification of typical approaches and the errors in student solutions. They believe that timely feedback can improve students' programming learning efficiency. Zhao et al. (2010) designed the program for the automatic detection and correction of student program work. It can screen the similar procedures and supervise and encourage students to finish the homework independently. On the review of the graphics homework, Yang et al. (2014) designed and implemented an automatic grading system for civil engineering drawing based on vector graphics platform ATVGP. Peiying (2001) used VC programming to realize the automatic correction of engineering drawing homework based on Web. Li et al. (2019) put forward a program for automatic recognition and rating of homework pictures taken by mobile phones, which has achieved good results. The above research on automatic review of homework focuses on images and texts, which cannot solve the problems of detection and correction of video homework. Here, we attempt to study and realize the abnormal detection of video homework.

At present, the research on abnormal detection of video mainly focus on the video content, such as traffic violations (Ye et al. 2012), people's behaviors testing (Lian et al. 2002). These researches are quite different from the abnormal detection of video homework, so they cannot solve the problem in this paper. The problem of anomaly detection in this paper mainly includes four aspects: file type identification, face detection, video direction recognition and audio detection.

File type identification is relatively simple, it is generally implemented through methods based on statistical characteristic (Zheng et al. 2007) and content (McDaniel et al. 2020). The file types involved in this paper are relatively fixed, so we choose simple suffix name matching to realize file type identification. There are many studies on video face detection. Keke et al. (2008) conduct face detection by using the face detection function in Open CV. Goyal et al. (2017) conduct an in-depth study of face detection using open CV, Ma et al. (2018) use the multi-task cascaded convolutional neural networks to realize the frontal and the non-frontal face detection, this paper does not cover the non-frontal face detection, so we chose Open CV (2016) which is easy to implement face detection. The detection of video direction is rarely involved in other problems, and relevant researches are scare. According to the specific problems in this paper, we choose to use the comparison of specific parameters to realize the detection of video direction. In this paper, it is difficult to solve the audio detection problem, and many researchers have done related researches. Muda et al. (2010) used Mel-Frequency Cepstral Coefficients (MFCC) to extract sound feature, and used the Dynamic Time Warping (DTW) to realize sound recognition. Yu et al. (2006) added Linear Prediction Cepstrum Coefficient (LPCC) on the basis of MFCC to describe sound feature, and used the methods of vectorization and DTW to realize speaker detection. Ali Technology (2018) makes use of the MFCC characteristics of human voice samples and non-human voices samples and the Inception-V3 model of CNN to realize the prediction of voice audio files. Based on MFCC + CNN, Wei et al. (2018) used random forest to classify audio, this method improved the accuracy of audio classification. Zhang (2019) replace CNN with ResNet to promote the accuracy of ESC recognition task. And Huang et al. (2020) used the multi-mode neural network to cluster the voices of different speakers (teachers and students) in the course audio, then realized the differentiation of multiple speakers by text matching. Most of these researches are aimed at specific kinds of problems; they are temporarily unable to solve the audio detection problem. The audio of video homework is different, as it mainly consists of the voices of other students in the student's living environment. Due to the big student's population and overlapping, this problem cannot be solved by matching voice print features. Therefore, we choose to use MFCC to describe audio features of video homework and use the trained classifier to detect the sound clarity of video homework.

4 Abnormal Video Homework Automatic Detection System (AVHADS)

Based on the above questions and related researches, this paper puts forward the AVHADS (Abnormal Video Homework Automatic Detection System) which can realize the automatic detection and feedback of abnormal video homework.

4.1 System framework

The whole system is divided into four modules. The first module is file type Identification which adopts the file suffix (zip, rar etc.) matching to realize file type identification. In the module, after uploading the video file, the system will detect the direction of the video. The system adopts the comparison of video length and width to determine whether the video direction is in the normal landscape state. If the direction of the video is correct, it invokes Open CV face detection classifier to identify whether there are students in the video homework. If there is a face in video, the system will detect whether the audio of the video homework is clear voice or not. If the homework file passes the detection, it will be uploaded successfully. When a certain module is not satisfied, the system outputs a reason of failure to upload homework. The whole system framework is shown in Fig. 1.

As file type recognition and image direction detection can be realized by simple parameter comparison, the paper will not be further discussed in detail.

4.2 Face detection

There have been many studies about face detection. The Open CV (Open Source Computer Vision Library) (Bradski 2008), which is developed by Intel, is open source library of visual algorithm and image processing. It is quite mature and widely used in face detection and recognition. This paper chooses alt2 classifier (haarcascade_frontalface_alt2. XML) to realize video work face detection. And it proves that this classifier performs better in Open CV (Lian 2016). The file of the classifier contains Haar-like features describing various parts of the human body. It realizes the classification of faces and non-faces through Integral image, AdaBoost algorithm and cascade classifier.

Haar-like feature is a way of feature representation based on the differences between black and white pixels in gray images. It includes three forms: edge feature, linear feature,

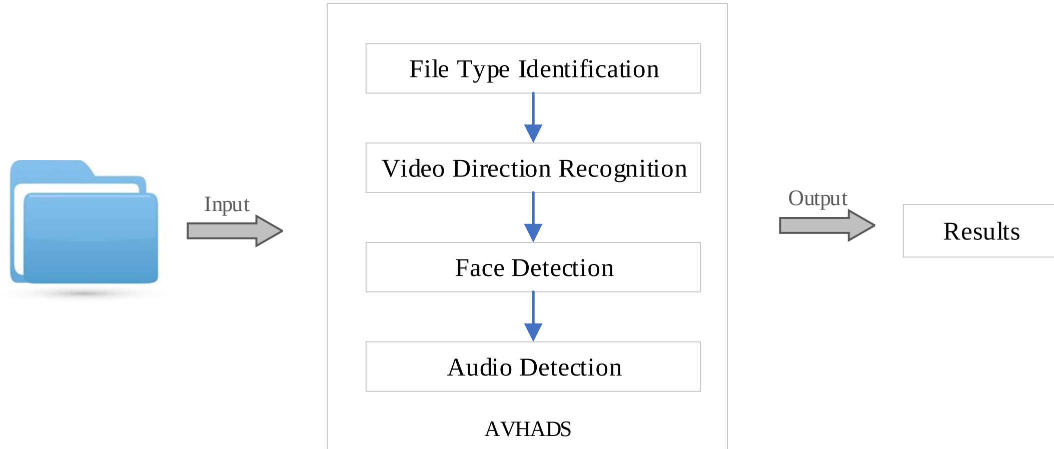


Fig. 1 System framework

Fig. 2 Haar-like features based on human eye features

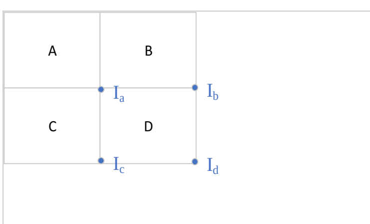


Fig. 3 Integral image

and center feature. Viola and Jones (2001, 2004) optimized it and applied it to face feature extraction. Lienhart and Maydt (2002) further expanded it and eventually applied it to Open CV classifier. Figure 2 shows Haar-like features based on human eye features, it is a kind of edge character, and the area of the black pixel represents the eye color darker than the surrounding area.

Integral Image is a fast method proposed by Viola and Jones (2001) to extract Haar-like features. It is a matrix representation method that can describe global information (Huang et al. 2005). It represents each point on the image as the sum of all pixels in the upper left of the point. Image feature representation can be realized by adding and subtracting pixel points between different rectangles. As shown in Fig. 3, point **I** can be expressed as the pixels sum of A, B, C, D, the pixel sum of D area may be expressed by the $\mathbf{I_b} + \mathbf{I_c} - \mathbf{I_a}$. Integral Image improves the efficiency of Haar-like feature representation.

AdaBoost algorithm is a kind of adaptive algorithm, which seeks the optimal classifier through numerous loop iteration (Lin 2013). Different facial features represent different classifiers, namely weak classifiers (He and Cheng 2018). Through multiple training iterations, the weak classifier with better classification performance is selected to form a strong classifier, and the final classifier is formed through the cascade of strong classifiers.

The main process of Haar classifier is that using the sliding window and Integral Image to achieve rapid traverse of gray image and Haar-like features calculation. Next through AdaBoost algorithm based on the Haar-like features to train face weak classifier and build strong classifier, and then through multiple strong classifier combined enhancing the effect of classification. As a result, face classification can be realized. The process is shown in Fig. 4.

Here we use haar classifier of Open CV to realize face detection in video homework that has been trained through the above process. Specific face detection process is that the video homework is divided into frames of images. After image gray-processing, the detectMultiScale() function in the trained alt2 identifies whether there are faces in images. The process is shown in Fig. 5.

4.3 Audio detection

Noises are inevitable when students record video homework in the dormitory or classroom. Most of the noises are students' conversation voices and other noises around them. The existing research on audio classification and detection focuses on specific audio matching, speaker recognition and content extraction, which cannot solve the problem of audio detection of students' video homework. Therefore, we need to use the audio data from students' homework to train model to realize audio detection (Fig. 6).

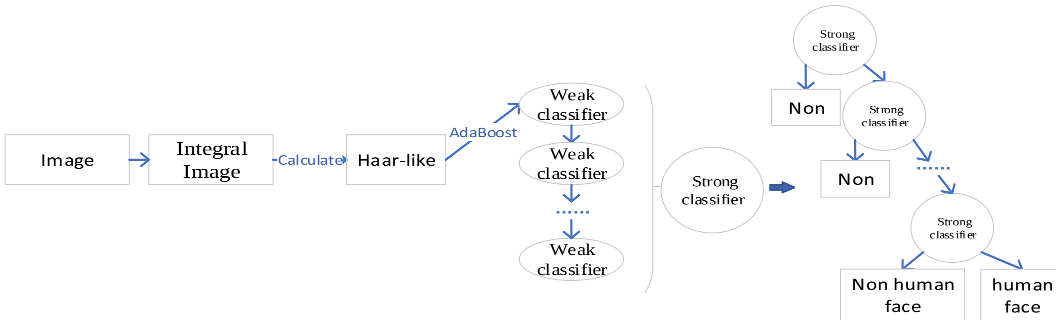
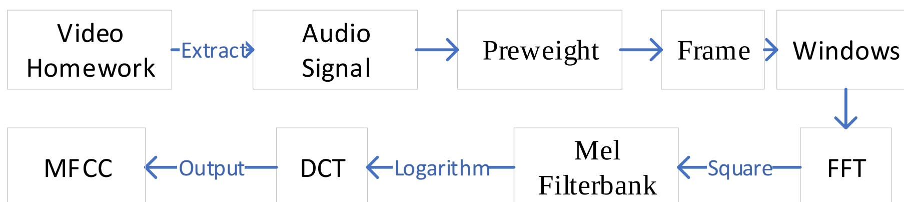


Fig. 4 Face classifier

Fig. 5 Face detection in video homework

Fig. 6 MFCC extraction process of video homework



Firstly we select 14 samples out of the 89 unqualified video homework and set them as noise samples manually. Then, we choose 42 samples from qualified video homework and defined them as clear samples. And we select the audio detection model with higher accuracy through training.

Audio detection is divided into two parts: audio feature extraction and detection model training.

4.3.1 Audio feature extraction

Audio feature extraction is to identify the noticeable features in the audio and eliminate the rest of the redundant information. Basing on the relevant studies on audio processing and the need for the sound clarity of students' video homework, we select Mel-Frequency Cepstral Coefficients (MFCC) based on human ear perception characteristics (Chundong et al 2019) to describe the characteristics of clear audio and noisy audio. The process is as follows (Li et al. 2017 and Lingnizhan 2019).

(1) Pretreatment

The audio pretreatment includes pre-emphasis, framing and windowing.

The purpose of pre-emphasis is to highlight the high frequency formant. The filter coefficient is set as 0.97 in the pre-emphasis, and the formula is:

$$S(n)^* = S(n) - \partial \times S(n-1) \tag{1}$$

The audio is decomposed into shorter frames and processed as steady-state signals, and the smooth transition from frame to frame is realized through the partial overlap between each frame. Basing on the short-time stabilization characteristic of the audio of the student video homework, we frame the signal into 25 ms, set frame shift = 10 ms and N = 512. And each frame (***$S_i(n)$***) multiplied by the Hamming window (***$W(n)$***) to increase the continuity of left and right ends and reduce the leakage in the frequency domain, and we set $\alpha = 0.46$. The formula is:

$$W(n, a) = (1 - \partial) - \partial \times \cos\left(\frac{2\pi n}{N-1}\right), n = 0, 1, 2, \ldots, N-1 \tag{2}$$

$$S_i(n)' = S_i(n) \times W(n) \tag{3}$$

(2) FFT

The frequency domain signal Xi (k) of each frame is obtained by the Discrete Fourier Transform. The formula is:

$$X_i(k) = \sum_{n=1}^{N} X_i(n) e^{-\frac{j2\pi kn}{N}}, \quad 1 \le k \le K \tag{4}$$

where i is the number of frames and K is the length of DFT.

(3) Mel filter bank

The power spectrum E (I, k) is obtained by taking the square of the result of FFT operation. It was filtered through a filter to map the linear spectrum to the Mel nonlinear spectrum based on auditory perception. The conversion formula is as follows.

The formula for converting from frequency to Mel scale is:

$$\mathrm{Mel}(f) = 2595 * \log_{10}\left(1 + \frac{f}{700}\right) \tag{5}$$

To go from Mel back to frequency:

$$f = 700\left(10^{\frac{Mel(f)}{2595}} - 1\right) \tag{6}$$

Then the energy of the power spectrum of each frame in the MEL filter is calculated:

$$SE(i,m) = \sum_{k=0}^{N-1} E(i,k)H_m(k), 0 \le m \le M \tag{7}$$

where i is the frame number, K is the spectral line k in the frequency domain, $H_m(k)$ is the frequency domain response of Mel filter, and M is the number of filters. In our experiment, we set M = 24.

(4) Discrete Cosine Transform (DCT)

Logarithm of the energy obtained through the filter is taken decorrelation processing by DCT to obtain the MFCC.

$$C(i,n) = \sum_{m=0}^{N-1} SE(i,m)\cos\left(\frac{\pi n(m-0.5)}{M}\right), \quad 0 < n \le L \tag{8}$$

where i is the frame number, **M** is the "mth" filter, and **L** is the parameter order of MFCC. In this experiment, we set **L** = 12.

Finally, we use the plt function and related parameters to obtain the MFCC spectrum diagram of audio.

MFCC feature were extracted with the above process to describe the audio features of the manually screened samples. The audio in 56 video homework selected manually were extracted. Then, first 3.5 s of the audio were intercepted. The integrity features of audio were preserved by pre-weighting, framing and windowing. After that, filter and DCT transformation, the MFCC feature of the audio in video homework was extracted through FFT. The extracted MFCC feature image will be used as the input of the audio detection classification model.

4.3.2 Model training and evaluating

The distinction between clear and noisy samples is essentially a dichotomy problem, so we can use the classification algorithm to realize the audio detection of video homework. Essentially, classification algorithm is to distinguish samples with different features, and the computer learns features to distinguish different categories. We choose more classical KNN, SVM and CNN models to train the manually screened data sets, and compare the training effect of using common spectrum features and MFCC features to describe the audio. Then, we select the training model with higher accuracy and apply it to the audio detection in the system.

(1) KNN

K Nearset Neighbor Classifier (KNN) was proposed by Cover and Hart (1967). KNN has been widely used in many fields because of its simplicity and high classification accuracy (Zhang et al. 2008). It calculates the adjacent sample of the predicting samples based on the distance function, and confirms the category of the predicting samples according to the category of the adjacent sample. The category of predicting audio samples of the video homework is determined by the number of the category of the nearest K samples. Among k adjacent samples, the predicting sample is regarded as a clear sample if there are more clear samples. The predicting sample is regarded as a noisy sample vice versa. Figure 7 shows an example of KNN classification when K = 6. The experiment invokes the KNeighborsClassifier() function to realize the training of KNN.

(2) SVM

Cortes et al. (1995) proposed support vector machines (SVM), it has its unique advantages when solving small sample, nonlinear and high dimensional pattern recognition problems (Liu et al. 2003). SVM searches for the optimal classification surface based on two types of sample data, which not only enables the two types of samples to be separated without error, but maximizes the classification interval between the two types (Vapnik 1997). The experiment invokes the svm.SVC () function to realize the training of KNN.

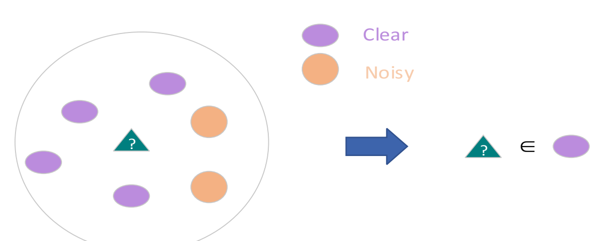


Fig. 7 K nearset neighbor classifier

(3) CNN

With the development of deep learning, CNN has been widely used in many fields. Based on labeled sample data, it learns the sample features of different categories through iterative calculation to achieve classification. This experiment uses a five-layer convolutional neural networks to realize the classification training of video homework audio (Fig. 8), which includes two convolutional layers, two pooling layers and a full connection layer. The specific parameters of each layer are as follows:

Input: spectrum diagram of 128*128*3.

Layer1: convolution layer, convolution kernel size is (5,5), the number is 64, strides = 1;

Layer2: pooling layer with kernel size of (2,2);

Layer3: convolution layer, convolution kernel size is (5,5), the number is 128, strides = 1;

Layer4: pooling layer with kernel size of (2,2);

Layer5: full connection layer with 512 neurons.

We select ReLU as activation function. The features of sample spectrum diagram extracted by the convolution layer are inputted the ReLU function in the form of vector to nonlinear transformation. The ReLU function converges quickly and calculates easily. Problems are not detected in the gradient disappearance (Kutyniok 2019). Its function formula is:

$$\mathrm{ReLU}(x) = \max(0, x) \tag{9}$$

Our experiment is actually a binary classification problem. Therefore, we choose the cross entropy function as the loss function. It can measure the effect of the model and is relatively easy to calculate. The prediction probability of the positive sample is p and the negative sample is 1-p, and its calculation formula is (Ezail 2019):

$$L = -\frac{1}{N} \sum_i \left[y_i \times \log\left(p_i\right) + \left(1 - y_i\right) \times \log\left(1 - p_i\right) \right] \tag{10}$$

where $\mathbf{y_i} = 1$ if $\mathbf{i}$ sample is positive and $\mathbf{y_i} = 0$ if $\mathbf{i}$ sample is negative.

At the same time, we choose the Adam optimizer proposed by Kingma and Lei Ba to optimize the experiment, it has the advantages of high computational efficiency, simple implementation and small memory occupancy (Kingma and Ba 2014).

In the audio detection experiment, clear samples and noisy samples were input into the training model in the form of sample-label. The average accuracy of model was taken as the evaluation index to compare the effectiveness of the model in audio detection after lots of training. The experimental results are shown in Table 1.

Table 1 Results

Method	The average accuracy (%)
Spectrum + KNN	58.33
Spectrum + SVM	73.33
Spectrum + CNN	71.84
MFCC + KNN	92.38
MFCC + SVM	89.58
MFCC + CNN	81.17

According to Table 1, the average accuracy of MFCC + KNN reaches 92.38%, which is optimal in the comparison experiment and can be well applied to audio classification. Therefore, this system chooses MFCC + KNN method to realize audio detection of video homework (Fig. 9).

4.4 System application and evaluation

The final system framework is shown in Fig. 10.

We have tested the system with the collected video homework, the accuracy rate of the system reached 84.26%. The system detected 89 unqualified video homework within 5 min and 42 s, which is much faster than a few hours of manual screening. In the detection of individual homework, the system provides prompt feedback to students when they submit homework. Compared with the method of manual screening by teachers, this method is much more efficient.

5 Conclusions

Automatic detection of the unqualified video homework is getting more important as video homework becomes a more popular. This paper puts forward the AVHADS (Abnormal Video Homework Automatic Detection System), which is based on the problem of uploading video homework in “big data acquisition and processing project of actual combat” and other courses. Based on MFCC feature and CNN to realize the automatic detection and feedback of abnormal video homework, the system uses suffix and parameter identification, Open CV, and the audio classification model. It shows that the AVHADS is feasible and effective through experiments.

In conclusion, AVHADS can realize preliminary detection of the unqualified video homework, which is much more time-saving and can sent feedback to students promptly. Nevertheless, the accuracy of the system can be further improved through training. In addition, this system is only the preliminary form detection of students’ video homework, and it does not review the specific content of homework.

Fig. 8 Convolutional neural networks

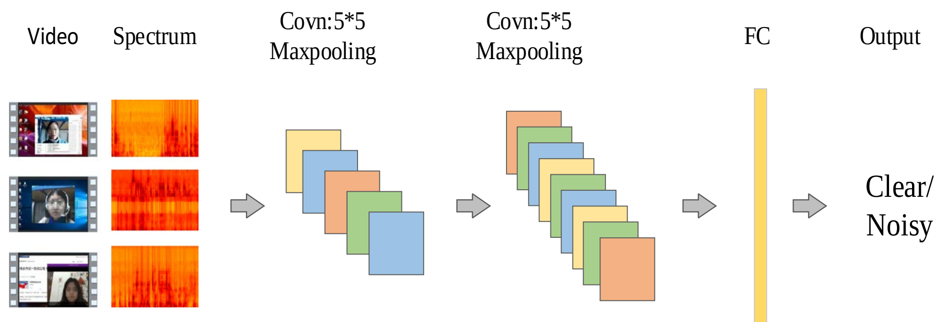


Fig. 9 Audio detection

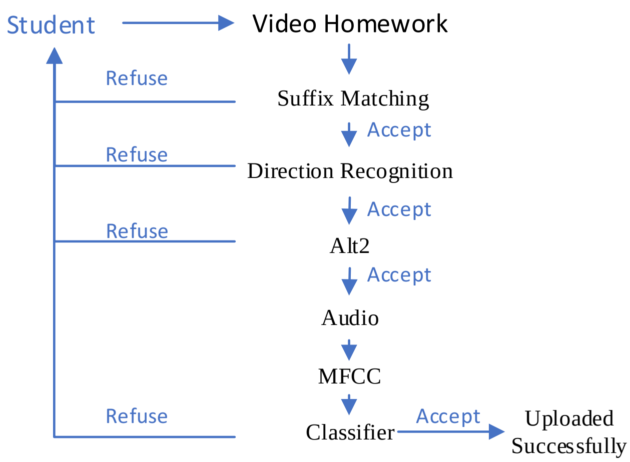


Fig. 10 Video homework detection

In the further researches, facial expression analysis, tone change, voice pause and other features can be combined to realize automatic review of video homework with artificial intelligence technology.

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Domain knowledge graph-based research progress of knowledge representation

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Abstract
Domain knowledge graph has become a research topic in the era of artificial intelligence. Knowledge representation is the key step to construct domain knowledge graph. There have been quite a few well-established general knowledge graphs. However, there are still gaps on the domain knowledge graph construction. The research introduces the related concepts of the knowledge representation and analyzes knowledge representation of knowledge graphs by category, which includes some classical general knowledge graphs and several typical domain knowledge graphs. The paper also discusses the development of knowledge representation in accordance with the difference of entities, relationships and properties. It also presents the unsolved problems and future research trends in the knowledge representation of domain knowledge graph study.

Keywords Domain knowledge graph · Knowledge representation · Entity · Relationship · Property

1 Introduction

Domain knowledge graph (industry knowledge graph or vertical knowledge graph) is based on domain-specific data. Domain knowledge graph is different from general knowledge graph which contains common sense information. Information in a domain knowledge graph is mostly suitable for a specific industry. It contains more complex knowledge and structure and plays an important role in domain information integration. With the in-depth study of knowledge graph and the progress of artificial intelligence technology, the construction of domain knowledge graph has more technical support, and studies of domain knowledge graph have gradually become a heated research topic.

At present, most researches on knowledge graph construction focus on the construction of general knowledge graph, and there are still gaps between the research of domain knowledge graph construction which contains more complex information and data. Knowledge representation, as a first step to knowledge graph construction, is the foundation of knowledge graph construction. Firstly, this research introduces knowledge representation of classical general knowledge graphs and current typical domain knowledge graphs. Secondly, it discusses the development of knowledge representation according to the difference in entities, relationships and properties.

The relevant concepts of knowledge representation are introduced in the second part. The third part discusses the knowledge representation of general knowledge graphs in different categories; the fourth part introduces the knowledge representation of typical domain knowledge graphs. And some unsolved problems in knowledge representation research have been presented in the last part.

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2 Basic concept

2.1 Concept of knowledge representation

Knowledge representation is a set of rules to describe the world. It is the symbolization, formalization or modeling of the knowledge. Different knowledge representation methods are different formal knowledge models. In the concept of knowledge engineering representation, representation is a computer model describing the natural world, and it should meet the specific limitations of computers. Therefore, representation can be understood as a kind of data structure and a set of operations. It emphasizes the image form of the information of the natural world in a certain type of data structure in the computer and the processing methods adopted for the stored contents [1]. Knowledge representation defines the domain basic cognitive framework, which defines the basic concepts in domain and the basic semantic relationships between concepts [2].

2.2 Relevant concepts

Knowledge representation is a part of the study of knowledge graph. Wang Haofen, a professor of East China University of Science and Technology, believes that the purpose of knowledge graph is to describe various entities or concepts existing in the real world. Each entity or concept is identified with a globally unique ID, which is called identifier. Each property-value pair is used to describe the internal characteristics of an entity, and the relationship is used to connect two entities and describe their associations [3]. Therefore, knowledge representation not only involves knowledge, but also involves entities, properties and relationships.

Entities refer to something that exists in the objective world. Entities have distinction and can exist independently. An entity is a basic unit of the knowledge graph [4]. In the knowledge graph, nodes are regarded as entities [5]. A semantic class/concept is an abstract name for a set of things that have the same characteristics. A property refers to a property value from an entity, which describes the characteristics of this entity [5]. Relationships describe the contact between two or more entities [4, 5].

Knowledge is the set of all facts, concepts, rules or principles. Here, set is acquired and summarized by observing, learning and thinking about various phenomena in the objective world [3]. Knowledge includes language knowledge, commonsense knowledge, encyclopedic knowledge, domain knowledge, etc. Therefore, knowledge graph can be divided into language knowledge graph, commonsense knowledge graph, encyclopedic knowledge graph and domain knowledge graph [6]; more broadly, they can be summarized as general knowledge graph and domain knowledge graph according to their scope of application [4].

3 General knowledge graph

This section mainly introduces some general knowledge graphs and analyzes their knowledge representation. General knowledge graph includes language knowledge graph, commonsense knowledge graph and encyclopedic knowledge graph. This section selected several typical general knowledge graphs in different categories and analyzed their similarities and differences in knowledge representation. These knowledge graphs are not built successfully at one time, and each new knowledge graph is formed in the optimization of the original knowledge graph. The knowledge representation between them is different though there are also some similarities.

3.1 Language knowledge graph

Before the popularization of the Internet, lots of original expert systems and knowledge bases were constructed artificially, among which the early representative model was WordNet [6], and it can be regarded as a language knowledge graph. WordNet is the achievement of the task to develop a dictionary database undertaken by a group of psycho lexicologists and linguists at Princeton University since 1985 [7]. WordNet is regarded as an online electronic (synonymous) dictionary system, which is a proposal to combine traditional dictionary information with modern high-speed computing more effectively [8]. Its knowledge mainly comes from artificial construction, and we can simply understand WordNet as an electronic dictionary with some encyclopedic knowledge and real relationships.

WordNet assumes the role of a dictionary database, so the division of concepts or entities is not very clear. In our research, we will mainly analyze its knowledge representation through words. It takes the word as the smallest unit and builds a set of synonyms with the same meaning words. In addition, it defines a name for them and treats them as a concept. For example, *car, railcar, railway car, railroad car—(a wheeled vehicle adapted to the rails of railroad; "Three cars had jumped the rails")*—are a synonym set for streetcars; each synonym set includes a description of the concept. A word may have more than one meaning, so it may appear in more than one synonym set.

WordNet contains more relationships between words than entities. It includes the following basic relationships: synonym relationship, antonym relationship, hypernym and hyponym relationship, whole and part relationship [7–9]. Synonym relationship is a most basic relationship in WordNet, because word nodes are related by synonym relationship. It refers to the relationships between words with the same semantic meaning. Antonym relationship is mainly the relationships between the adjectives, and there are direct antonym relationship and indirect antonym relationship. Direct antonym relationship refers to the relationships between words that have opposite meaning. Indirect antonym relationship refers to the relationships between a word and the antonym of its synonym, such as Fig. 1 [8]; *good* and *bad* is the direct antonym relationship, and *great* and *bad* is the indirect antonym relationship. The hyponymy relationship (*is kind of, is a generalization of*) mainly refers to the hierarchical relation between nouns. For example, the hypernym of *dog* is the synset of *animal*, and the hypernym of *animal* is the synset of *organism*. A word may contain many hyponymy words. WordNet contains 25 basic classes (final hypernym). WordNet also includes the relationships between whole and part (*is part of*), which means a *is a component of* b, a *is members of* b or a *is substance of* b. Relationships in WordNet are generally connected by pointers, but some noun entities are also connected by relational adjectives [8].

WordNet can be regarded as an electronic dictionary with encyclopedic knowledge, and it contains some basic features and functional properties. It takes some real things in the noun set as an entity, such as robin, dog, apple, etc. Their feature properties are linked to adjectives, and function properties are linked to verbs. An entity is connected with a descriptive property by property name, such as *WEIGHT(package) = heavy*. It means that *package* has a property *WEIGHT*, and the property value is *heavy*. An entity and its functional properties are linked by pointers between noun and verb sets.

3.2 Commonsense knowledge graph

Language knowledge graph (WordNet) realized the task of adding some simple facts to knowledge network, but it lacks representation of real events. Real-life events cannot be described by one word, and general relationships and properties also cannot show more facts in the real world. So people build commonsense knowledge graph which includes Cyc [10] and ConceptNet [11]. The knowledge in Cyc is represented by higher-order logic; according to concepts and assertions, Cyc uses argumentation to achieve the reasoning of common sense knowledge based on contextual contents [12–14]. ConceptNet originated in the

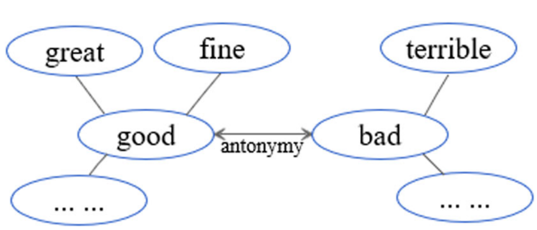

Fig. 1 Antonym relationship

Open Mind Common Sense (OMCS) project at the MIT Media Lab, which was proposed by famous artificial intelligence expert Marvin Minsky in 1999 [4]. It is a crowd sourcing knowledge base and a semantic network. ConceptNet contains a lot of common sense information, which helps computers to understand the real world. It extends the knowledge network that language knowledge graph has built. This section focuses on the knowledge representation of ConceptNet.

The node of ConceptNet is no longer a simple word, but semistructured English segments. It is usually a compound phrase or an action. ConceptNet contains more abundant knowledge of the real world than WordNet. It focuses on the common sense meaning of the natural language words (Unnamed Entity). It will connect the concepts with a lot of common sense and contains a lot of the complex relationships in real world. In addition, it can be better in context-based reasoning, whose knowledge mainly comes from OMCS project, expert knowledge base, purposeful games and other knowledge bases. It is a knowledge base automatically constructed by extracting knowledge according to certain rules [4].

The concepts and entities in ConceptNet are mainly composed with words or phrases. Najmi et al. [15] regard that entities in ConceptNet are described by noun phrase (NP). These phrases usually consist of one or more main nouns as root, with one or more other words to describe this main noun. Verb phrase (VP) is used to describe a concept sometimes. These concepts are usually extracted from the text of natural language [4]. They are more consistent with our usual expression habits. Its nodes contain not only the entity such as people, objects and regions, but also some of our actual action states, such as drink coffee, eat breakfast; these nodes help the expression of commonsense knowledge. Compared with the simple knowledge in language knowledge graph, ConceptNet passes commonsense information to the computer. For example, an entity *apple* is a fruit in WordNet and red is a property of it. But in ConceptNet, it might correspond to *Apple inc.*, rather than a fruit. The specific property and meaning must be inferred from its context.

ConceptNet5 includes 21 predefined and multilingual generic relationships (e.g., *IsA, UsedFor*, etc.) and non-formal relationships extracted from natural language texts that are closer to natural language descriptions (e.g., *on top of, caused by*, etc.) [4]. Compared with the hyponym relationship in WordNet, ConceptNet can summarize commonsense topics or categories by text and connect them with *SuperThematicKLine*, such as *buy food* and *purchase food* can be connected with *buy* by *SuperThematicKLine*. In addition to simple relationships in WordNet (*IsA, PartOf, MadeOf, SimilarTo*, etc.), ConceptNet also contains many complex relationships in reality, such as *fall* *off bicycle* and *get hurt* connected by the relationship *EffectOf*. There is no such commonsense knowledge in WordNet, nor as relationships [16]. Examples of ConceptNet are shown in Fig. 2 [17].

Najmi et al. [15] analyzed relationships and properties in ConceptNet from the upper ontology construction. They believe that properties in ConceptNet are not defined like general ontology relationships. Even if some properties are logically incorrect, it may be "meaningful" in common sense. For example, *succeed* as a property is connected with *a person* through *Desires* [18]. It is not a property in the ordinary sense. However, it conforms to our common sense, so it is expressed in such way. They also pointed out that ConceptNet also has a number of adjective phrases (AP) used to describe properties, and they are often connected with *hasProperty*. Some of the functional properties are achieved by verb phrase (VP). For example, *Movement Forward* is a verb phrase, and it can be linked to *bike* with *isCapableOf*. Liu et al. [16] pointed out that if a property appears on many nodes, and these nodes belong to one parent node, this property can be extracted to the parent node. For example, *fruit* is a parent node for *apple* and *banana*, and *sweet* is a common property for them, so it can extract (*"sweet" PropertyOf "fruit"*). In addition, some adjective phrases which have modifiability can be connected with entities as a property.

The main improvements in ConceptNet compared with WordNet are summarized as follows.

ConceptNet uses an automated approach to build knowledge graph. It includes lots of informal commonsense knowledge accumulated from human experience in the real world. On the node of entities and concepts, it is no longer a single word, but a phrase which can contain certain state information. In relationships, in addition to simple relationships and category relationships, it also adds fact relationships contained in the real world, such as causative relationships, causal relationships, etc. In properties, ConceptNet extends the way to extract properties. In addition, it also contains properties from commonsense.

Fig. 2 Example of ConceptNet

3.3 Encyclopedic knowledge graph

Encyclopedia knowledge graph is mainly centered on the open knowledge graph supported by LOD [19] project. It mainly includes Wikidata [20], YAGO [21], Google Knowledge Graph [22], Freebase [23], etc. Wikimedia launched Wikidata in October 2012. It links pages which has same theme and allows readers to add or change data entries. Data in Wikidata are basically described by property-value pairs. For some complex information, property-value pairs are allowed to add dependencies property-value pairs. YAGO is a large semantic knowledge base conducted by the Max Planck Institute in Germany, and it has a million entities and more than five million facts [6]. It extracts facts from Wikipedia's classification system and information boxes and combines classification relationships from WordNet [24, 25]. It describes event information in more detail than Wikidata [26]. Google Knowledge Graph [22, 27] was proposed by Google in May 2012. It builds connection between entities and changes the rules of search based on keywords. It generalizes the content of the same topic and describes entities using structured fields. In addition, it clusters entities and properties based on the user's Google retrieval data. Freebase is a semantic web project started by a MetaWebin 2005. Its construction based on Wikipedia and swarm intelligence [4, 6]. It also allows to add or change data entries like Wikipedia. The knowledge representation of encyclopedia knowledge graph is relatively structured. In this section, we chose Freebase to analyze the detailed.

Compared with the previous two knowledge representations which have defined relationships, the most noticeable characteristics of Freebase are it does not control the top-level ontology very strictly [23], and visitors can create and edit the definition of classes and relationships by themselves. It can be more flexible to express different knowledge. Another notable feature of Freebase is that knowledge is stored structurally in base. Freebase is an open, shared, collaboratively built large-scale linked database [4], as well as a practical, extensible, graphical, structured database of general human knowledge. It is inspired by semantic Web research and collaborative data communities such as Wikipedia [28]. Freebase is built by community member's collaboration. Its main data sources include database such as Wikipedia and the contributions of community users. Freebase's knowledge representation framework mainly includes the following elements: Domain, Topic, Type and Property.

Each piece of information in Freebase is called a topic. Topic can be a specific and meaningful data (such as Arnold Schwarzenegger), or an abstract concept (such as PI in mathematics, Christianity) [28]. It corresponds to the node in the graph and contains information, which is unique. Each Topic corresponds to a type (category) node, and Type is equivalent to a classification of Topic. For example, Topic "Yao Ming" can correspond to Type of "Person" and "Athlete," etc. Each Type represents a unique category. However, in order to match the complex information in real life, Type can be given a different name [29, 30]. Type that belongs to the same domain can constitute a Domain. This constitutes the basic structure of Freebase: Domain -> Type -> Topic [30].

As knowledge in Freebase is structured, it uses a lightweight classification system (Type System) [29]. Therefore, it contains relationships and properties which are different from the knowledge representation of WordNet and ConceptNet. Jun [29] believes that the property is the most important concept in Freebase. Property value can be either a literal value or a relationship with other node (such as "is a parent of"). In order to show the structure of Freebase more intuitively, here is an example which is provided by Ruan Yifeng, as shown in Fig. 3 [31]. The core Topic is *Arnold Schwarzenegger*, which corresponds to several types. Though a property is connected to the node of *Arnold Schwarzenegger*, it also corresponds to a property of Type. For example, *Arnold Schwarzenegger* corresponds to Type: *Person*, the property of Person is *country of birth*, its value is *Austria*. Topic: *Arnold Schwarzenegger* and Topic: *Austria* is connected by this property, which is also a relationship between these two topics [31]. Each Type involves different properties. Therefore, Type can be regarded as a property container, which contains the most commonly used properties needed to describe a concept.

Another difference from the above two knowledge representations is that Freebase proposes a new structure to handle multiple relationships: CVT (Compound Value Types). CVT is a node that does not require an explicit name, which is used to express complex data [32]. It can be understood as a table in which multiple relationships and properties are stored, and this table is connected with node. For example, in Fig. 4 [4], CVT describes multiple relationships about Obama's tenure. When you look up Obama's tenure, there is an implicit condition for looking up the length of the tenure. They can be looked up as a whole through the CVT. The multiple relationships contain "office position," "from," "to" [4]. The structure may be more complex without the CVT.

The main differences of Freebase compared with the above two are summarized as the follows:

Freebase contains a larger scope of knowledge. It includes not only common sense and encyclopedic knowledge, but also some knowledge of popular culture, art, location information, etc. In structure, it does not have the strict ontology constraints like the above two, and its metadata are flexible to modify and add, and it can be completed by users more conveniently. In order to reflect users' different opinions and understandings, there may be conflict and contradiction in type and property [28]. It also has CVT, a compound value type for storing complex data that are not found in the above two databases. It uses a more simple structure to display knowledge.

4 Domain knowledge graph

The above are some general knowledge graphs, whose entities and concepts come from the common knowledge in real life. In some areas with strong industry knowledge background, they cannot meet the requirements fully. Therefore, researches that focus on domain knowledge graph emerged. Several typical domain knowledge graphs are introduced in this section.

4.1 Geographic information knowledge graph

GeoNames [33] is a classical knowledge graph in the field of geography, which contains over ten million pieces of geographic information (area name, location, etc.), and it is

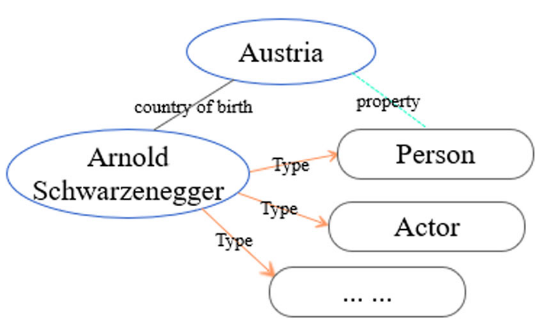

Fig. 3 Example of Freebase

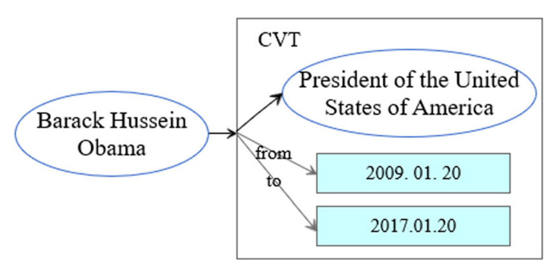

Fig. 4 Example of CVT

mainly displayed in English [34]. GeoName data were collected from the United States Geological Survey, the National Statistical Office, the National Post Office and the U.S. Army [35, 36].

GeoNames divides knowledge which contains nine feature classes, which are subdivided into 645 feature codes [37, 38]. The minimum feature set is the name, coordinates of latitude and longitude, parent regions and countries. It contains population data, aliases and links to Wikipedia, etc. [39]. It treats countries or cities as entities which corresponds to 19 pieces of information each. And some of the information fields are allowed to be empty. These pieces of information can be divided to two sorts. One is property information, such as area, population. These properties are basically geographical information related to the region. And the other is relationship information. For example, an entity can connect to feature classes by feature codes. Level 1 administrative code *admin1 code* and level 2 administrative code *admin2 code* can form hypernym and hyponym relationship [40]. Relationships contained in GeoNames are relatively simple. And these relationships are mainly based on the division of administrative regions, geographical location, attribution, geographic information etc. A simple example of GeoNames is shown in Fig. 5 [33].

The main differences of GeoNames are summarized as follows.

In terms of knowledge scope, the knowledge GeoNames contains is mainly from geographical field. Compared with the previous knowledge graphs, it covers more geographical information. On the structure, the structure of the GeoNames is relatively simple; the entities it contains have fixed and uniform properties, so there is a standard framework of knowledge representation structure. This is quite similar to encyclopedic knowledge graph such as Freebase, and it also supports user to edit data information. Because it relates to geographic information, it links to some specific map. This is not included in the general knowledge graph.

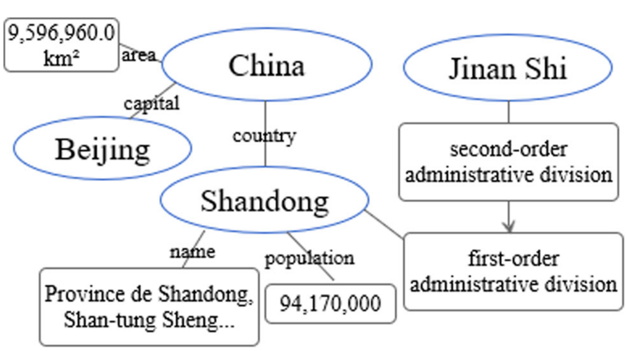

Fig. 5 Example of GeoNames

4.2 Knowledge graph of medical field

In the medical field, the construction of knowledge graphs has also been explored. There are relatively complete medical knowledge bases in this field, such as ICD-11 [41] which uses a tree structure to describe diseases and UMLS [42, 43] which use a structure form to store medical information. And Chinese scholars have also constructed knowledge graphs about traditional Chinese medicine [44–46]. These knowledge graphs contain medical concepts. Their structure is similar to the encyclopedic knowledge graph. In this section, we chose CMeKG [47] which contains more knowledge to analyze its knowledge representation.

CMeKG is mainly composed of concepts of diseases, drugs and diagnostic techniques and their relationships and properties. At present, CMeKG 2.0 [48] has 11,076 diseases, 18,471 drugs, 14,794 symptoms and 3546 treatment techniques, and it includes 1,566,494 triples to describe medical concepts, relationships and properties. It has being updated and improved constantly. Its entities include diseases, symptoms, medicines, etc. By far, the most important entity is disease. It contains treatment options, treatment drugs, diagnostic methods, symptoms, etiology and other properties. The general knowledge graph does not contain such detailed medical knowledge. CMeKG mainly includes the relationships between diseases and other entities, such as related causes, complications, related diseases, etc. In addition, it also includes relationships between symptoms and symptoms, drugs and drugs, etc. Like the general knowledge graph, it provides nodes that link to other knowledge bases. CMeKG is a simple Chinese medical knowledge graph, and its practical application

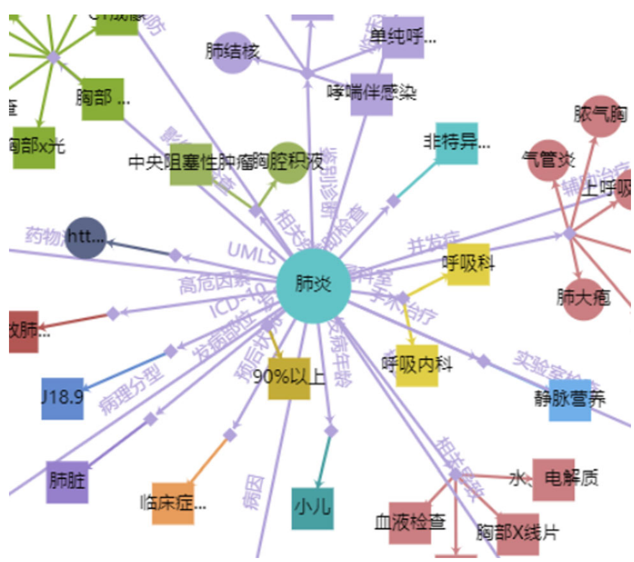

Fig. 6 An interface for CMeKG

needs more exploration. Figure 6 [48] shows an interface for CMeKG.

The main differences of CMeKG compared with the above knowledge graphs are summarized as follows:

In terms of knowledge scope, the knowledge CMeKG contains is mainly from medical field. Compared with the previous knowledge graphs, it covers more detailed medical information. On the structure, its properties and relationships are completely different from other knowledge graphs. Its properties and relationships are based on the medical field.

4.3 Knowledge graph of e-commerce field

The study on knowledge graphs of e-commerce field started earlier. The e-commerce knowledge graph is relatively mature and has been applied in various scenarios. Alibaba built the e-commerce semantic base in 2013 [49], and it includes six subsets, which are basic base, e-commerce base, entertainment base, book base, living base and miscellaneous base. It contains 33 first classes, 10 M entries and 150 relationships. The simple structure is shown in Fig. 7 [49]. This is a simple prototype of the e-commerce knowledge graph.

With the increase in data in e-commerce industry, product knowledge graph of e-commerce field is gradually established [49–52]. The data source includes e-commerce data, Web site information, industry information and encyclopedic information. In product knowledge graph, entities are the products and properties are the related features about this product. Goods belonging to different categories have different properties. For example, the food product has color, smell, shelf life and other properties, while the mobile phone product has accessories, model, battery, screen and other properties. Relationships in product knowledge graph can be roughly summarized as complement (co-buy), co-view, substitute, describe, search and IsA [52]. More broadly, it can be summarized as synonyms relationship, hypernym and hyponym relationship, holistic and partial relationship [51]; it is similar to the language knowledge graph WordNet, but relationships in product knowledge graph are more complex. Most

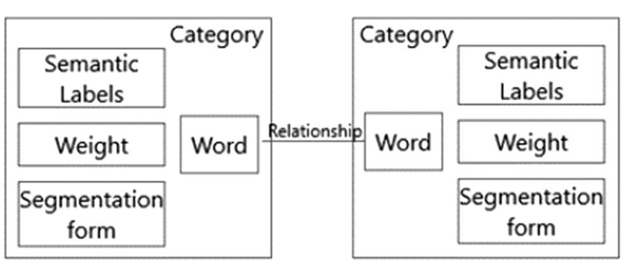

Fig. 7 Structure of e-commerce semantic base

relationships are N to N [52]. Taking mobile phones for example, *battery*, *mobile phone stents*, *audio speaker*, *charger* have *complement* relationship with *Mobile phone*. But at a finer semantic granularity, they correspond to *accessory*, *structural attachment*, *enhancement* and *add-on*. So the semantic meaning of relationships which contained in the product knowledge graph is more complicated.

With the upgrading of application scenarios, the e-commerce cognitive knowledge graph has been gradually constructed [53]. It mainly realized the function of commodity search and personalized recommendation. It includes user knowledge graph, product knowledge graph and scene knowledge graph. Through data fusion and relationships extraction, it links the three knowledge graphs to form the e-commerce cognitive knowledge graph.

Besides basic product properties, product knowledge graph includes some labels, such as *no salt*, *sugar free* or some keywords that users often search. These all are stored in the knowledge graph as properties. These properties are extracted from national regulations and user historical usage records.

The data of the user knowledge graph are derived from account information and historical usage records. In the user knowledge graph, entities are users, relationships between entities are social relationships and its properties are different from other knowledge graphs. The user knowledge graph contains general user information (*name, age, gender,* etc.), which is similar to the general user knowledge graph. Differences mainly lie in the label of the user description. It labels the user by age or some historical search data in e-commerce platform. Those labels are included in the user's properties, such as *old person*, *early pregnancy*. And the purchasing power and preferences of consumers can be inferred from their historical purchase data, and those labels also can be included in the user's properties. These properties are not included in other knowledge graphs.

In addition, the scene knowledge graph is built to connect user knowledge graph and product knowledge graph [53, 54]. Its main data source includes user's search data, product title, hot spots on the network and some industry data. It is a unique knowledge graph in e-commerce field. The scene in scene knowledge graph refers to the conceptualization of user needs, and it is a conceptual node abstracted from user's demand characteristics. The scene knowledge graph uses a short and precise phrase to describe a class of user demands. It takes the implicit user demand information as an entity and creates new nodes which are not included in other knowledge graphs, such as *Outdoor Barbecue, Breakfast for Pregnancy, Keep Warm for kids*. The name of these nodes is from the eight categories in e-commerce concept vocabulary. The eight categories are Time, Location, Object, Function, Incident, Cate/Brand, Style and IP [54]. These scene nodes have certain properties such as color, so the nodes do not have special annotated properties. Relationships in the scene knowledge graph are mainly hypernym and hyponym relationship. Figure 8 [53] is a simple example of e-commerce knowledge graph.

Compared with other knowledge graphs, the differences are summarized as follows.

In terms of knowledge scope, this knowledge graph covers more e-commerce information and contains e-commerce scenario knowledge. On the structure, it enriches the contents of entities and creates new nodes. In addition, it uses a graph as a bridge to establish the connection between the two graphs, which are different from other knowledge graphs.

4.4 Conclusion

Through the research on the knowledge representation of several domain knowledge graphs, it can be seen that the design of knowledge representation in domain knowledge graphs is mainly related to the domain business requirements and the construction of domain knowledge graph can refer to the structure and content of the general knowledge graph to some extent. The main differences between domain knowledge graph and general knowledge graph are breadth, depth and granularities [2]. General knowledge graph has a wider breadth, which covers more knowledge.

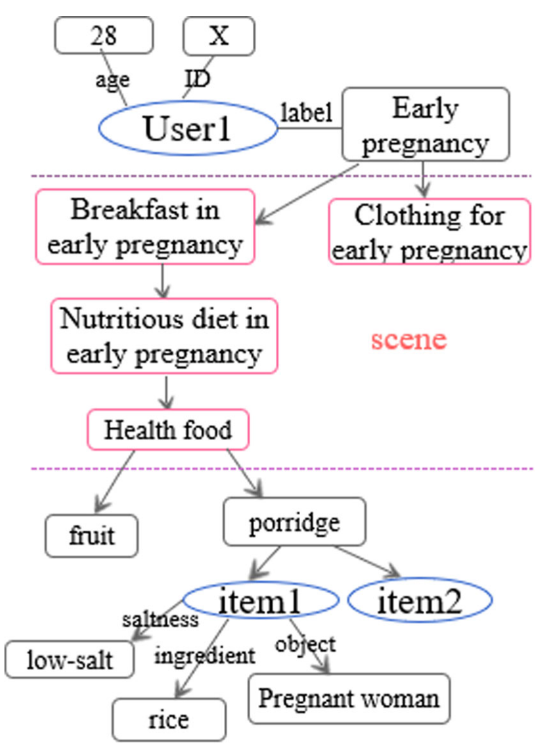

Fig. 8 Example of e-commerce knowledge graph

Domain knowledge graph which shows more detailed knowledge within the field has a deeper depth. In addition, there are some differences in the granularity of their knowledge partitioning. The main reason for the differences lies in their different knowledge backgrounds and data sources. Domain knowledge graph has more domain-specific data and knowledge, so its entities and properties may be quite different from general knowledge graph.

5 Research trends and prospects

There have been lots of researches which focus on general knowledge graph, and some researches have focused on knowledge representation learning, such as distance model SE [55], translation model TransE [56]. Liu et al. [57] summarized the method of knowledge representation learning. Research on domain knowledge graph is emerging. Knowledge representation is the first step for knowledge graph construction. Learning it helps beginners to understand the concept of knowledge graph and lays a foundation for domain knowledge graph construction.

For the research on domain knowledge graph construction, some problems should be explored.

(1) Expansion of knowledge representation

The main way to express knowledge is relational triple, whether it can be extended to multicomponent to express diverse information. For complex unstructured problems, such as the corresponding relationship between major and school in the education industry, a simple inclusion relationship cannot express it fully, whether properties and relationships can be extended?

(2) Multimode of knowledge representation

There are a lot of information resources on the network. They not only contain text, also include video and image, etc. Video and image maybe explain knowledge better than text. Therefore, how to design these nontextual resources into the structure of knowledge representation is an important problem.

(3) Knowledge representation automatic learning

Most of the knowledge representation learning methods are applicable to general knowledge graph. It is not well qualified for automatic extraction of domain knowledge with complex information. Therefore, domain knowledge automatic learning is a problem to be solved.

(4) Knowledge fusion

Compared with general knowledge, the structure of domain knowledge is more complex and it requires more data experimentation and better algorithms if we want to integrate knowledge into industry background.

(5) Data collection

The establishment of knowledge graph requires lots of data. In some specific area, such as education, a complete education knowledge graph can assist teachers to do course designing and help students collect information. There are enough data to support education knowledge graph construction. However, data collection in the education industry is still not completed. So data collecting and analyzing platform is going to be a research trend of domain knowledge graph construction.

(6) Dynamic update

The knowledge contained in the domain knowledge graph is not unchanged all the time, such as major courses every year, the grade of school or major in the education field. Therefore, how to realize the dynamic change and update of knowledge in a quick way is an important research area.

Clarifying the concept and content of knowledge representation by sorting out the development of knowledge representation is expected, which will put forward the knowledge representation about higher education in the next step and will lay a foundation for the construction of education knowledge graph as well.

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Compliance with ethical standards

Conflict of interest There are no conflicts of interests of this work.

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Online teaching quality evaluation based on multi-granularity probabilistic linguistic term sets

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Abstract. In today's education industry, online teaching is increasingly becoming an important teaching way, and it is necessary to evaluate the quality of online teaching so as to improve the overall level of the education industry. The online teaching quality evaluation is a typical multi-attribute group decision-making (MAGDM) problem, and its evaluation index can be expressed by linguistic term sets (LTSs) by decision makers (DMs). Especially, multi-granularity probabilistic linguistic term sets (MGPLTSs) produced from many DMs are more suitable to express complex fuzzy evaluation information, and they can not only provide different linguistic term set for different DMs the give their preferences, but also reflect the importance of each linguistic term. Based on the advantages of MGPLTSs, in this paper, we propose a transformation function of MGPLTSs based on proportional 2-tuple fuzzy linguistic representation model. On this basis, the operational laws and comparison rules of MGPLTSs are given. Then, we develop a new Choquet integral operator for MGPLTSs, which considers the relationship among attributes and does not need to consider the process of normalizing the probabilistic linguistic term sets (PLTSs), and can effectively avoid the loss of evaluation information. At the same time, the properties of the proposed operator are also proved. Furthermore, we propose a new MAGDM method based on the new operator, and analyze the effectiveness of the proposed method by online teaching quality evaluation. Finally, by comparing with some existing methods, the advantages of the proposed method are shown.

Keywords: Multiple-attribute group decision-making, online teaching quality evaluation, multi-granularity probabilistic linguistic term sets, Choquet integral

1. Introduction

With the development of the Internet, the traditional teaching way is combined with the Internet, online teaching appeared. Online teaching is a long-distance education model based on the Internet. Due to the flexibility and diversity of online teaching, it is developing rapidly. He et al. [1] mentioned that online teaching is becoming an increasingly important teaching way in higher educational institutions. Now, online teaching is a research hotspot. Bennett et al. [2] analyzed the learning differences between online teaching and traditional classes. Martin et al. [3] studied how to determine curriculum design and evaluation from the perspective of award-winning online faculty. Jones and Meyer [4] pointed out that the effective teachers are the key to the success of students in online teaching. In recent years, there have been many studies on the impact of online teaching quality. Schmidt et al. [5] believed that curriculum development and online teaching methods are two key factors for effective online teaching.

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Rhode et al. [6] gave the research results that online teaching quality should be improved from teachers' attitude, belief and technical level. Diaz et al. [7] gave the research results that teacher development and information technology have an important impact on the quality of online teaching. Online teaching quality evaluation is a comprehensive evaluation process in which multiple decision makers (DMs) make some value judgments on online teaching based on evaluation methods, analyzing teaching information and teaching resources. Therefore, online teaching quality evaluation is a typical multi-attribute group decision-making (MAGDM) problem. Some scholars studied the MAGDM method for online teaching quality evaluation. Liu and Rong [50] selected four evaluation attributes to evaluate the online courses quality of China National Open University, Liu et al. [51] evaluated the quality of the live platform online education from four evaluation attributes. In order to evaluate online teaching from more appropriate attributes, based on some standards for online course evaluation proposed by the Ministry of Education of China, the online education evaluation includes the following evaluation attributes: teaching philosophy and curriculum design, teaching contents and learning resources, faculty and teaching activities, user interface design and technical support.

MAGDM can be recognized as a procedure of evaluating several alternatives or selecting the optimal alternative by some DMs according to multiple attributes [8, 10, 53, 54]. Owing to the complexity of decision-making and the fuzziness of human thinking, DMs cannot accurately express their evaluation information with real numbers. In order to overcome this obstacle, Zadeh [11] introduced linguistic variable and Herrera et al. [12] presented the concept of linguistic term sets (LTSs). Due to the different knowledge backgrounds and educational experiences of DMs, "the granularity of uncertainty" (cardinality of LTSs) used by each DM is different. Herrera et al. [13] proposed a fusion approach of multi-granularity linguistic term sets (MGLTSs), Herrera and Martínez [14] proposed a 2-tuple fuzzy linguistic model to compute with words, which can avoid the problem of information loss. Based on the 2-tuple fuzzy linguistic model, Wang and Hao [15] proposed proportional 2-tuple fuzzy linguistic representation model.

However, due to complexity of the problem, DMs may be hesitant in several linguistic terms. Rodriguez et al. [16] proposed concept of hesitant fuzzy LTSs (HFLTSs) based on hesitant fuzzy sets (HFSs) and LTSs to deal with this problem. After that, scholars focus on the researches from three aspects of HFLTSs.

(1) The basic theories of HFLTSs, such as some operations [17, 18], distance measures [19, 20], and preference relations [21, 22].
(2) The decision-making methods based on HFLTSs. Wu et al. [23] developed compromise solutions for MAGDM problem using HFLTSs. Lin et al. [24] extended the traditional TODIM method to deal with the HFLTSs based on the novel comparison function and distance measure.
(3) The aggregation operators (AOs) based on HFLTSs. Wei [25] studied arithmetic and geometric aggregation operators with interval valued hesitant fuzzy uncertain linguistic information. Liu et al. [26] proposed the hesitant fuzzy linguistic (HFL) Muirhead mean operator and the weighted HFL Muirhead mean (WHFLMM) operator. Zhu and Li [27] presented some HFL aggregation operators based on the Hamacher t-norm and t-conorm.

However, the HFLTSs also have some shortcomings. It cannot reflect the different importance and different frequencies of each linguistic term in HFLTS given by DMs. In order to solve this shortcoming, Pang et al. [28] proposed probabilistic LTSs (PLTSs) with the different importance of each linguistic term. Then, Bai et al. [29] proposed possibility degree of PLTSs to compare two PLTSs. Liu and You [30] extended TODIM to PLTSs to solve the multi-attribute decision-making (MADM) problem. Lin et al. [52] combined PLTSs and Best-Worst method to calculate the criteria weights, and proposed a new probabilistic linguistic TODIM method to rank Internet of Things platforms. Liu and Teng [31] established an extended probabilistic linguistic TODIM method to assess online product. In the real decision environment, because the preferences of DMs are different, they can use PLTSs with different granularity levels to give decision information. Therefore, in order to improve the applicability of PLTSs in complex environment, the multi-granularity PLTSs (MGPLTSs) were developed. Wang et al. [32] determined the distance measure between two MGPLTSs, and proposed a novel MAGDM method. Wang [33] proposed some novel distance measures between two MGPLTSs. Song and Li [34] presented a large-scale group decision-making with incomplete MGPLTSs. Obviously, MGPLTSs have widely been used in MAGDM problems.

In MAGDM process, aggregation operators (AOs) are a powerful tool for information fusion. Many researches on AOs can be divided into two aspects: operations and the functions.

(1) About operations. Pang et al. [28] put forward some basic operational laws and the comparison method of PLTSs. Gou and Xu [35] proposed some logical operational laws for PLTSs to overcome some unreasonable problems. Lin et al. [56] proposed new distance measure and comparison method for PLTSs. Wang et al. [36] introduced a rational comparison method and proposed extended Hausdorff distance of PLTSs. In order to measure the relationship between two PLTSs, Lin et al. [57] proposed correlation coefficient. Wang et al. [32] defined generalized probabilistic linguistic Hamming distance, generalized probabilistic linguistic Euclidean distance and generalized probabilistic linguistic Hausdorff distance of MGPLTSs, which improved the accuracy of MGPLTSs in MAGDM problems.
(2) About functions. Pang et al. [28] proposed probabilistic linguistic averaging (PLA) operator and probabilistic linguistic weighted averaging (PLWA) operator, Liu and Li [37] proposed a probabilistic linguistic-dependent weighted average (PLDWA) operator, and then combined the PLDWA operator with the MULTIMOORA method. Kobina et al. [38] proposed the probabilistic linguistic power average (PLPA), the weighted probabilistic linguistic power average (WPLPA) operators, the probabilistic linguistic power geometric (PLPG) and the weighted probabilistic linguistic power geometric (WPLPG) operators. Lin et al. [55] defined probabilistic uncertain linguistic term set and proposed four operators. Wang [33] proposed an MAGDM algorithm with MGPLTSs based on the distance measures and prospect theory (PT), and verified the validity of the proposed MAGMD method.

In practical decision-making, interrelationship among attributes is very common. Sugeno [39] proposed the fuzzy measure and defined λ-fuzzy measure for the MAGDM problem to handle the interrelationship among attributes. Then Murofushi and Sugeno [40] proposed Choquet integrals of fuzzy measures, and discussed the rationality. Chen et al. [41] proposed probabilistic linguistic Choquet integral operator based on PLTSs to aggregate the enterprise resource planning package evaluation matrices. Choquet integral is widely used in MAGDM method, which has strong practicability.

At present, there are few researches on MGPLTSs. Most of the existing decision-making methods for dealing with MGPLTSs are to transform MGPTLSs into PTLSs with same granularity level according to the transformation function. This means that they cannot directly handle MGPLTSs. No matter in MGPLTSs or PLTSs, the existing operations and AOs cannot avoid the process of normalizing the PLTSs in the calculation process. Based on the above discussion, the motivations and contributions of this paper are as follows:

(1) A new transformation function for MGPLTSs based on the proportional 2-tuple fuzzy linguistic representation model is proposed, which avoids the process of normalizing the PLTSs and reduces the complexity of existing operations of PLTSs [33, 42–44], then the operational laws and comparison rules of MGPLTSs are given.
(2) Based on the new transformation function, a new Choquet integral operator for MGPLTSs is proposed, which simplifies the steps of transforming MGPLTSs into the PLTSs with same granularity level before aggregation [33].
(3) A new MAGDM method based on the created operator is proposed to solve decision-making problems with relationship between attributes.
(4) The validity of the created MAGDM method is verified, and the new MAGDM method is applied to solve the problem of online teaching quality evaluation.

The rest of this paper is organized as follows. Section 2 briefly introduces the basic concepts. Section 3 proposes some new operations for MGPLTSs. In Section 4, based on the Choquet integral, a new operator for MGPLTSs is proposed and its properties are proved. Section 5 proves the effectiveness of the proposed method by a case study. Then by comparative analysis, the advantages of the created MAGDM method are reflected. In Section 6, concluding remarks are drawn.

2. Preliminaries

2.1. PLTS

A LTS can be denoted as $S = \left\{\Re_i | i = 0, ..., 2g, g \in N^+\right\}$, and $2g + 1$ is the granularity of LTS. In general, suppose that $S^{MG} = \left\{S^t | t = 1, 2..., T\right\}$ is a MGLTS, where $S^t\,(t = 1, 2, ..., T)$ is a LTS. It is assumed that $S^t = \left\{\Re_0^t, \Re_1^t, ..., \Re_{2g^{(t)}}^t\right\}$, the granularity of S^t is $2g^{(t)} + 1$, and $\varsigma_i^t \in S^t$ means ς_i^t is the ith tern of S^t.

Definition 1 [28]. Assumed that $S = \left\{\varsigma_0, \varsigma_1, ..., \varsigma_{2g}\right\}$ is a LTS, then a PLTS can be described as

$$L(p) = \left\{ \Re_i\,(p_i) | \,\Re_i \in S, \, p_i \geq 0, i = 0, 1, ..., \#L(p), \sum_{i=0}^{\#L(p)} p_i \leq 1 \right\} \tag{1}$$

where $\varsigma_i\,(p_i)$ represents the linguistic term ς_i with its probability p_i, and $\#L(p)$ represents the number of linguistic terms in PLTS.

If $\sum_{i=0}^{\#L(p)} p_i = 1$, it means that the probabilistic information of each LTS in PLTS is completely known;
If $0 < \sum_{i=0}^{\#L(p)} p_i < 1$, it means that probabilistic information is partly unknown;
If $\sum_{i=0}^{\#L(p)} p_i = 0$, it means that the probabilistic information is completely unknown.

2.2. The relative theories of 2-tuple linguistic model

Definition 2 [45]. Assumed that $S = \{\varsigma_i | i = 0, ..., g\}$ is a LTS, and $\beta \in \left[0, g\right]$ means the result of a symbolic aggregation operation. Then, the function Δ used to obtain the 2-tuple linguistic information equivalent to β can be described as:

$$\Delta : [0, g] \to S \times [-0.5, 0.5)$$

$$\Delta(\beta) = \begin{cases} \varsigma_i & i = round(\beta) \\ \alpha = \beta - i & \alpha = [-0.5, 0.5) \end{cases}$$

where $round\,(\cdot)$ means the rounding operation, ς_i has the closest index label to β, and α is the value of the symbolic translation.

Definition 3 [45]. Assumed that $S = \{\varsigma_i | i = 0, ..., g\}$ is a LTS, and (ς_i, α) is a 2-tuple linguistic representation model. Then a 2-tuple linguistic representation model can be transformed into equivalent numerical value $\beta \in [0, g]$ by the function Δ^{-1}.

$$\Delta^{-1} : S \times [-0.5, 0.5)$$

$$\Delta^{-1}(\varsigma_i, \alpha) = i + \alpha.$$

A representational model of MGLTS is linguistic hierarchy [9], which can be denoted as

$$LH = \bigcup\nolimits_k^K l\,(k, n\,(k))$$

where $l\,(k, n\,(k))$ is the LTS of the level k, and the granularity is $n\,(k)$, and can be denoted as $S^{n(k)} = \left\{\varsigma_0^{n(k)}, \varsigma_1^{n(k)}, ..., \varsigma_{n(k)-1}^{n(k)}\right\}, k = 1, 2, ..., K.$

Definition 4 [45]. Assumed that $LH = \bigcup_k^K l\,(k, n\,(k))$ is a linguistic hierarchy, and LTSs are $S^{n(k)} = \left\{\varsigma_0^{n(k)}, \varsigma_1^{n(k)}, ..., \varsigma_{n(k)-1}^{n(k)}\right\}, \quad k = 1, 2, ..., K.$ Therefore, the transformation function $TF_{k'}^k$ to map the set of linguistic variables between different levels can be obtained as:

$$TF_{k'}^k\left(\varsigma_i^{n(k)}, \alpha^{n(k)}\right) = \Delta\left(\frac{\Delta^{-1}(\varsigma_i^{n(k)}, \alpha^{n(k)}) \cdot (n(k' - 1))}{n(k) - 1}\right)$$

To extend the application scope of 2-tuple linguistic representation model, Wang and Hao [15] proposed proportional 2-tuple fuzzy linguistic representation model.

2.3. The relative theories of proportional 2-tuple linguistic model

Definition 5 [15]. Assumed that $S = \{\varsigma_i | i = 0, ..., g\}$ is a LTS. Then the proportional 2-tuple fuzzy linguistic model is $(\alpha\varsigma_i, (1 - \alpha)\,\varsigma_{i+1}), \alpha \in [0, 1], \varsigma_i, \varsigma_{i+1} \in$

S. The set of all ordinal proportional 2-tuple on LTS S is shown as following.

$$\overline{S} = \{(\varsigma_i, (1-\alpha)\,\varsigma_{i+1})\,|\alpha \in [0,1]\,, i = 0, ..., g-1\}\,.$$

Assumed that $(\alpha\varsigma_i, (1-\alpha)\,\varsigma_{i+1})$ and $(\beta\varsigma_i, (1-\beta)\,\varsigma_{i+1})$ are two proportional 2-tuple linguistic terms, then we have

$$\begin{aligned}
&(\alpha\varsigma_i, (1-\alpha)\,\varsigma_{i+1}) < (\beta\varsigma_i, (1-\beta)\,\varsigma_{i+1})\\
&\Leftrightarrow \alpha i + (1-\alpha)(i+1) < \beta j + (1-\beta)(j+1)\\
&\Leftrightarrow i + (1-\alpha) < j + (1-\beta)\,.
\end{aligned}$$

Thus, for any two proportional 2-tuples $(\alpha\varsigma_i, (1-\alpha)\,\varsigma_{i+1})$ and $(\beta\varsigma_i, (1-\beta)\,\varsigma_{i+1})$, the comparison rules between them are as follows:

(1) if $i < j$, then
   (a) if $i = j-1$ and $\alpha = 0$, $\beta = 1$, then $(\alpha\varsigma_i, (1-\alpha)\,\varsigma_{i+1})$ and $(\beta\varsigma_i, (1-\beta)\,\varsigma_{i+1})$ represent the same linguistic information,
   (b) otherwise: $(\beta\varsigma_i, (1-\beta)\,\varsigma_{i+1}) < (\beta\varsigma_i, (1-\beta)\,\varsigma_{i+1})$;
(2) if $i = j$, then
   (a) if $\alpha = \beta$, then $(\alpha\varsigma_i, (1-\alpha)\,\varsigma_{i+1})$ and $(\beta\varsigma_i, (1-\beta)\,\varsigma_{i+1})$ represent the same linguistic information,
   (b) if $\alpha < \beta$, then $(\alpha\varsigma_i, (1-\alpha)\,\varsigma_{i+1}) < (\beta\varsigma_i, (1-\beta)\,\varsigma_{i+1})$,
   (c) if $\alpha > \beta$, then $(\alpha\varsigma_i, (1-\alpha)\,\varsigma_{i+1}) > (\beta\varsigma_i, (1-\beta)\,\varsigma_{i+1})$.

2.4. Choquet integral

Definition 6 [40]. Assumed that $P(X)$ is the power set of $X = \{x_1, ..., x_h\}$. A fuzzy measure on the set X is a function $\mu : P(X) \to [0, 1]$, and it satisfies the following two conditions:

(1) $\mu(\phi) = 0, \mu(X) = 1$;
(2) $\mu(B) \le \mu(C)\,, \forall B, C \in P(X)$ and $B \subset C$.

If X is infinite, it need to add a continuity condition [46]. However, in practical decision problems, the set X is generally limited. According to **Definition 6**, in order to determine the fuzzy measure, $2^h - 2$ parameters need to be calculated. To reduce the calculation complexity of the fuzzy measure, the general fuzzy measure can be replaced by the λ-fuzzy measure.

Definition 7 [40]. Assumed that $P(X)$ is the power set of $X = \{x_1, ..., x_h\}$, for $\forall A, B \in P(X)\,, A \cap B = \phi$. If the fuzzy measure μ satisfies the following conditions:

$$\mu(A \cup B) = \mu(A) + \mu(B) + \lambda\mu(A)\,\mu(B)$$

where $\lambda \in (-1, \infty)$, μ is called λ-fuzzy measure (μ_λ).

According to **Definition 7**, if $\lambda = 0$, it means that λ-fuzzy measure μ_λ has additivity, in other words, set A and set B are independent of each other. If $\lambda \neq 0$, it means that λ-fuzzy measure μ_λ has no additivity, in other words, there is an interrelationship between set A and set B; if $\lambda > 0$, then $\mu_\lambda(A \cup B) > \mu_\lambda(A) + \mu_\lambda(B)$, it means that set A and set B have super-additivity; if $\lambda < 0$, then $\mu_\lambda(A \cup B) < \mu_\lambda(A) + \mu_\lambda(B)$, it means that set A and set B have sub-additivity.

According to the definition of λ-fuzzy measure μ_λ, $\mu_\lambda(X) = 1$, then μ_λ can be expressed as follows:

$$\mu_\lambda(X) = \begin{cases} \dfrac{1}{\lambda}\left(\prod\limits_{i=1}^{h}(1 + \lambda\mu_\lambda(x_i)) - 1\right), \lambda \neq 0 \\ \sum\limits_{i=1}^{h}\mu_\lambda(x_i)\,, \lambda = 0 \end{cases} \tag{1}$$

Due to $\mu_\lambda(X) = 1$, when $\lambda \neq 0$, the parameter λ can be determined by the following formula:

$$\lambda + 1 = \prod_{i=1}^{h}(1 + \lambda\mu(x_i)) \tag{2}$$

Definition 8 [47]. Assumed that f is a nonnegative function defined on $X = \{x_0, ..., x_{2h}\}$ and μ is a fuzzy measure defined on X, then the discrete Choquet integral of f with respect to the fuzzy measure μ is:

$$\int f d\mu = \sum_{i=1}^{h} f\left(x_{(i)}\right)\left[\mu\left(A_{(i)}\right) - \mu\left(A_{(i+1)}\right)\right] \tag{3}$$

where subscript (i) is permutation of $f(x_{(i)})$, making $0 \le f\left(x_{(1)}\right) \le f\left(x_{(2)}\right) \le ... \le f\left(x_{(i)}\right)$; $A_{(i)} = \left(x_{(i)}, x_{(i+1)}, ..., x_{(h)}\right)$, and $A_{(h+1)} = \phi$.

3. Some new operations for MGPLTSs

3.1. The transformation function for MGPLTSs

The transformation function of MGPLTSs based on the proportional 2-tuple fuzzy linguistic representation model is shown as follows.

Definition 9. Assumed that $L_1(p)$ and $L_2(p)$ are two arbitrary PLTSs with different granularity levels, $L_1(p) = \left\{ \varsigma_i^{1,n(1)} \left(p_i^{1,n(1)} \right) | \varsigma_i^{1,n(1)} \in S^{n(1)}, p_i^{1,n(1)} \geq 0, i = 0, 1, ..., \#L_1(p), \sum_{i=0}^{\#L_1(p)} p_i^{1,n(1)} \leq 1 \right\}$ and $L_2(p) = \left\{ \varsigma_i^{2,n(2)} \left(p_i^{2,n(2)} \right) \middle| \varsigma_i^{2,n(2)} \in S^{n(2)}, p_i^{2,n(2)} \geq 0, i = 0, 1, ..., \#L_2(p), \sum_{i=0}^{\#L_2(p)} p_i^{2,n(2)} \leq 1 \right\}$. Then, the transformation function TF from $L_1(p)$ to $L_2(p)$ is

$$TF_2^1 \left(\varsigma_i^{1,n(1)} \left(p_i^{1,n(1)} \right) \right) = \left\{ \varsigma_\beta^{1,n(2)} \left(\gamma_\beta^i p_i^{1,n(1)} \right), \varsigma_{\beta+1}^{1,n(2)} \left(\alpha_{\beta+1}^i p_i^{1,n(1)} \right) \right\} \quad (4)$$

where $(i = 0, 1, ..., n(1) - 1)$, $\beta = round\left(\frac{i \times (n(2)-1)}{n(1)-1}\right)$, $\alpha_{\beta+1}^i = \frac{i \times (n(2)-1)}{n(1)-1} - \beta$, $\gamma_\beta^i = 1 - \alpha_{\beta+1}^i$, $\varsigma_\beta^{1,n(2)}$ is a linguistic term transformed from $L_1(p)$ to granularity $n(2)$.

After the transformation of each probabilistic linguistic term in $L_1(p)$, we can calculate the probabilities of the same linguistic terms, and the result is as follows:

$$\begin{aligned} &TF_2^1 \left(L_1(p) = \left\{ \varsigma_0^{1,n(1)} \left(p_0^{1,n(1)} \right), \varsigma_1^{1,n(1)} \left(p_1^{1,n(1)} \right), ..., \varsigma_{n(1)-1}^{1,n(1)} \left(p_{n(1)-1}^{1,n(1)} \right) \right\} \right) \\ &= \left(\varsigma_0^{1,n(2)} \left(\sum_{i=0}^{n(1)\text{ - }1} \left(\gamma_0^i p_i^{1,n(1)} + \alpha_0^i p_i^{1,n(1)} \right) \right), \varsigma_1^{1,n(2)} \left(\sum_{i=0}^{n(1)\text{ - }1} \left(\gamma_1^i p_i^{1,n(1)} + \alpha_1^i p_i^{1,n(1)} \right) \right), ..., \right. \\ &\left. \varsigma_j^{1,n(2)} \left(\sum_{i=0}^{n(1)\text{ - }1} \left(\gamma_j^i p_i^{1,n(1)} + \alpha_j^i p_i^{1,n(1)} \right) \right), ..., \varsigma_{n(2)-1}^{1,n(2)} \left(\sum_{i=0}^{n(1)\text{ - }1} \left(\gamma_{n(2)-1}^i p_i^{1,n(1)} + \alpha_{n(2)-1}^i p_i^{1,n(1)} \right) \right) \right) \\ &= \left\{ \varsigma_0^{1,n(2)} \left(p_0^{1,n(2)} \right), \varsigma_1^{1,n(2)} \left(p_1^{1,n(2)} \right), ..., \varsigma_j^{1,n(2)} \left(p_j^{1,n(2)} \right), ..., \varsigma_{n(2)-1}^{1,n(2)} \left(p_{n(2)-1}^{1,n(2)} \right) \right\} \end{aligned} \quad (6)$$

Example 1. Assumed that $L_1(p) = \left(\varsigma_0^{1,n(1)}(0.1), \varsigma_1^{1,n(1)}(0.2), \varsigma_2^{1,n(1)}(0.7) \right)$ and $L_2(p) = \left\{ \varsigma_0^{2,n(2)}(0.2), \varsigma_1^{2,n(2)}(0.2), \varsigma_2^{2,n(2)}(0.2), \varsigma_3^{2,n(2)}(0.2), \varsigma_4^{2,n(2)}(0.2) \right\}$ are two PLTSs,

With respect to the linguistic level $(2, n(2))$, $L_1(p)$ can be transformed into $L_1'(p)$ as follows.

$TF_2^1 \left(\varsigma_0^{1,n(1)}(0.1) \right) = \left\{ \varsigma_0^{1,n(2)}(1 \times 0.1) \right\} = \left\{ \varsigma_0^{1,n(2)}(0.1) \right\}$,
$TF_2^1 \left(\varsigma_1^{1,n(1)}(0.2) \right) = \left\{ \varsigma_2^{1,n(2)}(1 \times 0.2) \right\} = \left\{ \varsigma_2^{1,n(2)}(0.2) \right\}$,
$TF_2^1 \left(\varsigma_2^{1,n(1)}(0.7) \right) = \left\{ \varsigma_4^{1,n(2)}(1 \times 0.7) \right\} = \left\{ \varsigma_4^{1,n(2)}(0.7) \right\}$.

The result is $L_1'(p) = \left\{ \varsigma_0^{1,n(2)}(0.1)\ \varsigma_2^{1,n(2)}(0.2), \varsigma_4^{1,n(2)}(0.7) \right\}$

With respect to the linguistic level $(1, n(1))$, $L_2(p)$ can be transformed into $L_2'(p)$ as follows.

$TF_1^2 \left(\varsigma_0^{2,n(2)}(0.2) \right) = \left\{ \varsigma_0^{2,n(1)}(1 \times 0.2) \right\} = \left\{ \varsigma_0^{2,n(1)}(0.2) \right\}$,
$TF_1^2 \left(\varsigma_1^{2,n(2)}(0.2) \right) = \left\{ \varsigma_0^{2,n(1)}(0.5 \times 0.2), \varsigma_1^{2,n(1)}(0.5 \times 0.2) \right\} = \left\{ \varsigma_0^{2,n(1)}(0.1), \varsigma_1^{2,n(1)}(0.1) \right\}$,
$TF_1^2 \left(\varsigma_2^{2,n(2)}(0.2) \right) = \left\{ \varsigma_1^{2,n(1)}(1 \times 0.2) \right\} = \left\{ \varsigma_1^{2,n(1)}(0.2) \right\}$,
$TF_1^2 \left(\varsigma_3^{2,n(2)}(0.2) \right) = \left\{ \varsigma_1^{2,n(1)}(0.5 \times 0.2), \varsigma_2^{2,n(1)}(0.5 \times 0.2) \right\} = \left\{ \varsigma_1^{2,n(1)}(0.1), \varsigma_2^{2,n(1)}(0.1) \right\}$,
$TF_1^2 \left(\varsigma_4^{2,n(2)}(0.2) \right) = \left\{ \varsigma_2^{2,n(1)}(1 \times 0.2) \right\} = \left\{ \varsigma_2^{2,n(1)}(0.2) \right\}$.

The result is $L_2'(p) = \left\{ \varsigma_0^{2,n(1)}(0.3), \varsigma_1^{2,n(1)}(0.4), \varsigma_2^{2,n(1)}(0.3) \right\}$.

Therefore, the PLTSs with different granularity levels can be transformed into the same granularity level.

3.2. The operational laws for MGPLTSs

Theorem 1 [48]. Assumed that $S = \{\varsigma_0, \varsigma_1, \ldots, \varsigma_{2g}\}$ is a LTS. $L_1(p)$, $L_2(p)$ and $L_3(p)$ are three PLTSs on S, and $0 \le a \le 1$, where $L_1(p) = \left\{\varsigma_i\left(p_i^1\right)\middle|\varsigma_i \in S, p_i^1 \ge 0, i = 0, 1, \ldots, 2g, \sum_{i=0}^{2g} p_i^1 \le 1\right\}$, $L_2(p) = \left\{\varsigma_i\left(p_i^2\right)\middle|\varsigma_i \in S, p_i^2 \ge 0, i = 0, 1, \ldots, 2g, \sum_{i=0}^{2g} p_i^2 \le 1\right\}$, $L_3(p) = \left\{\varsigma_i\left(p_i^3\right)\middle|\varsigma_i \in S, p_i^3 \ge 0, i = 0, 1, \ldots, 2g, \sum_{i=0}^{2g} p_i^3 \le 1\right\}$.

Then we have the following operational laws [48]:

$$L_1(p) \oplus L_2(p) =$$

$$\left\{\varsigma_i\left(\frac{p_i^1 p_i^2 + p_i^1\left(1-\sum_{i=0}^{2g} p_i^2\right) + p_i^2\left(1-\sum_{i=0}^{2g} p_i^1\right)}{\left(1-\sum_{i=0}^{2g} p_i^2\right)\left(1-\sum_{i=0}^{2g} p_i^1\right) + \sum_{i=0}^{2g}\left(p_i^1 p_i^2 + p_i^1\left(1-\sum_{i=0}^{2g} p_i^2\right) + p_i^2\left(1-\sum_{i=0}^{2g} p_i^1\right)\right)}\right)\right\} \tag{7}$$

$$aL_3(p) = \left\{\varsigma_i\left(ap_i^3\right) | i = 0, \ldots, 2g\right\} \tag{8}$$

$$L_1(p) \oplus L_2(p) = L_2(p) \oplus L_1(p) \tag{9}$$

$$(L_1(p) \oplus L_2(p)) \oplus L_3(p) = L_2(p) \oplus (L_1(p) \oplus L_3(p)) \tag{10}$$

In order to calculate MGPLTSs directly, we propose the operational laws of MGPLTSs based on **Definition 9** and **Theorem 1.**

Theorem 2. Assumed that $L_1(p)$, $L_2(p)$, $L_3(p)$ are three PLTSs with different granularity levels, $L_1(p) = \left\{\varsigma_i^{1,n(1)}\left(p_i^{1,n(1)}\right)\middle|\varsigma_i^{1,n(1)} \in S, \quad p_i^{1,n(1)} \ge 0, i = 0, 1, \ldots, \#L_1(p), \sum_{i=0}^{\#L_1(p)} p_i^{1,n(1)} \le 1\right\}$, $(n(1) = 2g^{(1)} + 1,\ g^{(1)} \in N^+)$, $L_2(p) = \left\{\varsigma_i^{2,n(2)}\left(p_i^{2,n(2)}\right)\middle| \varsigma_i^{2,n(2)} \in S, \quad p_i^{2,n(2)} \ge 0, \quad i = 0, 1, \ldots, \#L_2(p), \sum_{i=0}^{\#L_2(p)} p_i^{2,n(2)} \le 1\right\}$, $(n(2) = 2g^{(2)} + 1,\ g^{(2)} \in N^+)$, $L_3(p) = \left\{\varsigma_i^{3,n(3)}\left(p_i^{3,n(3)}\right)\middle| \varsigma_i^{3,n(3)} \in S, \ p_i^{3,n(3)} \ge 0, i = 0, 1, \ldots, \#L_3(p), \sum_{i=0}^{\#L_3(p)} p_i^{3,n(3)} \le 1\right\}$, $(n(3) = 2g^{(3)} + 1,\ g^{(3)} \in N^+)$, and $L_1(p)$ is the basic LTS (BLTS). The operational laws are as follows:

$$L_1(p) \oplus L_2(p) = L_4(p) =$$

$$\left\{\varsigma_i^{4,n(1)}\left(\frac{p_i^{1,n(1)} p_i^{2,n(1)} + p_i^{1,n(1)}\phi_2 + p_i^{2,n(1)}\phi_1}{\phi_2\phi_1 + \sum_{i=0}^{n(1)-1}\left(p_i^{1,n(1)} p_i^{2,n(1)} + p_i^{1,n(1)}\phi_2 + p_i^{2,n(1)}\phi_1\right)}\right)\right\} \tag{11}$$

where $p_i^{2,n(1)} = \sum_{j=0}^{n(2)-1}\left(\gamma_i^j p_j^{2,n(2)} + \alpha_i^j p_j^{2,n(2)}\right)$, $\phi_1 = \left(1 - \sum_{i=0}^{n(1)-1} p_i^{1,n(1)}\right)$, $\phi_2 = \left(1 - \sum_{i=0}^{n(1)-1} p_i^{2,n(1)}\right)$, $(i = 0, 1, \ldots, n(1))$.

Some other operational laws:

$$aL_3(p) = \left\{\varsigma_i^{3,n(3)}\left(ap_i^{3,n(3)}\right) | i = 0, \ldots, n(3) - 1\right\}, \quad (0 \le a \le 1) \tag{12}$$

$$L_1(p) \oplus L_2(p) = L_2(p) \oplus L_1(p) \tag{13}$$

$$(L_1(p) \oplus L_2(p)) \oplus L_3(p) = L_2(p) \oplus (L_1(p) \oplus L_3(p)) \tag{14}$$

Proof. According to Equations (5)–(7), we can easily derive Equation (11). According to Equations (5) and Equation (8), we can derive Equation (13). The expressions of Equation (13) and Equation (14) are consistent with Equation (9) and Equation (10).

3.3. The comparison between MGPLTSs

According to Equation (5) and Equation (6), the comparison rules MGPLTSs can be given.

Definition 10 [48]. Assumed that $L_1(p)$, $L_2(p)$ are two PLTSs with different granularity levels, $L_1(p) = \left\{ \varsigma_i^{1,n(1)} \left(p_i^{1,n(1)} \right) \middle| \ \varsigma_i^{1,n(1)} \in S,\ p_i^{1,n(1)} \geq 0, i = 0, 1, ..., \#L_1(p), \sum_{i=0}^{\#L_1(p)} p_i^{1,n(1)} \leq 1 \right\}, \left(n(1) = 2g^{(1)} + 1,\ g^{(1)} \in N^+\right), L_2(p) = \left\{ \varsigma_j^{2,n(2)} \left(p_j^{2,n(2)} \right) \middle| \ \varsigma_j^{2,n(2)} \in S,\quad p_j^{2,n(2)} \geq 0,\quad j = 0, 1, ..., \#L_2(p), \sum_{j=0}^{\#L_2(p)} p_j^{2,n(2)} \leq 1 \right\}$, $\left(n(2) = 2g^{(2)} + 1,\ g^{(2)} \in N^+\right)$, and $L_1(p)$ is the BLTS. Then the score function $D(L_1(p))$ and uncertain function $F(L_1(p))$ of $L_1(p)$ can be expressed as:

$$D(L_1(p)) = \frac{2}{n(1) - 1} \sum_{i=0}^{n(1)-1} \left(i \times p_i^{1,n(1)} \right) \tag{15}$$

$$F(L_1(p)) = 1 - \sum_{i=0}^{n(1)-1} p_i^{1,n(1)} \tag{16}$$

where $D(L_1(p)) \in [0, 2]$ and $F(L_1(p)) \in [0, 1]$. The score function $D(L_2(p))$, and uncertain function $F(L_2(p))$ of $L_2(p)$ can be expressed as:

$$D(L_2(p)) = \frac{2}{n(1) - 1} \sum_{i=0}^{n(1)-1} \left(i \times \left(\sum_{j=0}^{n(2)-1} \left(\gamma_i^j p_j^{2,n(2)} + \alpha_i^j p_j^{2,n(2)} \right) \right) \right) \tag{17}$$

$$F(L_2(p)) = 1 - \sum_{i=0}^{n(1)-1} \left(\sum_{j=0}^{n(2)-1} \left(\gamma_i^j p_j^{2,n(2)} + \alpha_i^j p_j^{2,n(2)} \right) \right) \tag{18}$$

where $D(L_1(p)) \in [0, 2]$ and $F(L_1(p)) \in [0, 1]$.

According to **Definition 10**, Equation (15) and Equation (16) are used to compare two PLTSs with the same granularity level. Based on score function $D(L_2(p))$ and uncertain function $F(L_2(p))$, the comparison rules of MGPLTSs are as follows:

Definition 11. Assumed that $L_1(p)$ and $L_2(p)$ are two PLTSs with the different granularity levels, then:

(1) If $D(L_1(p)) < D(L_2(p))$, then $L_1(p) \prec L_2(p)$;
(2) If $D(L_1(p)) > D(L_2(p))$, then $L_1(p) \succ L_2(p)$;
(3) If $D(L_1(p)) = D(L_2(p))$, then
 (a) If $F(L_1(p)) < F(L_2(p))$, then $L_1(p) \succ L_2(p)$,
 (b) If $F(L_1(p)) = F(L_2(p))$, then $L_1(p) \sim L_2(p)$,
 (c) If $F(L_1(p)) > F(L_2(p))$, then $L_1(p) \prec L_2(p)$.

Definition 11 is also applicable to compare two PLTs with the same granularity level.

4. The decision making method based on multi-granularity probabilistic linguistic Choquet integral operator

4.1. The multi-granularity probabilistic linguistic Choquet integral operator

Based on Equations (2)–(7), we propose a new operator for MGPLTSs.

Definition 12. Assumed that $L_1(p), L_2(p), ..., L_m(p)$ are m arbitrary PLTSs with the different granularity levels, and $\left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_a$ is the weight of the $L_a(p), (a = 1, 2, .., m)$. Suppose $L_1(p)$ is the BLTS. The multi-granularity probabilistic linguistic Choquet integral (MGPLCA) operator is defined as

$$\begin{aligned}
&MGPLCA\left(L_1(p), L_2(p), ..., L_m(p)\right) \\
&= \left\{ \left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_1 \left\{ \varsigma_j^{1,n(1)} \left(p_j^{1,n(1)}\right) \right\} \right. \\
&\quad \oplus \left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_2 \left\{ \varsigma_l^{2,n(2)} \left(p_l^{2,n(2)}\right) \right\} \\
&\quad \left. \oplus ... \oplus \left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_m \left\{ \varsigma_s^{m,n(m)} \left(p_s^{m,n(m)}\right) \right\} \right\} \\
&= \left\{ \left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_1 \left\{ \varsigma_j^{1,n(1)} \left(p_j^{1,n(1)}\right) \right\} \right. \\
&\quad \oplus \left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_2 \left\{ \varsigma_j^{2,n(1)} \left(p_j^{2,n(1)}\right) \right\} \\
&\quad \left. \oplus ... \oplus \left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_m \left\{ \varsigma_s^{m,n(1)} \left(p_s^{m,n(1)}\right) \right\} \right\} \\
&= \left\{ \varsigma_j^{m+1,n(1)} \left(\left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_1 p_j^{1,n(1)} \right. \right. \\
&\quad \oplus \left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_2 p_j^{2,n1} \\
&\quad \left. \oplus ... \oplus \left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_m p_j^{m,n(1)} \right) \\
&\quad \left. \middle| j = 0, ..., n(1) - 1 \right\}
\end{aligned} \tag{19}$$

Theorem 3. Assumed that $L_1(p), L_2(p), ..., L_m(p)$ are m arbitrary PLTSs with the different granularity levels. Suppose $L_1(p)$ is the BLTS, the aggregation outputs by MGPLCA operator is also a PLTS, where

$$MGPLCA\left(L_1(p), L_2(p), ..., L_m(p)\right) = \left\{ \varsigma_j^{m+1,n(1)} \left(p_j^{m+1,,n(1)} \right) \right\}. \tag{20}$$

Proof. We can use mathematical induction to prove this theorem.

(1) When $m = 2$, we derive

$$MGPLCA\left(L_1(p), L_2(p)\right) = \left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_1 L_1(p) \oplus \left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_2 L_2(p).$$

According to **Theorem 1** and **Definition 12**, we can derive

$$\left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_1 L_1(p) = \left\{ \varsigma_j^{1,n(1)} \left(\left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_1 p_j^{1,n(1)} \right) \middle| \; j = 0, ..., n(1) - 1 \right\}$$

$$\left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_2 L_2(p) = \left\{ \varsigma_l^{2,n(2)} \left(\left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_2 p_l^{2,n(1)} \right) \middle| \; l = 0, ..., n(2) - 1 \right\}$$
$$= \left\{ \varsigma_j^{2,n(1)} \left(\left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_2 p_j^{2,n(2)} \right) \middle| \; j = 0, ..., n(1) - 1 \right\}.$$

Then,

$$\left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_1 L_1(p) \oplus \left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_2 L_2(p)$$
$$= \left\{ \varsigma_j^{1,n(1)} \left(\left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_1 p_j^{1,n(1)} \oplus \left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_2 p_j^{2,n(1)} \right) \middle| \; j = 0, ..., n(1) - 1 \right\}$$
$$= \left\{ \varsigma_j^{3,n(1)} p_j^{3,n(1)} \middle| \; j = 0, ..., n(1) - 1 \right\}.$$

i.e., when $m = 2$, Equation (20) holds.

(2) Assume that when $m = q$, Equation (20) holds. That is

$$\left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_1 L_1(p) \oplus ... \oplus \left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_q L_q(p)$$
$$= \left\{ \varsigma_j^{1,n(1)} \left(\left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_1 p_j^{1,n(1)} \oplus ... \oplus \left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_q p_j^{q,n(1)} \right) \middle| \; j = 0, ..., n(1) - 1 \right\}$$
$$= \left\{ \varsigma_j^{q+1,n(1)} p_j^{q+1,n(1)} \middle| \; j = 0, ..., n(1) - 1 \right\}.$$

Then, when $m = q + 1$, from Equation (9), we have

$$\left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_1 L_1(p) \oplus ... \oplus \left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_q L_q(p) \oplus \left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_{q+1} L_{q+1}(p)$$
$$= \left\{ \varsigma_j^{q+2,n(1)} \left(\begin{array}{l} \left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_1 p_j^{1,n(1)} \oplus ... \oplus \left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_q p_j^{q,n(1)} \oplus \\ \left[\mu\left(A_{(i)}\right) - u\left(A_{(i+1)}\right)\right]_{q+1} p_j^{q+1,n(1)} \end{array} \right) \middle| \; j = 0, ..., n(1) - 1 \right\}$$
$$= \left\{ \varsigma_j^{q+2,n(1)} p_j^{q+2,n(1)} \middle| \; j = 0, ..., n(1) - 1 \right\}.$$

i.e., when $m = q + 1$, Equation (20) holds.

According to (1) and (2), Equation (20) holds.

For Equation (19) and Equation (20), we can see that the calculation method of PLTSs with the same granularity level or MGPLTSs are the same. Therefore, in the following, we use PLTSs with the same granularity level to prove the properties of MGPLCA operator.

(1) **Commutativity**: Assumed that $L_1(p) = \left\{ \varsigma_0^1 \left(p_0^1 \right), ..., \varsigma_{2g}^1 \left(p_{2g}^1 \right) \right\}$, $L_2(p) =$

$\left\{\varsigma_0^2\left(p_0^2\right), ..., \varsigma_{2g}^2\left(p_{2g}^2\right)\right\}$ are two different PLTSs with the same granularity level, then $MGPLCA\left(L_1(p), L_2(p)\right) = MGPLCA\left(L_2(p), L_1(p)\right)$.

Based on the Equation (9) and Equation (10), we can easily get this result, it can be omitted here.

(2) **Boundedness:** Assumed that $L_1(p) = \left\{\varsigma_0^1\left(p_0^1\right), ..., \varsigma_{2g}^1\left(p_{2g}^1\right)\right\}$, $L_2(p) = \left\{\varsigma_0^2\left(p_0^2\right), ..., \varsigma_{2g}^2\left(p_{2g}^2\right)\right\}$ are two different PLTSs with the same granularity level. $MGPLCA\left(L_1(p), L_2(p)\right) = \left\{\varsigma_0^3\left(p_0^3\right), ..., \varsigma_{2g}^3\left(p_{2g}^3\right)\right\} = L_3(p)$. Then $0 < \sum_{i=0}^{2g} p_i^3 < 1, (i = 0, 1, ..., 2g)$.

Proof. When $g = 1$, suppose there are two PLTSs, $L_1(p) = \left\{\varsigma_0^1\left(p_0^1\right), \varsigma_1^1\left(p_1^1\right), \varsigma_2^1\left(p_2^1\right)\right\} = \left\{\varsigma_0^1(a), \varsigma_1^1(b), \varsigma_2^1(e)\right\}$, $(0 \le a + b + e \le 1)$ and $L_2(p) = \left\{\varsigma_0^2\left(p_0^2\right), \varsigma_1^2\left(p_1^2\right), \varsigma_2^2\left(p_2^2\right)\right\} = \left\{\varsigma_0^2(c), \varsigma_1^2(d), \varsigma_2^2(f)\right\}, (0 \le c + d + f \le 1)$. And the fuzzy measure of $L_1(p)$ is $0 < \mu\left(L_1(p)\right) < 1$, the fuzzy measure of $L_2(p)$ is $0 < \mu\left(L_2(p)\right) < 1$.

Calculate the weights of $L_1(p)$ and $L_2(p)$ by Equation (3) and Equation (4). For simplicity, suppose the weight of $L_1(p)$ is ω_1, the weight of $L_2(p)$ is ω_2. Then based on Equation (11), we can obtain

(3) **Monotonicity:** Assumed that $L_1(p) = \left\{\varsigma_0^1\left(p_0^1\right), ..., \varsigma_{2g}^1\left(p_{2g}^1\right)\right\}$, $L_2(p) = \left\{\varsigma_0^2\left(p_0^2\right), ..., \varsigma_{2g}^2\left(p_{2g}^2\right)\right\}$ are two different PLTSs with the same granularity level. The weights of $L_1(p)$ and $L_2(p)$ are ω_1 and ω_2. Then, adjust the probability of $L_1(p)$, get $L_3(p) = \left\{\varsigma_0^3\left(p_0^3\right), \varsigma_1^3\left(p_1^1\right), ..., \varsigma_{2g}^3\left(p_{2g}^1\right)\right\}$, $\left(p_0^3 > p_0^1\right)$ and to make $\omega_1 = \omega_3$. We have $MGPLCA\left(L_1(p), L_2(p)\right) = \left\{\varsigma_0^4\left(p_0^4\right), \varsigma_0^4\left(p_1^4\right), ..., \varsigma_{2g}^4\left(p_{2g}^4\right)\right\} = L_4(p)$, $MGPLCA\left(L_3(p), L_2(p)\right) = \left\{\varsigma_0^5\left(p_0^5\right), \varsigma_0^5\left(p_1^5\right), ..., \varsigma_{2g}^5\left(p_{2g}^5\right)\right\} = L_5(p)$. Then $p_0^4 < p_0^5, p_i^4 > p_i^5, (i = 1, 2, ..., 2g)$.

Proof. When $g = 1$, suppose there are two different PLTSs, $L_1(p) = \left\{\varsigma_0^1\left(p_0^1\right), \varsigma_1^1\left(p_1^1\right), \varsigma_2^1\left(p_2^1\right)\right\} = \left\{\varsigma_0^1(a), \varsigma_1^1(b), \varsigma_2^1(e)\right\}$, $(0 \le a + b + e \le 1)$ and $L_2(p) = \left\{\varsigma_0^2\left(p_0^2\right), \varsigma_1^2\left(p_1^2\right), \varsigma_2^2\left(p_2^2\right)\right\} = \left\{\varsigma_0^2(c), \varsigma_1^2(d), \varsigma_2^2(f)\right\}, (0 \le c + d + f \le 1)$.

For simplicity, suppose the weight of $L_1(p)$ is ω_1, the weight of $L_2(p)$ is ω_2. Then, adjust the probability of $L_1(p)$, get $L_3(p) = \left\{\varsigma_0^3\left(p_1^3\right), \varsigma_1^3\left(p_1^3\right), \varsigma_2^3\left(p_2^3\right)\right\} = \left\{\varsigma_0^3(A), \varsigma_1^3(b), \varsigma_2^3(e)\right\}$, $(A = a + B \ge a, B > 0, 0 \le A + b + e \le 1)$, and to make $\omega_1 = \omega_3$.

Based on Equation (11), we have

$$L_1(p) \oplus L_2(p) = \left\{\varsigma_i\left(\omega_1 p_i^1 \oplus \omega_2 p_i^2\right) | i = 0, 1, 2\right\}$$

$$= \left\{\varsigma_0^3\left(\frac{ac + a(1-\omega_2) + c(1-\omega_1)}{(1-\omega_2)(1-\omega_1) + ac + a(1-\omega_2) + c(1-\omega_1) + bd + b(1-\omega_2) + d(1-\omega_1) + ef + e(1-\omega_2) + f(1-\omega_1)}\right),\right.$$

$$\varsigma_1^3\left(\frac{bd + b(1-\omega_2) + d(1-\omega_1)}{(1-\omega_2)(1-\omega_1) + ac + a(1-\omega_2) + c(1-\omega_1) + bd + b(1-\omega_2) + d(1-\omega_1) + ef + e(1-\omega_2) + f(1-\omega_1)}\right),$$

$$\left.\varsigma_2^3\left(\frac{ef + e(1-\omega_2) + f(1-\omega_1)}{(1-\omega_2)(1-\omega_1) + ac + a(1-\omega_2) + c(1-\omega_1) + bd + b(1-\omega_2) + d(1-\omega_1) + ef + e(1-\omega_2) + f(1-\omega_1)}\right)\right\}$$

$$= \left\{\varsigma_0^3\left(p_0^3\right), \varsigma_1^3\left(p_1^3\right), \varsigma_2^3\left(p_2^3\right)\right\} = L_3(p).$$

Then

$$p_0^3 + p_1^3 + p_2^3 = \frac{ac + a(1-\omega_2) + c(1-\omega_1) + bd + b(1-\omega_2) + d(1-\omega_1) + ef + e(1-\omega_2) + f(1-\omega_1)}{ac + a(1-\omega_2) + c(1-\omega_1) + bd + b(1-\omega_2) + d(1-\omega_1) + ef + e(1-\omega_2) + f(1-\omega_1) + (1-\omega_2)(1-\omega_1)}$$

Therefore, $0 < p_0^3 + p_1^3 + p_2^3 < 1$. Further, when $g = 2, 3, ..., 0 < \sum_{i=0}^{2g} p_i^3 < 1, (i = 0, 1, ..., 2g)$ holds.

$$L_1(p) \oplus L_2(p) = \left\{ \varsigma_i \left(\omega_1 p_i^1 \oplus \omega_2 p_i^2 \right) | i = 0, 1, 2 \right\}$$
$$= \left\{ \varsigma_0^4 \left(\frac{ac + a(1-\omega_2) + c(1-\omega_1)}{(1-\omega_2)(1-\omega_1) + ac + a(1-\omega_2) + c(1-\omega_1) + bd + b(1-\omega_2) + d(1-\omega_1) + ef + e(1-\omega_2) + f(1-\omega_1)} \right), \right.$$
$$\varsigma_1^4 \left(\frac{bd + b(1-\omega_2) + d(1-\omega_1)}{(1-\omega_2)(1-\omega_1) + ac + a(1-\omega_2) + c(1-\omega_1) + bd + b(1-\omega_2) + d(1-\omega_1) + ef + e(1-\omega_2) + f(1-\omega_1)} \right),$$
$$\left. \varsigma_2^4 \left(\frac{ef + e(1-\omega_2) + f(1-\omega_1)}{(1-\omega_2)(1-\omega_1) + ac + a(1-\omega_2) + c(1-\omega_1) + bd + b(1-\omega_2) + d(1-\omega_1) + ef + e(1-\omega_2) + f(1-\omega_1)} \right) \right\}$$
$$= \left\{ \varsigma_0^4 \left(p_0^4 \right), \varsigma_1^4 \left(p_1^4 \right), \varsigma_2^4 \left(p_2^4 \right) \right\} = L_4(p)$$

$$L_3(p) \oplus L_2(p) = \left\{ \varsigma_i \left(\omega_3 p_i^3 \oplus \omega_2 p_i^2 \right) | i = 0, 1, 2 \right\}$$
$$= \left\{ \varsigma_0^5 \left(\frac{Ac + A(1-\omega_2) + c(1-\omega_1)}{(1-\omega_2)(1-\omega_1) + Ac + A(1-\omega_2) + c(1-\omega_1) + bd + b(1-\omega_2) + d(1-\omega_1) + ef + e(1-\omega_2) + f(1-\omega_1)} \right), \right.$$
$$\varsigma_1^5 \left(\frac{bd + b(1-\omega_2) + d(1-\omega_1)}{(1-\omega_2)(1-\omega_1) + Ac + A(1-\omega_2) + c(1-\omega_1) + bd + b(1-\omega_2) + d(1-\omega_1) + ef + e(1-\omega_2) + f(1-\omega_1)} \right),$$
$$\left. \varsigma_2^5 \left(\frac{ef + e(1-\omega_2) + f(1-\omega_1)}{(1-\omega_2)(1-\omega_1) + Ac + A(1-\omega_2) + c(1-\omega_1) + bd + b(1-\omega_2) + d(1-\omega_1) + ef + e(1-\omega_2) + f(1-\omega_1)} \right) \right\}$$
$$= \left\{ \varsigma_0^5 \left(p_0^5 \right), \varsigma_1^5 \left(p_1^5 \right), \varsigma_2^5 \left(p_2^5 \right) \right\} = L_5(p).$$

Because of $A = a + B > a$, we can easily obtain

$$\frac{bd + b(1-\omega_2) + d(1-\omega_1)}{(1-\omega_2)(1-\omega_1) + ac + a(1-\omega_2) + c(1-\omega_1) + bd + b(1-\omega_2) + d(1-\omega_1) + ef + e(1-\omega_2) + f(1-\omega_1)} >$$
$$\frac{bd + b(1-\omega_2) + d(1-\omega_1)}{(1-\omega_2)(1-\omega_1) + Ac + A(1-\omega_2) + c(1-\omega_1) + bd + b(1-\omega_2) + d(1-\omega_1) + ef + e(1-\omega_2) + f(1-\omega_1)};$$

$$\frac{ef + e(1-\omega_2) + f(1-\omega_1)}{(1-\omega_2)(1-\omega_1) + ac + a(1-\omega_2) + c(1-\omega_1) + bd + b(1-\omega_2) + d(1-\omega_1) + ef + e(1-\omega_2) + f(1-\omega_1)} >$$
$$\frac{ef + e(1-\omega_2) + f(1-\omega_1)}{(1-\omega_2)(1-\omega_1) + Ac + A(1-\omega_2) + c(1-\omega_1) + bd + b(1-\omega_2) + d(1-\omega_1) + ef + e(1-\omega_2) + f(1-\omega_1)};$$

and

$$\frac{Ac + A(1-\omega_2) + c(1-\omega_1)}{(1-\omega_2)(1-\omega_1) + Ac + A(1-\omega_2) + c(1-\omega_1) + bd + b(1-\omega_2) + d(1-\omega_1) + ef + e(1-\omega_2) + f(1-\omega_1)} >$$
$$\frac{ac + a(1-\omega_2) + c(1-\omega_1)}{(1-\omega_2)(1-\omega_1) + ac + a(1-\omega_2) + c(1-\omega_1) + bd + b(1-\omega_2) + d(1-\omega_1) + ef + e(1-\omega_2) + f(1-\omega_1)}.$$

Obviously, $p_0^4 < p_0^5, p_1^4 > p_1^5, p_2^4 > p_2^5$. And so on,
When $g = 2, 3, ...$, it holds.

Example 2. It is assumed that there are four PLTSs:

$$L_1(p) = \left\{ \varsigma_0^1(0), \varsigma_1^1(0), \varsigma_2^1(0.0833), \varsigma_3^1(0.8167), \varsigma_4^1(0.1) \right\}, L_2(p) = \left\{ \varsigma_0^2(0), \varsigma_1^2(0), \varsigma_2^2(0.05), \varsigma_3^2(0.8), \varsigma_4^2(0.15) \right\},$$
$$L_3(p) = \left\{ \varsigma_0^3(0), \varsigma_1^3(0), \varsigma_2^3(0.1), \varsigma_3^3(0.7944), \varsigma_4^3(0.1056) \right\}, L_4(p) = \left\{ \varsigma_0^4(0), \varsigma_1^4(0), \varsigma_2^4(0.05), \varsigma_3^4(0.8944), \varsigma_4^4(0.0556) \right\}$$

and $\mu(\phi) = 0, \mu(L_1(p)) = 3/9, \mu(L_2(p)) = 4/9, \mu(L_3(p)) = 2/9, \mu(L_4(p)) = 3/9$.

According to Equation (2), Equation (3), we derive $\lambda = -0.3333$, then

$$\mu(L_1(p), L_2(p)) = 0.692, \mu(L_1(p), L_3(p)) = 0.513,$$
$$\mu(L_1(p), L_4(p)) = 0.602,$$
$$\mu(L_2(p), L_3(p)) = 0.61, \mu(L_2(p), L_4(p)) = 0.692,$$
$$\mu(L_3(p), L_4(p)) = 0.513,$$
$$\mu(L_1(p), L_2(p), L_3(p)) = 0.825, \mu(L_1(p), L_2(p), L_4(p)) = 0.892,$$
$$\mu(L_1(p), L_3(p), L_4(p)) = 0.747, \mu(L_2(p), L_3(p), L_4(p)) = 0.825,$$
$$\mu(L_1(p), L_2(p), L_3(p), L_4(p)) = 1.$$

The according to Equation (19), we can get the result:

$$MGPLCA(L_1(p), L_2(p), L_3(p), L_4(p)) = \{\varsigma_2(0.0309), \varsigma_3(0.5826), \varsigma_4(0.0612)\}.$$

4.2. The procedure of proposed method

Based on the above calculations and discussion, we summarize the decision-making process for a MAGDM method by using MGPLCA operator. For a MAGDM problem with MGPLTSs, let $X = \{x_1, x_2, ..., x_m\}$ be a set of alternatives, $C = \{c_1, c_2, ..., c_n\}$ be the set of attributes, and $E = \{e_1, e_2, ..., e_d\}$ be a set of DMs, where, $x_i\,(i = 1, 2, ..., m)$ represents the ith alternative, $c_j = (j = 1, 2, ..., n)$ represents the jth attribute and let $u = (u(c_1), u(c_2), ..., u(c_n))$ be the fuzzy measure vector of attributes $c_j = (j = 1, 2, ..., n)$, and $u(c_1, c_2, ..., c_n) = 1$, moreover, $e_v\,(v = 1, 2, ..., d)$ represents the vth DM, and let $y = (y_1, y_2, ..., y_d)^T$ be the weight vector of the DMs with $e_v\,(v = 1, 2, ..., d)$, $y_v \in [0, 1], v = 1, 2, ..., d$ and $\sum_{v=1}^{d} y_v = 1$. Let $S^{MG} = \left\{S^t | t = 1, 2..., T\right\}$ be a MGLTS, DM will choose a LTS S^t to give the decision matrix $D_v = \left[L_t^{v,ij}(p)\right]_{m\times n}(v = 1, 2, ..., d)$, where $L_t^{v,ij}(p)$ is a PLTS, which represents the evaluation information of the alternative $x_i\,(i = 1, 2, ..., m)$ about the attribute $c_j\,(j = 1, 2, ..., n)$ given by the DM $e_v\,(v = 1, 2, ..., d)$, Fig. 1 shows the flow chart of the proposed MAGDM methodology, and the specific steps of our proposed method are as follows:

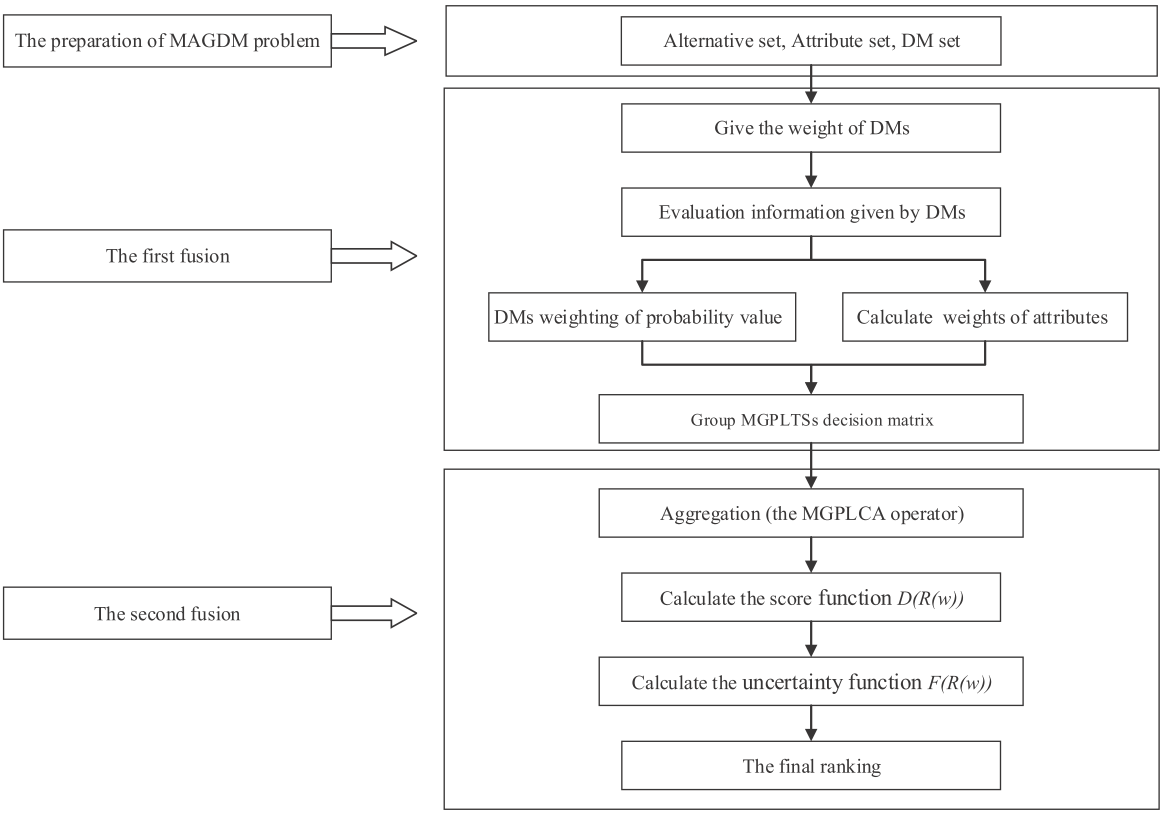

Fig. 1. Procedures involved in the created MAGDM method.

Step 1. According to their own evaluation habits of DMs, DM $e_v\,(v = 1, 2, ..., d)$ can choose a LTS S^t to give the decision matrix of MGPTLSs, respectively. Then, d decision matrices are obtained. Then multiply each probability value by the weight of the corresponding DM, and integrate d decision matrices into one matrix.

Step 2. Calculate λ by Equation (3) and calculate fuzzy measure by Equation (2). Then, calculate weights w_j of attributes by Equation (4).

Step 3. Choose a LTS as the BLTS. According to the weights between different attributes, calculate the aggregation result $R_i = MGPLCA\,(L_1(p), L_2(p), ..., L_n(p))$, $i = 1, 2, ..., m$ of each alternative by MGPLCA operator.

Step 4. The score function $D\,(R_i\,(w))$ can be calculated by Equation (15) and the uncertainty function $F\,(R_i\,(w))$ can be calculated by Equation (16) based on the aggregation results $R_i\,(i = 1, 2, ..., m)$.

Step 5. According to **Definition 11**, first compare score function $D\,(R_i\,(w))$ of each alternative, if there are several alternatives with the same score function $D\,(R_i\,(w))$, then compare the uncertainty function $F\,(R_i\,(w))$ of these alternatives. Finally, we can obtain the ranking of alternatives and the optimal alternative.

5. Application examples

In this section, an example about the online teaching quality evaluation is used to illustrate the application of the created MAGDM method, and some comparisons of the created MAGDM method with other existing methods are given.

5.1. Application of the created multi-attribute group decision-making method

Example 3. We invited three DMs $E = \{e_1, e_2, e_3\}$, and assume that the weights of DMs are $y = (y_1, y_2, y_3)^T = (0.5, 0.3, 0.2)^T$. There are four online teaching courses $X = \{x_1, x_2, x_3, x_4\}$ to be evaluated based on four attributes which are as follows: (1) teaching philosophy and curriculum design (c_1), (2) teaching content and learning resources (c_2), (3) faculty and teaching activities (c_3), user interface design and technical support (c_4). Assume that the fuzzy measure of each attribute is $\mu(\phi) = 0$, $\mu(c_1) = 0.2$, $\mu(c_2) = 0.3$, $\mu(c_3) = 0.4$, $\mu(c_4) = 0.2$. Three PLTSs are with three, five and nine granularity level.

$$S^{1,n(1)} = \left\{\varsigma_0^{1,n(1)} = bad,\ \varsigma_1^{1,n(1)} = medium,\ \varsigma_2^{1,n(1)} = good\right\}$$

$$S^{2,n(2)} = \left\{\varsigma_0^{2,n(2)} = very\ bad,\ \varsigma_1^{2,n(2)} = bad,\ \varsigma_2^{2,n(2)} = medium,\ \varsigma_3^{2,n(2)} = good,\ \varsigma_4^{2,n(2)} = very\ good\right\}$$

$$S^{3,n(3)} = \left\{\begin{array}{l}\varsigma_0^{3,n(3)} = extremely\ bad,\ \varsigma_1^{3,n(3)} = very\ bad,\ \varsigma_2^{3,n(3)} = a\ little\ bad,\ \varsigma_3^{3,n(3)} = bad,\ \varsigma_4^{3,n(3)} \\ = medium,\ \varsigma_5^{3,n(3)} = good,\ \varsigma_6^{3,n(3)} = a\ little\ good,\ \varsigma_7^{3,n(3)} = very\ bad,\ \varsigma_8^{3,n(3)} = emely\ good\end{array}\right\}.$$

Step 1. The evaluation information given by three DMs with MGPLTSs are shown in Tables 1–3.

Multiply the probability in the transformed evaluation information by the weight of corresponding DM, and we can integrate 3 decision matrices into one matrix shown in Table 4.

Step 2. According to Equation (3), we get $\lambda = -0.2368$.

Based on Equation (2), the fuzzy measures of the attributes are obtained as follows:

$$\mu\,(c_1, c_2) = 0.4858,\ \mu\,(c_1, c_3) = 0.5811,\ \mu\,(c_1, c_4) = 0.3905,\ \mu\,(c_2, c_3) = 0.6716,\ \mu\,(c_2, c_4) = 0.4858,$$
$$\mu\,(c_3, c_4) = 0.5811,\ \mu\,(c_1, c_2, c_3) = 0.8398,$$
$$\mu\,(c_1, c_2, c_4) = 0.6628,\ \mu\,(c_1, c_3, c_4) = 0.7536,$$
$$\mu\,(c_2, c_3, c_4) = 0.8398,\ \mu\,(c_1, c_2, c_3, c_4) = 1.$$

Step 3. Suppose $S^{2,n(2)}$ is the BLTS. According to the MGPLCA operator, we can get the result $R_i\,(w)\,, (i = 1, 2, 3, 4)$ as follows:

$$R_1\,(w) = \left\{\varsigma_2^{4,n(2)}\,(0.0242)\,,\ \varsigma_3^{4,n(2)}\,(0.3500)\,,\ \varsigma_4^{4,n(2)}\,(0.2604)\right\},$$

$$R_2\,(w) = \left\{\varsigma_2^{5,n(2)}\,(0.3665)\,,\ \varsigma_3^{5,n(2)}\,(0.2363)\,,\ \varsigma_4^{5,n(2)}\,(0.0703)\right\},$$

$$R_3\,(w) = \left\{\varsigma_2^{6,n(2)}\,(0.1972)\,,\ \varsigma_3^{6,n(2)}\,(0.3623)\,,\ \varsigma_4^{6,n(2)}\,(0.0718)\right\},$$

$$R_4\,(w) = \left\{\varsigma_0^{7,n(2)}\,(0.0237)\,,\ \varsigma_1^{7,n(2)}\,(0.3493)\,,\ \varsigma_2^{7,n(2)}\,(0.2374)\,,\ \varsigma_3^{7,n(2)}\,(0.0084)\,,\ \varsigma_4^{7,n(2)}\,(0.0085)\right\}.$$

Table 1
The decision matrix D_1 provided by the DM e_1

	c_1	c_2	c_3	c_4
x_1	$S^{3,n(3)} = \left\{ \varsigma_7^{3,n(3)}(1) \right\}$	$\left\{ \varsigma_7^{3,n(3)}(1) \right\}$	$\left\{ \varsigma_6^{3,n(3)}(0.4), \varsigma_7^{3,n(3)}(0.6) \right\}$	$\left\{ \varsigma_6^{3,n(3)}(0.3), \varsigma_7^{3,n(3)}(0.7) \right\}$
x_2	$\left\{ \varsigma_5^{3,n(3)}(0.7), \varsigma_6^{3,n(3)}(0.3) \right\}$	$\left\{ \varsigma_4^{3,n(3)}(0.2), \varsigma_5^{3,n(3)}(0.8) \right\}$	$\left\{ \varsigma_4^{3,n(3)}(1) \right\}$	$\left\{ \varsigma_4^{3,n(3)}(1) \right\}$
x_3	$\left\{ \varsigma_5^{3,n(3)}(0.3), \varsigma_6^{3,n(3)}(0.7) \right\}$	$\left\{ \varsigma_5^{3,n(3)}(0.3), \varsigma_6^{3,n(3)}(0.7) \right\}$	$\left\{ \varsigma_6^{3,n(3)}(0.8), \varsigma_7^{3,n(3)}(0.2) \right\}$	$\left\{ \varsigma_4^{3,n(3)}(1) \right\}$
x_4	$\left\{ \varsigma_2^{3,n(3)}(0.2), \varsigma_3^{3,n(3)}(0.8) \right\}$	$\left\{ \varsigma_3^{3,n(3)}(0.8), \varsigma_4^{3,n(3)}(0.2) \right\}$	$\left\{ \varsigma_2^{3,n(3)}(1) \right\}$	$\left\{ \varsigma_2^{3,n(3)}(0.5), \varsigma_3^{3,n(3)}(0.5) \right\}$

Table 2
The decision matrix D_2 provided by the DM e_2

	c_1	c_2	c_3	c_4
x_1	$\left\{ \varsigma_3^{2,n(2)}(1) \right\}$	$\left\{ \varsigma_3^{2,n(2)}(0.4), \varsigma_4^{2,n(2)}(0.6) \right\}$	$\left\{ \varsigma_3^{2,n(2)}(0.9), \varsigma_4^{2,n(2)}(0.1) \right\}$	$\left\{ \varsigma_3^{2,n(2)}(1) \right\}$
x_2	$\left\{ \varsigma_2^{2,n(2)}(0.5), \varsigma_3^{2,n(2)}(0.5) \right\}$	$\left\{ \varsigma_2^{2,n(2)}(0.4), \varsigma_3^{2,n(2)}(0.6) \right\}$	$\left\{ \varsigma_1^{2,n(2)}(0.3), \varsigma_2^{2,n(2)}(0.7) \right\}$	$\left\{ \varsigma_2^{2,n(2)}(0.3), \varsigma_3^{2,n(2)}(0.7) \right\}$
x_3	$\left\{ \varsigma_2^{2,n(2)}(0.3), \varsigma_3^{2,n(2)}(0.7) \right\}$	$\left\{ \varsigma_3^{2,n(2)}(1) \right\}$	$\left\{ \varsigma_2^{2,n(2)}(0.6), \varsigma_3^{2,n(2)}(0.4) \right\}$	$\left\{ \varsigma_3^{2,n(2)}(0.8), \varsigma_4^{2,n(2)}(0.2) \right\}$
x_4	$\left\{ \varsigma_2^{2,n(2)}(1) \right\}$	$\left\{ \varsigma_1^{2,n(2)}(1) \right\}$	$\left\{ \varsigma_1^{2,n(2)}(0.8), \varsigma_2^{2,n(2)}(0.2) \right\}$	$\left\{ \varsigma_2^{2,n(2)}(0.7), \varsigma_3^{2,n(2)}(0.3) \right\}$

Table 3
The decision matrix D_3 provided by the DM e_3

	c_1	c_2	c_3	c_4
x_1	$\left\{ \varsigma_1^{1,n(1)}(0.2), \varsigma_2^{1,n(1)}(0.8) \right\}$	$\left\{ \varsigma_2^{1,n(1)}(1) \right\}$	$\left\{ \varsigma_1^{1,n(1)}(0.3), \varsigma_2^{1,n(1)}(0.7) \right\}$	$\left\{ \varsigma_1^{1,n(1)}(0.6), \varsigma_2^{1,n(1)}(0.4) \right\}$
x_2	$\left\{ \varsigma_1^{1,n(1)}(0.1), \varsigma_2^{1,n(1)}(0.9) \right\}$	$\left\{ \varsigma_1^{1,n(1)}(0.7), \varsigma_2^{1,n(1)}(0.3) \right\}$	$\left\{ \varsigma_1^{1,n(1)}(1) \right\}$	$\left\{ \varsigma_1^{1,n(1)}(0.9), \varsigma_2^{1,n(1)}(0.1) \right\}$
x_3	$\left\{ \varsigma_1^{1,n(1)}(0.3), \varsigma_2^{1,n(1)}(0.7) \right\}$	$\left\{ \varsigma_1^{1,n(1)}(0.8), \varsigma_2^{1,n(1)}(0.2) \right\}$	$\left\{ \varsigma_1^{1,n(1)}(0.4), \varsigma_2^{1,n(1)}(0.6) \right\}$	$\left\{ \varsigma_1^{1,n(1)}(0.5), \varsigma_2^{1,n(1)}(0.5) \right\}$
x_4	$\left\{ \varsigma_0^{1,n(1)}(0.5), \varsigma_1^{1,n(1)}(0.5) \right\}$	$\left\{ \varsigma_0^{1,n(1)}(0.6), \varsigma_1^{1,n(1)}(0.4) \right\}$	$\left\{ \varsigma_1^{1,n(1)}(0.8), \varsigma_2^{1,n(1)}(0.2) \right\}$	$\left\{ \varsigma_1^{1,n(1)}(1) \right\}$

Step 4. The score function $D\left(R_i\left(w\right)\right) = \frac{2}{n(1)-1} \sum_{s=0}^{n(1)-1} \left(s \times p_s^{1,n(1)}\right)$ for $R_i\left(w\right), (i = 1, 2, 3, 4)$ are shown as follows:

$$D\left(R_1\left(w\right)\right) = \frac{1}{2} \times (2 \times 0.0242 + 3 \times 0.35 + 4 \times 0.2604) = 1.07;$$

$$D\left(R_2(w)\right) = \frac{1}{2} \times (2 \times 0.3665 + 3 \times 0.2363 + 4 \times 0.0703) = 0.8616;$$

$$D\left(R_3(w)\right) = \frac{1}{2} \times (2 \times 0.1972 + 3 \times 0.3623 + 4 \times 0.0718) = 0.8843;$$

$$D\left(R_4(w)\right) = \frac{1}{2} \times (0 \times 0.0237 + 1 \times 0.3493 + 2 \times 0.2374 + 3 \times 0.0084 + 4 \times 0.0085) = 0.4416.$$

Table 4
The decision matrix D_4 after weighting

	c_1	c_2	c_3	c_4
x_1	$\left\{\{\varsigma_7^{3,n(3)}(0.5)\},\ \varsigma_3^{2,n(2)}(0.3),\ \varsigma_1^{1,n(1)}(0.04),\ \varsigma_2^{1,n(1)}(0.16)\right\}$	$\left\{\varsigma_7^{3,n(3)}(0.5),\ \varsigma_3^{2,n(2)}(0.12),\ \varsigma_4^{2,n(2)}(0.18),\ \varsigma_2^{1,n(1)}(0.2)\right\}$	$\left\{\varsigma_6^{3,n(3)}(0.2),\ \varsigma_7^{3,n(3)}(0.3),\ \varsigma_3^{2,n(2)}(0.27),\ \varsigma_4^{2,n(2)}(0.03),\ \varsigma_1^{1,n(1)}(0.06),\ \varsigma_2^{1,n(1)}(0.14)\right\}$	$\left\{\varsigma_6^{3,n(3)}(0.15),\ \varsigma_7^{3,n(3)}(0.35),\ \varsigma_3^{2,n(2)}(0.3),\ \varsigma_1^{1,n(1)}(0.12),\ \varsigma_2^{1,n(1)}(0.08)\right\}$
x_2	$\left\{\varsigma_5^{3,n(3)}(0.35),\ \varsigma_6^{3,n(3)}(0.15),\ \varsigma_2^{2,n(2)}(0.15),\ \varsigma_3^{2,n(2)}(0.15),\ \varsigma_1^{1,n(1)}(0.02),\ \varsigma_2^{1,n(1)}(0.18)\right\}$	$\left\{\varsigma_4^{3,n(3)}(0.1),\ \varsigma_5^{3,n(3)}(0.4),\ \varsigma_2^{2,n(2)}(0.12),\ \varsigma_3^{2,n(2)}(0.18),\ \varsigma_1^{1,n(1)}(0.14),\ \varsigma_2^{1,n(1)}(0.06)\right\}$	$\left\{\varsigma_4^{3,n(3)}(0.5),\ \varsigma_1^{2,n(2)}(0.09),\ \varsigma_2^{2,n(2)}(0.21),\ \varsigma_1^{1,n(1)}(0.2)\right\}$	$\left\{\varsigma_4^{3,n(3)}(0.5),\ \varsigma_2^{2,n(2)}(0.09),\ \varsigma_3^{2,n(2)}(0.21),\ \varsigma_1^{1,n(1)}(0.18),\ \varsigma_2^{1,n(1)}(0.02)\right\}$
x_3	$\left\{\varsigma_5^{3,n(3)}(0.15),\ \varsigma_6^{3,n(3)}(0.35),\ \varsigma_2^{2,n(2)}(0.09),\ \varsigma_3^{2,n(2)}(0.21),\ \varsigma_1^{1,n(1)}(0.06),\ \varsigma_2^{1,n(1)}(0.14)\right\}$	$\left\{\varsigma_5^{3,n(3)}(0.15),\ \varsigma_6^{3,n(3)}(0.35),\ \varsigma_3^{2,n(2)}(0.3),\ \varsigma_1^{1,n(1)}(0.16),\ \varsigma_2^{1,n(1)}(0.04)\right\}$	$\left\{\varsigma_6^{3,n(3)}(0.4),\ \varsigma_7^{3,n(3)}(0.1),\ \varsigma_2^{2,n(2)}(0.18),\ \varsigma_3^{2,n(2)}(0.12),\ \varsigma_1^{1,n(1)}(0.08),\ \varsigma_2^{1,n(1)}(0.12)\right\}$	$\left\{\varsigma_4^{3,n(3)}(0.5),\ \varsigma_3^{2,n(2)}(0.24),\ \varsigma_4^{2,n(2)}(0.06),\ \varsigma_1^{1,n(1)}(0.1),\ \varsigma_2^{1,n(1)}(0.1)\right\}$
x_4	$\left\{\varsigma_2^{3,n(3)}(0.1),\ \varsigma_3^{3,n(3)}(0.4),\ \varsigma_2^{2,n(2)}(0.3),\ \varsigma_0^{1,n(1)}(0.1),\ \varsigma_1^{1,n(1)}(0.1)\right\}$	$\left\{\varsigma_3^{3,n(3)}(0.4),\ \varsigma_4^{3,n(3)}(0.1),\ \varsigma_1^{2,n(2)}(0.3),\ \varsigma_0^{1,n(1)}(0.12),\ \varsigma_1^{1,n(1)}(0.08)\right\}$	$\left\{\varsigma_2^{3,n(3)}(0.5),\ \varsigma_1^{2,n(2)}(0.24),\ \varsigma_2^{2,n(2)}(0.06),\ \varsigma_1^{1,n(1)}(0.16),\ \varsigma_2^{1,n(1)}(0.04)\right\}$	$\left\{\varsigma_2^{3,n(3)}(0.25),\ \varsigma_3^{3,n(3)}(0.25),\ \varsigma_2^{2,n(2)}(0.21),\ \varsigma_3^{2,n(2)}(0.09),\ \varsigma_1^{1,n(1)}(0.2)\right\}$

Table 5
The evaluation information after changed by the DM e_1

	c_1	c_2	c_3	c_4
x_4	$\left\{\varsigma_2^{3,n(3)}(0.3),\ \varsigma_3^{3,n(3)}(0.7)\right\}$	$\left\{\varsigma_2^{3,n(3)}(0.2),\ \varsigma_3^{3,n(3)}(0.8)\right\}$	$\left\{\varsigma_1^{3,n(3)}(0.7),\ \varsigma_2^{3,n(3)}(0.3)\right\}$	$\left\{\varsigma_2^{3,n(3)}(0.5),\ \varsigma_3^{3,n(3)}(0.5)\right\}$

Table 6
The evaluation information after changed by the DM e_2

	c_1	c_2	c_3	c_4
x_4	$\left\{\varsigma_2^{2,n(2)}(1)\right\}$	$\left\{\varsigma_1^{2,n(2)}(1)\right\}$	$\left\{\varsigma_1^{2,n(2)}(0.1),\ \varsigma_2^{2,n(2)}(0.9)\right\}$	$\left\{\varsigma_2^{2,n(2)}(0.9),\ \varsigma_3^{2,n(2)}(0.1)\right\}$

Table 7
The evaluation information after changed by the DM e_3

	c_1	c_2	c_3	c_4
x_4	$\left\{\begin{array}{l}\varsigma_0^{1,n(1)}(0.8),\\ \varsigma_1^{1,n(1)}(0.2)\end{array}\right\}$	$\left\{\begin{array}{l}\varsigma_0^{1,n(1)}(0.6),\\ \varsigma_1^{1,n(1)}(0.4)\end{array}\right\}$	$\left\{\begin{array}{l}\varsigma_1^{1,n(1)}(0.8),\\ \varsigma_2^{1,n(1)}(0.2)\end{array}\right\}$	$\left\{\begin{array}{l}\varsigma_0^{1,n(1)}(0.1),\\ \varsigma_1^{1,n(1)}(0.9)\end{array}\right\}$

Step 5. According to the score function results, we know $D(R_1(w)) > D(R_3(w)) > D(R_2(w)) > D(R_4(w))$.

The ranking of alternatives is $x_1 \succ x_3 \succ x_2 \succ x_4$. Therefore, the optimal alternative is x_1.

5.2. Validity and reliability test of the created MAGDM method

For the same decision-making problem, different MAGDM methods will lead to different results. Wang and Triantaphyllou [49] presented three test criteria to verify the reliability and validity of the MAGDM methods.

Test criteria 1. An effective MAGDM method, without changing the attribute weights, if a non-optimal alternative replaces another non-optimal alternative, the optimal alternative should not be changed.

According to **Test criteria 1**, change the evaluation information of three DMs on alternative x_4 in **Example 3**.

Based on the above steps, we can get

$$R_4(w) = \left\{\varsigma_0^{8,n(2)}(0.0758), \varsigma_1^{8,n(2)}(0.2697), \varsigma_2^{8,n(2)}(0.2691), \varsigma_4^{8,n(2)}(0.0086)\right\},$$

$$D(R_4(w)) = \frac{1}{2} \times (0 \times 0.0745 + 1 \times 0.2693 + 2 \times 0.2651 + 4 \times 0.0083) = 0.4212.$$

Because $D(R_1(w)) > D(R_3(w)) > D(R_2(w)) > D(R_4(w))$, the ranking of alternatives is $x_1 \succ x_3 \succ x_2 \succ x_4$, and the best alternative is x_1. Therefore, the created MAGDM method passed the **Test criteria 1**.

Test criterion 2. An effective MAGDM method should have transitivity.

Test criterion 3. A MAGDM problem is divided into several sub-problems, which are calculated by the same MAGDM method. The comprehensive ranking of the alternatives should be the same as the ranking of the original MAGDM problem.

According to **Test criteria 2** and **Test criteria 3**, we divide the four alternatives in **Example 3** into two parts. The first part is to evaluate $\{x_1, x_2, x_3\}$, and the second part is to evaluate $\{x_2, x_3, x_4\}$, and other information in **Example 3** remains unchanged.

Based on the proposed MAGDM method, we get that the ranking of the first part is $x_1 \succ x_3 \succ x_2$, and the ranking of the second part is $x_3 \succ x_2 \succ x_4$. Combine the two rankings to get the comprehensive ranking $x_1 \succ x_3 \succ x_2 \succ x_4$. This ranking result is the same as the original MAGDM problem. Therefore, the created MAGDM method passed the **Test criteria 2** and **Test criteria 3**.

5.3. Comparison analysis and discussion

In order to further verify the effectiveness of the proposed method, it is compared with the existing four MAGDM methods: Lei et al.'s method [42] based on the TOPSIS; Lu et al.'s method [43] based on the TOPSIS; Mao et al.'s method [44] based on the Generalized probabilistic linguistic Hamacher weighted averaging (GPLHWA) operator; Wang's method [33] based on prospect theory (PT). It is assumed that $\gamma = 1$, $\lambda = 1$ for Mao et al.'s method [44], and it is assumed that $\lambda = 1$, $\theta = -2.25$, $\alpha = 0.88$, and $\beta = 0.88$ for Wang's method [33]. We set the attribute weight vector in **Example 3** to $w = (w_1, w_2, w_3, w_4)^T = (0.18, 0.27, 0.37, 0.18)^T$, other information remains unchanged. The ranking results of the online teaching courses in **Example 3** for the different methods are listed in Table 8.

From Table 8, we can find that only the proposed method and Wang's method [33] can get the same ranking result, i.e., $x_1 \succ x_3 \succ x_2 \succ x_4$, whereas Lei et al.'s method [42], Lu et al.'s method [43] and Mao et al.'s method [44] cannot get the ranking results. Because these three methods cannot handle MGPLTSs. Therefore, in order to make these three methods can get ranking results, we transform MGPLTSs into the same granularity level by Equation (5) and Equation (6) show in Tables 9, 10 and 11. Then, we use these three methods to calculate and rank four alternatives, and the results are listed in Table 11.

In Table 12, all methods derive the same Ranking result, i.e., $x_1 \succ x_3 \succ x_2 \succ x_4$. This can prove that the method in this paper is effective. But Lei et al.'s method [42], Lu et al.'s method [43], Mao et al.'s method [44] and Wang's method [33] have different shortcomings in processing PLTSs. Thus, in what follows, we specifically analyze these methods.

(1) The Shortcomings of Lei et al.'s method [42], Lu et al.'s method [43]: First, these two methods cannot directly handle MGPLTSs. Before calculation, these two methods need to transform MGPLTSs into the same granularity level. Of course, the transformation function we proposed can handle this problem well. Second, these two methods are based on TOPSIS, so they can only give the relative ranking result, and cannot give the comprehensive values of alternatives, further, they can also lead to the change of ranking results when the alternatives are increased or

Table 8
Ranking of alternatives from two methods for Example 3

Approaches	Score values	Ranking
Lei et al.'s method [42] (Based on the PL- TOPSIS method)	Cannot be Obtained	—
Lu et al.'s method [43] (Based on the PL- TOPSIS method)	Cannot be Obtained	—
Mao et al.'s method [44] (Based on the GPLHWA operator)	Cannot be Obtained	—
Wang's method [33] based on the (PLTSs operator)	$C_1 = 0.87$, $C_2 = 0.36$, $C_3 = 0.49$, $C_4 = 0.31$.	$x_1 \succ x_3 \succ x_2 \succ x_4$
The created method (Based on the MGPLCA operator)	$D(R_1(w)) = 1.06$, $D(R_2(w)) = 0.79$, $D(R_3(w)) = 0.88$, $D(R_4(w)) = 0.44$.	$x_1 \succ x_3 \succ x_2 \succ x_4$

Table 9
The decision information provided by the DM e_1 transformed into 5 granularity level

	c_1	c_2	c_3	c_4
x_1	$\left\{\varsigma_3^{3,n(2)}(0.5), \varsigma_4^{3,n(2)}(0.5)\right\}$	$\left\{\varsigma_3^{3,n(2)}(0.5), \varsigma_4^{3,n(2)}(0.5)\right\}$	$\left\{\varsigma_3^{3,n(2)}(0.7), \varsigma_4^{3,n(2)}(0.3)\right\}$	$\left\{\varsigma_3^{3,n(2)}(0.65), \varsigma_4^{3,n(2)}(0.35)\right\}$
x_2	$\left\{\varsigma_2^{3,n(2)}(0.35), \varsigma_3^{3,n(2)}(0.65)\right\}$	$\left\{\varsigma_2^{3,n(2)}(0.6), \varsigma_3^{3,n(2)}(0.4)\right\}$	$\left\{\varsigma_2^{3,n(2)}(1)\right\}$	$\left\{\varsigma_2^{3,n(2)}(1)\right\}$
x_3	$\left\{\varsigma_2^{3,n(2)}(0.15), \varsigma_3^{3,n(2)}(0.85)\right\}$	$\left\{\varsigma_2^{3,n(2)}(0.15), \varsigma_3^{3,n(2)}(0.85)\right\}$	$\left\{\varsigma_3^{3,n(2)}(0.9), \varsigma_4^{3,n(2)}(0.1)\right\}$	$\left\{\varsigma_2^{3,n(2)}(1)\right\}$
x_4	$\left\{\varsigma_1^{3,n(2)}(0.6), \varsigma_2^{3,n(2)}(0.4)\right\}$	$\left\{\varsigma_1^{3,n(2)}(0.4), \varsigma_2^{3,n(2)}(0.6)\right\}$	$\left\{\varsigma_1^{3,n(2)}(1)\right\}$	$\left\{\varsigma_1^{3,n(2)}(0.75), \varsigma_2^{3,n(2)}(0.25)\right\}$

Table 10
The decision information provided by the DM e_2 transformed into 5 granularity level

	c_1	c_2	c_3	c_4
x_1	$\left\{\varsigma_3^{2,n(2)}(1)\right\}$	$\left\{\varsigma_3^{2,n(2)}(0.4), \varsigma_4^{2,n(2)}(0.6)\right\}$	$\left\{\varsigma_3^{2,n(2)}(0.9), \varsigma_4^{2,n(2)}(0.1)\right\}$	$\left\{\varsigma_3^{2,n(2)}(1)\right\}$
x_2	$\left\{\varsigma_2^{2,n(2)}(0.5), \varsigma_3^{2,n(2)}(0.5)\right\}$	$\left\{\varsigma_2^{2,n(2)}(0.4), \varsigma_3^{2,n(2)}(0.6)\right\}$	$\left\{\varsigma_1^{2,n(2)}(0.3), \varsigma_2^{2,n(2)}(0.7)\right\}$	$\left\{\varsigma_2^{2,n(2)}(0.3), \varsigma_3^{2,n(2)}(0.7)\right\}$
x_3	$\left\{\varsigma_2^{2,n(2)}(0.3), \varsigma_3^{2,n(2)}(0.7)\right\}$	$\left\{\varsigma_3^{2,n(2)}(1)\right\}$	$\left\{\varsigma_2^{2,n(2)}(0.6), \varsigma_3^{2,n(2)}(0.4)\right\}$	$\left\{\varsigma_3^{2,n(2)}(0.8), \varsigma_4^{2,n(2)}(0.2)\right\}$
x_4	$\left\{\varsigma_2^{2,n(2)}(1)\right\}$	$\left\{\varsigma_1^{2,n(2)}(1)\right\}$	$\left\{\varsigma_1^{2,n(2)}(0.8), \varsigma_2^{2,n(2)}(0.2)\right\}$	$\left\{\varsigma_2^{2,n(2)}(0.7), \varsigma_3^{2,n(2)}(0.3)\right\}$

decreased. As mentioned in the previous section, the effective MAGDM method should be verified by the three test criteria presented by Wang and Triantaphyllou [49]. Among the three test criteria, **Test criteria 2** is necessary for an effective MAGDM method, i.e., it should have transitivity, and **Test criteria 3** is the consistency between the smaller MAGDM problems and the original MAGDM problem. Obviously, these two methods do not have transitivity, and cannot pass the verification of consistency. Therefore, these two methods are not completely effective. We have verified the created method has passed **Test criterions 1, 2, 3** and is an effective MAGDM method. Third, in the process of processing PLTSs by these two methods, the sum of PLTS may be less than one, which requires the normalization of PLTS.

(2) The Shortcomings of Mao et al.'s method [44]: First, this method is the same as Lei et al.'s method [42], Lu et al.'s method [43], they can only be used in the PLTSs environment, and can't directly deal with MGPLTSs. By combined with our transformation function, we can get the ranking results in the complex MGPLTSs environment. It is worth mentioning that our transformation function is not only applicable to these three methods, but also effective for many operators and methods in PLTSs environment.

Table 11
The decision information provided by the DM e_3 transformed into 5 granularity level

	c_1	c_2	c_3	c_4
x_1	$\left\{ \varsigma_2^{1,n(2)}(0.2), \varsigma_4^{1,n(2)}(0.8) \right\}$	$\left\{ \varsigma_4^{1,n(2)}(1) \right\}$	$\left\{ \varsigma_2^{1,n(2)}(0.3), \varsigma_4^{1,n(2)}(0.7) \right\}$	$\left\{ \varsigma_2^{1,n(2)}(0.6), \varsigma_4^{1,n(2)}(0.4) \right\}$
x_2	$\left\{ \varsigma_2^{1,n(2)}(0.1), \varsigma_4^{1,n(2)}(0.9) \right\}$	$\left\{ \varsigma_2^{1,n(2)}(0.7), \varsigma_4^{1,n(2)}(0.3) \right\}$	$\left\{ \varsigma_2^{1,n(2)}(1) \right\}$	$\left\{ \varsigma_2^{1,n(2)}(0.9), \varsigma_4^{1,n(2)}(0.1) \right\}$
x_3	$\left\{ \varsigma_2^{1,n(2)}(0.3), \varsigma_4^{1,n(2)}(0.7) \right\}$	$\left\{ \varsigma_2^{1,n(2)}(0.8), \varsigma_4^{1,n(2)}(0.2) \right\}$	$\left\{ \varsigma_2^{1,n(2)}(0.4), \varsigma_4^{1,n(2)}(0.6) \right\}$	$\left\{ \varsigma_2^{1,n(2)}(0.5), \varsigma_4^{1,n(2)}(0.5) \right\}$
x_4	$\left\{ \varsigma_0^{1,n(2)}(0.5), \varsigma_2^{1,n(2)}(0.5) \right\}$	$\left\{ \varsigma_0^{1,n(2)}(0.6), \varsigma_2^{1,n(2)}(0.4) \right\}$	$\left\{ \varsigma_2^{1,n(2)}(0.8), \varsigma_4^{1,n(2)}(0.2) \right\}$	$\left\{ \varsigma_2^{1,n(2)}(1) \right\}$

Table 12
Ranking of alternative from two methods for Example 3

Approaches	Score values	Ranking
Lei et al.'s method [42] (Based on the PL- TOPSIS method)	$PLRCD(PLA_1, PLPIS) = 0$, $PLRCD(PLA_2, PLPIS) = 0.62$, $PLRCD(PLA_3, PLPIS) = 0.5$, $PLRCD(PLA_4, PLPIS) = 1$.	$x_1 \succ x_3 \succ x_2 \succ x_4$
Lu et al.'s method [43] (Based on the PL- TOPSIS method)	$PLRCD(PLA_1, PLNIS) = 1$, $PLRCD(PLA_2, PLNIS) = 0.35$, $PLRCD(PLA_3, PLNIS) = 0.50$, $PLRCD(PLA_4, PLNIS) = 0$.	$x_1 \succ x_3 \succ x_2 \succ x_4$
Mao et al.'s method [44] (Based on the GPLHWA operator)	$CD_1 = 0.88, CD_2 = 0.29$, $CD_3 = 0.53, CD_4 = 0$.	$x_1 \succ x_3 \succ x_2 \succ x_4$
Wang's method [33] (based on the PLTSs operator)	$C_1 = 0.87, C_2 = 0.36$, $C_3 = 0.49, C_4 = 0.31$.	$x_1 \succ x_3 \succ x_2 \succ x_4$
The created method (Based on the MGPLCA operator)	$D(R_1(w)) = 1.06, D(R_2(w)) = 0.79$, $D(R_3(w)) = 0.88, D(R_4(w)) = 0.44$.	$x_1 \succ x_3 \succ x_2 \succ x_4$

Second, this method cannot avoid the normalization of PLTS.

(3) The Shortcomings of Wang's method [33]: First, this method can handle MGPLTSs, but it also needs to transform the original MGPLTSs into the same granularity level before starting the calculation. That is, this method cannot directly aggregate MGPLTSs. But the proposed method based on the MGPLCA operator can directly aggregate the original MGPLTSs. Second, the method in [33] needs to be normalized twice, which increases the complexity of the operations. Different from this method [33], the proposed MAGDM method based on the MGPLCA operator omits the normalization of PLTS, which can undoubtedly reduce the complexity of the calculation. Third, the calculation results of this method [33] are not PLTSs, which means that operator leads to loss of probability information. On the contrary, **Theorem 3** shows that the calculation result of MGPLCA operator in the proposed method is still PLTS. So, the proposed MAGDM method avoids the loss of decision information, especially probability information, and the ranking results are more credible.

In summary, the advantages of the proposed method are that it can not only directly deal with MGPLTSs, but also avoids the problem of loss of decision information during the calculation process, and there is no need to normalizing the PLTSs, which reduces complexity.

6. Conclusion

In the Internet era, especially due to the impact of the COVID-19, online teaching has become particularly significant, and online teaching quality evaluation is a key for improving the quality of online teaching. Therefore, we choose MGPLTSs to reflect the preferences and habits of different DMs and the importance of different linguistic terms, and propose a new MAGDM method to evaluate the quality of online teaching. First, propose the transformation function of MGPLTSs based on the proportional 2-tuple fuzzy linguistic representation model. On this basis, the operational laws and comparison rules of MGPLTSs are presented. Then, considering the relationship among attributes, propose MGPLCA operator based on PLTSs and Choquet integral, and prove the properties of the MGPLCA operator. At the same time, develop a MAGDM method which does not need to consider the process of normalizing the PLTSs. Furthermore, provide a case of online teaching quality evaluation to illustrate reliability and validity of the created MAGDM method. Finally, compare the created MAGDM method with some existing methods, and illustrate the advantages of our MAGDM methods. Based on the case study, we can know that the created MAGDM method can be effectively applied to online teaching quality evaluation. However, there are also some limitations of the proposed method. First, we have verified the properties of the proposed MGPLCA operator, including commutativity, boundedness and monotonicity, but the MGPLCA operator has no idempotency. Second, the proposed MGPLCA operator, combined with Choquet integral, can be used to deal with the problem of the relationship between attributes, but it cannot handle the situation where the attribute weight is completely unknown.

In the future, we can extend the proposed method to the situation where the attribute weights are completely unknown, at the same time, we will also study consensus measure by considering the consensus among DMs with different cognitive and knowledge backgrounds.

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Research on the Quality Evaluation for Training of Undergraduate Majoring in Logistics Management and Engineering Based on Improved TOPSIS Method

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Research on the Quality Evaluation for Training of Undergraduate Majoring in Logistics Management and Engineering Based on Improved TOPSIS Method

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Abstract. In view of the Training Quality of Undergraduate Majoring in Logistics Management and Engineering, an improved TOPSIS method based on combinatorial weight is proposed to evaluate the training quality of undergraduate majoring in logistics management and engineering. Firstly, the paper studies and analyses the related literatures of training quality of undergraduate majoring in logistics management and engineering, and puts forward a set of evaluation of training quality indicator system for the undergraduate majoring in logistics management and engineering. Secondly, the objective weight and subjective weight of each indicator are determined by using the variable coefficient method based on mixed data and the improved AHP method based on triangular fuzzy number, and on this basis, the combined weight of each indicator is calculated by using the maximum method of comprehensive evaluation value. After that, the improved TOPSIS method is used to rank the training quality for undergraduate majoring in logistics management and engineering.

1. Introduction

In the 21st century, the development of the logistics industry presents the characteristics of the era of intelligence and knowledge. On the one hand, the widespread application of AI technology and automation technology has enabled the production and dissemination of logistics knowledge to break through the limitations of time and space, and accelerate the cross-integration of different disciplines, and give birth to new retail models such as Hema Fresh and Super Species; on the other hand, the explosive growth of logistics knowledge creation and the continuous shortening of the transformation cycle of logistics-related scientific research achievements have brought unprecedented challenges to the training of logistics talents.

In view of how to improve the quality of logistics talent training, the Ministry of Education promulgated the "National Standards for Teaching Quality of Undergraduate Majoring in Logistics Management and Engineering " in 2017 as the national standard and basic requirement for the training quality of logistics talents[1]. The standard points out that logistics management and engineering undergraduate majors include logistics management, logistics engineering and procurement management, and are committed to training compound professionals who can solve the theoretical and practical problems of logistics management and engineering science in social and economic system.

The Ministry of Education promulgated the " National Standards for Teaching Quality of Undergraduate Majoring in Logistics Management and Engineering", mainly to establish a sound quality assurance and monitoring and evaluation system, so that the quality of higher education can be evaluated, compared and monitored. However, for colleges and universities with logistics majors, it is still difficult to evaluate quality according to this standard. At present, the establishment of standards is to explore the formation of higher education quality standards that are in line with national conditions and school conditions. Therefore, how to find out the problems in the quality standard of undergraduate talent training under the new situation and construct a path is of great significance to enhance the cultivation of students' comprehensive quality and improve the quality of higher education. This paper will discuss it through the method of evaluating the training quality of undergraduate majoring in logistics management and engineering.

2. The quality evaluation indicator system for training of undergraduate majoring in logistics management and engineering

Because of the many factors involved in the evaluation of quality for training of undergraduate majoring in logistics management and engineering, this paper follows the principles of scientificness, representativeness, hierarchy and systematicness, and summarizes six indicators that can best measure the role of Quality for Training of Undergraduate Majoring in Logistics Management and Engineering from many indicator: Construction of school professional condition(B_1)[2],Reasonable optimization of curriculum system and teaching content(B_2)[3], Comprehensive quality of graduates(B_3), Basic qualities and needs of students(B_4)[4], Quality of practical teaching activities(B_5)[5], and Teachers' quality and ability and willingness to invest in Teaching(B_6)[6].each of which has multiple secondary indicators. The indicator system established based on the above five primary indicators and 15 secondary indicators is shown in Table 1.

Table 1. Quality for Training of Undergraduate Majoring in Logistics Management and Engineering evaluation indicator system

	First level indicator	Second level indicator
The quality evaluation indicator systemfor training of undergraduate majoring in logistics management and engineering	Construction of school professional condition(B_1)	Students' professional education needs(C_{11})
		Construction of practice teaching site for professional courses(C_{12})
		Library construction(C_{13})
		The construction of online courses(C_{14})
		Campus learning atmosphere(C_{15})
	Reasonable optimization of curriculum system and teaching content(B_2)	Reasonable business training target positioning(C_{21})
		The rationality of professional basic courses(C_{22})
		Reasonable setting of professional orientation courses(C_{23})
		Reasonable setting of professional practice courses(C_{24})
		Practicality of professional courses(C_{25})
	Comprehensive quality of graduates(B_3)	Ideological and political quality(C_{31})
		Scientific and cultural quality(C_{32})
		Physical and mental quality(C_{33})
		Professional quality(C_{34})
	Basic qualities and needs of students(B_4)	Basic knowledge reserve of students (C_{41})
		Students' learning skills(C_{42})
		Students' learning strategies(C_{43})
		Students' professional education needs(C_{44})
	Quality of practical teaching activities(B_5)	Students' English listening and speaking ability(C_{51})
		Student's Chinese expression ability(C_{52})
		Web design and production

	capability(C_{53})
	Network programming ability(C_{54})
	Team writing ability(C_{55})
	Familiarity with logistics facilities and equipment(C_{56})
	Website maintenance and management capabilities(C_{57})
Teachers' quality and ability and willingness to invest in Teaching(B_6)	Teacher's knowledge reserve capacity(C_{61})
	Teacher's practical teaching ability(C_{62})
	Teacher's theoretical teaching ability (C_{63})
	Teacher's willingness to teach (C_{64})

3. Research methods

3.1. Indicator weight calculation

In this paper, the hybrid decision matrix based on variation coefficient and the improved AHP method based on triangular fuzzy number are used to calculate the objective weight and subjective weight of each indicator at the same time[7]. Finally, the combination weight of the indicator is calculated by the maximum comprehensive evaluation value method. On the one hand, the subjective and objective method is adopted to make up for the problem that the indicator evaluation is too subjective in the previous research, which improves the effectiveness of the evaluation results; On the other hand, in the process of indicator evaluation, the form of mixed data is used to score, which not only enables the model to analyse quantitative indicators, but also analyse qualitative indicators by using language evaluation sets, triangular fuzzy numbers, etc. This makes the applicability of the model wider and improves the persuasiveness of the model.

3.1.1. Objective weight

Objective weight determination method of hybrid decision matrix based on coefficient of variation
In order to get the objective weight of the mixed decision matrix by using the variation coefficient method, the mixed data needs to be processed first to obtain standardized data[8]. Assuming that the attribute value f_{ij} (i, j represents the number of indicators) is normalized data, then:
1) If $\hat{f}_{ij}$ is a triangular fuzzy number, we use the mean area measurement method to find the average value, as shown in formula (1) (f^l, f^m, f^u representing the lower limit, maximum probability value and upper limit of the triangular fuzzy number):

$$f_{ij} = \left(f_{ij}^l + 2 f_{ij}^m + f_{ij}^u \right) / 4 \tag{1}$$

2) If f_{ij} is a linguistic variable, first transform it into a triangular fuzzy number, and then find the mean.
3) Calculate the mean value of the j-th evaluation indicator, as shown in formula (2):

$$\overline{f}_j = \frac{1}{m} \sum_{i=1}^{m} f_{ij}, j = 1, 2, .., n \tag{2}$$

4) Calculate the mean square value of the j-th evaluation indicator, as shown in formula (3):

$$D_j = \sqrt{\frac{1}{m-1} \sum_{i=1}^{m} \left(f_{ij} - \overline{f}_j \right)^2}, j = 1, 2, .., n \tag{3}$$

5) I Calculate the coefficient of variation of the j-th evaluation indicator, as shown in formula (4):

$$E_j = \frac{D_j}{\bar{f}_j}, j = 1, 2, \ldots, n \tag{4}$$

6) The coefficient of variation of each indicator is normalized to obtain the weight of each indicator, as shown in formula (5):

$$w_j = \frac{E_j}{\sum_{j=1}^{n} E_j}, j = 1, 2, \ldots, n \tag{5}$$

3.1.2. Improved AHP Subjective Weight

Improved AHP Subjective Weight Determination Method Based on Triangular Fuzzy Number[9]:

1)The difference between the improved AHP method and the traditional AHP method is that when establishing the pairwise comparison judgment matrix, the weight of the relative importance of the two indicators is no longer based on the traditional 1-9 scale, but is assigned by the reciprocal scale of triangular fuzzy number ($\hat{e}_{ij}$), as shown in formula (6)

$$\hat{e}_{ij} = \left(e_{ij}^L, e_{ij}^M, e_{ij}^U\right) \tag{6}$$

Among them, $\hat{1}$ means that compared with the two factors, it has the same importance; $\hat{3}$ indicates that x_i is slightly more important than x_j ; $\hat{5}$ indicates that x_i is obviously more important than x_j; $\hat{7}$ indicates that x_i is very more important than x_j; $\hat{9}$ indicates that x_i is extremely more important than x_j. The triangular fuzzy number is defined as: $\hat{1} = (1,1,2); \hat{x} = (x-1, x, x+1), x = 2, 3, \ldots, 8; \hat{9} = (8,9,9)$ and satisfies the reciprocal condition $\hat{e}_{ii} = 1, \hat{e}_{ij} = 1/\hat{e}_{ji}$. In addition, remember:

$$\hat{E} = \left[E^L, E^M, E^U\right] \tag{7}$$

2) When solving, first calculate the eigenvalues and eigenvectors satisfying formula (8).

$$E^L W^L = \lambda_{\max}^L W^L, E^M W^M = \lambda_{\max}^M W^M, E^U W^U = \lambda_{\max}^U W^U \tag{8}$$

This article will use the square root method to calculate. Then calculate the normalized eigenvector of the triangular fuzzy number reciprocal judgment matrix, as shown in formula (9):

$$\hat{W} = \left[\alpha W^L, \beta W^M, \gamma W^U\right] = \left(\hat{w}_1, \hat{w}_2, \ldots, \hat{w}_m\right)^T \tag{9}$$

Use the calculation result as a weight vector, where

$$\alpha = \sqrt{\sum_{j=1}^{m} \frac{1}{\sum_{i=1}^{m} e_{ij}^U}}, \beta = \sqrt{\sum_{j=1}^{m} \frac{1}{\sum_{i=1}^{m} e_{ij}^M}}, \gamma = \sqrt{\sum_{j=1}^{m} \frac{1}{\sum_{i=1}^{m} e_{ij}^L}} \tag{10}$$

3) In the consistency test, it is generally believed that when E^M has satisfactory consistency, $\hat{E}$ has also satisfactory consistency. Therefore, it is only necessary to perform consistency test on E^M of each judgment matrix.

4) Convert triangular fuzzy number weights into single value weights

This paper uses the center of gravity method to calculate, as shown in formula (11):

$$w_i = \frac{1}{3}\left(w_i^L + w_i^M + w_i^U\right) \tag{11}$$

Finally got $W=\left(w_1,w_2,\ldots,w_m\right)$

3.2. TOPSIS method

TOPSIS is a multi-attribute decision-making method from a geometric point of view[10]. It evaluates m schemes under n attributes, with the help of ideal solutions and negative ideal solutions in multi-objective decision-making problems. The so-called ideal solution is the best solution of a hypothesis (denoted as V+), while the negative ideal solution is the worst solution of another hypothesis (denoted as V-). In the original scheme set X, each scheme is compared with V+ and V-, and the distance information between them is used as the criterion for sorting m schemes.
Due to the different attributes of indicators, not all indicators can be quantitatively analysed. The main point of improvement in this article is that experts are not limited to quantitative scores when evaluating and determining the decision matrix, but can be selected according to the specific attributes of the indicators. Scoring by language evaluation set or triangular fuzzy number solves the evaluation problem of some qualitative indicators and makes the application scope of the model wider.

4. The quality evaluation steps for training of undergraduate majoring in logistics management and engineering

This article comprehensively applied the methods introduced above, processed each indicator, and established an evaluation model. The model is roughly divided into five steps: step one, normalize the indicators; step two, calculate the objective weight of each indicator based on the coefficient of variation method of mixed data; step three, calculate the subjective weight of each indicator based on the improved AHP method of triangular fuzzy numbers ; Step four, apply the combined weight based on the maximum comprehensive evaluation method to calculate the combined weight as the final weight of each indicator; step five, use the improved TOPSIS method to sort the different Logistics Management and Engineering Teaching Qualities.

5. Application example

Next, we apply this method to the evaluation of logistics management and engineering undergraduate training quality in three universities.

5.1. Standardized processing of indicators

The first level indicator is expressed as$\mathrm{C_i}(\mathrm{i}=1,2,\ldots,6)$.The secondary indicator$\mathrm{D_j}(\mathrm{j}=1,2,\ldots,30)$ is expressed as D_ j (j=1,2,⋯ ,30)。 In practice, due to the different attributes of different indicators, it is impossible that all indicators can be measured by accurate numbers. Therefore, this paper uses the mixed data such as precise numbers, linguistic evaluation sets and triangular fuzzy numbers introduced above to evaluate different types of indicators.
Through analysis, it can be seen that the six first-level indicators are suitable for the evaluation of language evaluation sets[11]. Set the language evaluation set:

$$\begin{aligned}\mathbf{A}&=(\boldsymbol{a_0},\boldsymbol{a_1},\boldsymbol{a_2},\boldsymbol{a_3},\boldsymbol{a_4},\boldsymbol{a_5},\boldsymbol{a_6})\\&=(\textbf{very poor},\textbf{poor},\textbf{medium poor},\textbf{favorable},\textbf{medium good},\textbf{good},\textbf{verygood})\end{aligned}$$

The result of converting it into a normalized triangular fuzzy number is shown in Table 2:

Table 2. Transformation of Language Evaluation Set into Triangular Fuzzy Number

Fuzzy linguistic variables representation	Standardized trapezoidal fuzzy numbers
very poor（VP）	（0，0，0.1，0.2）
poor（P）	（0.1，0.2，0.2，0.3）
medium poor（MP）	（0.2，0.3，0.4，0.5）
favorable（F）	（0.4，0.5，0.5，0.6）

medium good（MG）	（0.5，0.6，0.7，0.8）
good（G）	（0.7，0.8，0.8，0.9）
very good（VG）	（0.8，0.9，1，1）

In all the secondary indicators, one part can be evaluated by precise numbers, and the other part needs to be evaluated using language evaluation sets first and then converted into triangular fuzzy numbers.

5.2. Apply the coefficient of variation method to calculate the objective weight of each indicator

5.2.1. First level indicator

- Expert evaluation

Organize 10 experts in this field to form an expert group to assess the level of the six first-level indicators corresponding to the three universities. If more than half of the experts believe that the indicator's impact on the vulnerability of the emergency supply chain is at The indicators belong to this level. After evaluation by the expert group, the results of each first-level indicator level are shown in Table 3:

Table 3. First-level indicator rating

:

First-level indicator	C_1	C_2	C_3	C_4	C_5	C_6
A	a_2	a_5	a_3	a_1	a_6	a_4
B	a_5	a_1	a_5	a_6	a_4	a_3
C	a_1	a_4	a_3	a_4	a_6	a_5

- Calculate weight

step1: After calculation, the standardized decision matrix (A represents the first-level indicator layer) is:

$$R_A = \begin{bmatrix} 1.333 & 3.333 & 2 & 0.667 & 3.833 & 2.667 \\ 3.333 & 0.667 & 3.333 & 3.833 & 2.667 & 2 \\ 0.667 & 2.667 & 2 & 2.667 & 3.833 & 3.333 \end{bmatrix}$$

Step2: After calculation, the average value of each indicator

$$\bar{f}_j = (1.778, 2.222, 2.444, 2.389, 3.444, 2.667)$$

Step3: After calculation, the mean square deviation of each indicator was calculated

$$D_j = (1.388, 1.388, 0.77, 1.601, 0.678, 0.667)$$

Step4: After calculation, the coefficient of variation of each indicator

$$E_j = (0.781, 0.625, 0.315, 0.67, 0.197, 0.25)$$

Step5: The weight of each indicator is $W_A = (0.275, 0.22, 0.111, 0.236, 0.069, 0.088)$

5.2.2. Secondary indicators

The calculation steps of the secondary indicator weight are the same as the above calculation steps. Due to the limited space of this article, the calculation process of the remaining indicators is omitted, and only the final calculation result is given (C represents the secondary indicator layer):

$$W_{C^1} = (0.09, 0.21, 0.144, 0.407, 0.15); W_{C^2} = (0.208, 0.04, 0.3, 0.275, 0.177)$$

$$W_{C^3} = (0.337, 0.213, 0.249, 0.201); W_{C^4} = (0.228, 0.307, 0.055, 0.057, 0.353)$$

$$W_{C^5} = (0.116, 0.198, 0.098, 0.143, 0.238, 0.072, 0.134); W_{C^6} = (0.222, 0.121, 0.431, 0.226)$$

5.2.3. The objective overall weight

The objective overall weight of the secondary indicators is

$W_1 = (0.025, 0.058, 0.04, 0.112, 0.041); W_2 = (0.046, 0.009, 0.066, 0.061, 0.039)$

$W_3 = (0.037, 0.024, 0.028, 0.022); W_4 = (0.054, 0.072, 0.013, 0.013, 0.083)$

$W_5 = (0.008, 0.014, 0.007, 0.01, 0.016, 0.005, 0.009); W_6 = (0.02, 0.011, 0.038, 0.02)$

5.3. Apply the improved AHP method to calculate the subjective weight of each indicator

5.3.1. First level indicator

- Establish a comparison judgment matrix

Organize 10 experts in this field to form an expert group to establish a pairwise comparison judgment matrix for $C_1, C_2, \dots, C_6$ of the target level G. If more than half of the experts believe that the indicator C_i is important to the indicator C_i, the comparison result of the two indicators is considered to be that level , After evaluation by the expert group, the pairwise comparison results of each first-level indicator are:

$$E = \begin{bmatrix} 1 & \hat{1} & \hat{5} & \hat{3} & \hat{1} & \hat{7} \\ \hat{1}' & 1 & \hat{5} & \hat{1} & \hat{9} & \hat{3} \\ \hat{5}' & \hat{5}' & 1 & \hat{7} & \hat{5} & \hat{1} \\ \hat{3}' & \hat{1}' & \hat{7}' & 1 & \hat{3} & \hat{9} \\ \hat{1}' & \hat{9}' & \hat{5}' & \hat{3}' & 1 & \hat{7} \\ \hat{7}' & \hat{3}' & \hat{1}' & \hat{9}' & \hat{7}' & 1 \end{bmatrix}$$

- Hierarchical single sort

After calculation， $W_{E^L} = (0.271, 0.284, 0.152, 0.149, 0.096, 0.049)$

$W_{E^M} = (0.267, 0.278, 0.13, 0.213, 0.075, 0.037)$

$W_{E^U} = (0.364, 0.294, 0.142, 0.109, 0.062, 0.029)$

$\lambda_{\max}^{E^L} = 8.351, \lambda_{\max}^{E^M} = 9.854, \lambda_{\max}^{E^U} = 8.487$,

So， $\alpha = 1.235, \beta = 0.924, \gamma = 0.951$,

Finally got：

$\hat{W}_C = [(0.25, 0.236, 0.327), (0.263, 0.246, 0.264), (0.14, 0.115, 0.127),$

$(0.138, 0.188, 0.098), (0.088, 0.066, 0.056), (0.046, 0.033, 0.026)]$

- Consistency check

Looking up the table, RI=1.25, then CR=0.061<0.1, so the judgment matrix has satisfactory consistency.

d)Converted into single value weight After calculation and normalization:

$$W_C = (0.3, 0.286, 0.141, 0.157, 0.078, 0.039)$$

5.3.2. The secondary indicator

The calculation steps of the secondary indicator weight are the same as the above calculation steps. Due to the limited space of this article, the calculation process of the remaining indicators is omitted, and only the final calculation results are given:

The weight of the first set of secondary indicators is $W_{D_1} = (0.539, 0.193, 0.146, 0.069, 0.052)$, the result of the consistency test of the comparison matrix is :CR=0.037＜0.1。

The weight of the second group of secondary indicators is $W_{D_2} = (0.454, 0.213, 0.209, 0.078, 0.046)$, the result of the consistency test of the comparison matrix is:

CR=0.057＜0.1。
The weight of the third group of secondary indicators is $W_{D_3}=(0.624,0.232,0.062,0.082)$,the result of the consistency test of the comparison matrix is :CR=0.098＜0.1.
The weight of the forth group of secondary indicators is $W_{D_4}=(0.433,0.221,0.212,0.073,0.06)$,the result of the consistency test of the comparison matrix is :CR=0.056＜0.1。
The weight of the fifth group of secondary indicators is $W_{D_5}=(0.294,0.202,0.169,0.098,0.057,0.046,0.035)$， the result of the consistency test of the comparison matrix is :CR=0.037＜0.1。
The weight of the fifth group of secondary indicators is $W_{D_6}=(0.54,0.239,0.171,0.042)$， the result of the consistency test of the comparison matrix is :CR=0.097＜0.1。
The subjective global weight
The subjective global weight of secondary indicators is:

$$W_1=(0.163,0.058,0.044,0.021,0.016);W_2=(0.131,0.061,0.06,0.022,0.013);W_3=(0.089,0.033,0.009,0.012);$$
$$W_4=(0.068,0.035,0.034,0.012,0.01);W_5=(0.023,0.016,0.013,0.008,0.005,0.004,0.003);$$
$$W_6=(0.021,0.009,0.007,0.002)$$

5.4. Calculate combination weight

This paper uses the method of determining the combined weight based on the largest comprehensive evaluation value to calculate the combined weight of each indicator.

5.4.1. First level indicator

After calculation: $\alpha=0.675,\beta=0.325$， Substituting $W=\alpha\times\omega+\beta\times\lambda$ into the formula, the weights of all first-level indicators are:
W=（0.283, 0.241, 0.121, 0.21, 0.072, 0.072）

5.4.2. Second level indicator

After calculation: $\alpha=0.413,\beta=0.587$， Substituting $W=\alpha\times\omega+\beta\times\lambda$ into the formula, the weights of all first-level indicators are:

$$W=(0.106,0.058,0.042,0.059,0.026,0.096,0.04,0.062,0.038,0.024,0.068,0.029,0.017,0.016,$$
$$0.062,0.05,0.025,0.012,0.04,0.017,0.015,0.011,0.009,0.01,0.004,0.005,0.021,0.01,0.02,0.009)$$

5.5. Application of improved TOPSIS method for evaluation

The weight vector and the original normalized decision matrix have been given by the above calculations.

- After the indicators are in the same trend and the evaluation values are standardized, a weighted normalized matrix $V=(v_{ij})$ is constructed to find the positive ideal solution and negative ideal solution of each secondary indicator, and the distance between the three universities and the positive ideal solution and negative ideal solution is calculated :

$$\begin{cases}d_1^+=0.084\\d_1^-=0.108\end{cases},\quad\begin{cases}d_2^+=0.12\\d_2^-=0.079\end{cases},\quad\begin{cases}d_3^+=0.101\\d_3^-=0.084\end{cases}$$

- The relative closeness between the evaluation object and the positive ideal solution is：

$$C_1=0.438,\ C_2=0.602,\ C_3=0.545$$

5.6. Result analysis
Through the above empirical calculation, the evaluation result of the improved TOPSIS method can be seen intuitively, and the different degree of influence of each indicator can be analysed according to the calculated indicator weight. Among them, indicators with a greater degree of influence will have different effects on the training quality of logistics management and engineering undergraduate professionals in the three universities, which can confirm the reliability of the evaluation results.

6. Conclusion
In real life, there are many factors that affect the quality evaluation of logistics management and engineering undergraduate professional training, and these factors are often difficult to quantify. Therefore, this paper first uses language set to measure the factors that need qualitative analysis, and then transforms them into triangular fuzzy numbers, so as to achieve the combination of qualitative and quantitative. At the same time, through the combination of coefficient of variation method, AHP method based on triangular fuzzy number and improved TOPSIS method, a comprehensive evaluation model for evaluating the quality evaluation of logistics management and engineering undergraduate training is given, and the practicability of this method is verified by an example, which has practical significance for the quality evaluation of logistics management and engineering undergraduate training.

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Entity Coreference Resolution for Syllabus via Graph Neural Network

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Abstract. Automatic identification of coreference and the establishment of corresponding model is an essential part in course syllabus construction especially for the comprehensive Universities. In this type of tasks, the primary objective is to reveal as much information as possible about the course entities according to their names. However, it remains a difficulty to most of the latest algorithms since the references to courses are commonly in line with the specifications of each University. Thus, it is important to link the course entities with similar identities to the same entity name due to the contextual information. To resolve this issue, we put forward a graph neural network (GNN)-based pipeline which was designed for the characteristics of syllabus. It could provide both the similarity between each pair of course names and the structure of an entire syllabus. In order to measure the performance of presented approach, the comparative experiments were conducted between the most advanced techniques and the presented algorithm. Experimental results demonstrate that the suggested approach can achieve superior performance over other techniques and could be a potentially useful tool for the exact identification of the entities in the educational scenarios.

Keywords: Knowledge point · Convolutional neural network · Coreference resolution

1 Introduction

Coreference resolution has become one of the most popular research fields for detecting the same entities in various practical scenes [1, 2]. And a large amount of algorithms have been provided to address the task of coreference resolution in natural language processing (NLP). However, none of them has been specifically designed for the entity discovery for the syllabus in University. For instance, in the work of [3] a learning method was presented to coreference resolution of noun phrases in unlimited text. One small and annotated corpus was leveraged as the dataset to produce a certain type of noun phrases like pronouns. Within this study, the entity types are not confined to specific categories. Kottur et al. [4] focus on the visual coreference resolution issue, which consists of

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determining one noun phrase and pronouns whether refer to the same entity in a picture. A neural module network is employed for addressing this problem through using two elements: Refer and Exclude that could execute the coreference resolution in a detailed word level.

Since most of them focus on the association between each pair of entities rather than their contextual environment, it is also difficult for the previously proposed techniques to be adapted to the educational background. However, the rapid development of modern society proposes the higher requirements of students, the corresponding resources related to syllabus have grown greatly especially in the Universities. Therefore, the recognition of the same entities with similar or dissimilar names become much more complicated than ever before.

Meanwhile, the deep learning-based techniques have shown their performance in various NLP-oriented applications. For instance, Attardi et al. [5] propose an architecture of deep learning pipeline for NLP. A group of tools are built for creating distributional vector representations and addressing the NLP tasks in this work. In total, three techniques were introduced for embedding creation and two algorithms were exploited for the network training. And the convolutional network plays a vital role in this approach. In [6], a joint multiple-task model is introduced as well as a strategy for adapting its depth to the complexity of the tasks. Each layer contains the shortcut connection to both the word embedding and low-level predictions. One regularization with simple structure is used to implement the optimization of the objective function.

Recently, the graph neural network (GNN) could be a valuable deep learning model for implementing the coreference resolution tasks. Originally, GNN was used to deal with the non-Euclidean data. For instance, in the work of [7], a scalable approach based on a variant of convolutional neural network for semi-supervised classification within the graph structure data. Different from the traditional convolutional neural network, GNN is supposed to address the issues directly on graphs rather than the Euclidean data such as pixel images. And the original convolution operation is modified into the spectral graph convolution with the localized firstorder approximation. Both the local graph structure and the features of each node in the graph could be extracted with GNN. For clinical applications, a supervised GNN-based learning approach for predicting the products from organic reactions given the reactants, reagents, and solvents [8].

Base on the above analysis, we put forward a GNN-based pipeline trained by 1,312 pairs of entities for coreference resolution task. To note that all of the entities are extracted from the syllabus of the Universities in Shandong Province, China. The proposed GNN model adopts the spectral convolution operator as its primary computation unit. And each manually collected course entity is independently fed into the proposed GNN as one node of the whole graph of syllabus. Meanwhile, the similarity of each pair of entities and the corresponding adjacent relationship are taken as the characteristics of the nodes in the graph. In the trainings performed on the dataset, the parameters including the convolution and pooling layers' operators as well as the characteristics of the nodes could be optimized iteratively. With the labeled entities pairs, the trained GNN could be used to resolve the coreference in the given a new pair of course entities.

To measure the performance of the presented method, the comparison experiments were carried out on the samples of data collected manually between latest techniques and the presented approach. The corresponding results demonstrate that the presented GNN-based pipeline outperforms other techniques.

In general, this work has at least the following significance as:

- A GNN model is introduced to implement the coreference resolution task in course syllabus of Chinese University.
- The association between each pair of nodes in the presented graph structure could be used to represent the association between each pair of entities in the syllabus.
- Experiments on the real samples could demonstrate that the presented method is one potentially invaluable technique for coreference resolution.

The rest of this paper is as follows. In Sect. 2, we provide the concrete details of the presented approach. The results of the experiment are described in Sect. 3 and the conclusion is depicted in Sect. 4.

2 Methodology

2.1 Input of the Proposed GNN

According to Fig. 1, the proposed deep learning model adopts the similarity of each pair of entities and the corresponding adjacent relationship as its input. Each node in the input denotes one entity within the course syllabus and the link between each pair of nodes represents both the connection of the corresponding entities and their similarity. To note that the length of the link does not equal to the similarity of a pair of nodes.

2.2 Graph Convolutional Neural Network

1) Definition
It is assumed there are n entities (i.e. the course names) in general, $\mathrm{C_i} = [\mathrm{C_1}, \mathrm{C_2}, \ldots, \mathrm{C_n}]$. Each syllabus could be denoted by a matrix $\mathrm{C_i} \in \mathrm{R^{m \times n}}$, where *m* is the number of course in each syllabus, n is the dimensionality for the feature vector extracted from the original course samples and $\mathrm{n_i} \in \{0, 1\}$. The dataset from the syllabus could be represented with one weighted graph with a data structure of tuple $G = (V, E, W)$, where V denotes the m nodes in the graph, E represents the whole group of edges in the same graph, and $\mathrm{W} \in \mathrm{R^{m \times n_i}}$ is the corresponding adjacency matrix. Meanwhile, is the weight assigned to the edge, which links $\mathrm{V_i} \in \mathrm{V}$ to $\mathrm{V_j} \in \mathrm{V}$. To note that the value of the association (the edge) denotes the similarity of the connected entities. Therefore, it has been set as one hyperparameter in the following experiments.

The convolutional operator illustrated in Fig. 1 approximately equals to the multiplication operation in the spectral domain and relates to the common convolution operator in the time domain. The whole process could be mathematically formulated as follows:

$$\mathrm{L} = \mathrm{I_m} - D^{-\frac{1}{2}} W D^{-\frac{1}{2}} \tag{1}$$

where D denotes the matrix degree and I_m is the an identity matrix.

As mentioned by Defferrard et al. [9], the Laplacian matrix then could be represented by using Chebyshev polynomials:

$$T_k(L) = 2LT_{k-1}(L) - T_{(k-2)} \tag{2}$$

where $T_0(L) = 1$ and $T_1(L) = L$.

To note that a polynomial ordered by K can generate K filters without bias. And, the filtering of a signal with K filters could be implemented with:

$$o = g_\theta(L) * c = \sum\nolimits_k = O_k \theta_k T_k(\bar{L})c \tag{3}$$

where c denotes a course from the syllabus dataset for, $L = \frac{2}{\lambda_{max}} - I_d$ and $\lambda_{max}\lambda_{max}$ is the highest eigenvalue of the normalized L. Therefore, the output of the l^{th} layer for each sample in a GNN can be formulated as:

$$O_c^l = \sum_{i=1}^{F_{in}} g_{\theta_i^l}(L)c_s^l, i \tag{4}$$

Where F_{out} is the outcome filter and F_{in} represents the inputfilter that would yield $F_{out} \times F_{out}$ vectors, $\theta_i^l \in R^k$ are the Chebyshev coefficients, and $\theta_{s,i}^l$ is the input feature map for sample c at layer *l*.

2) Network architecture

The structure of the proposed GNN is provided in Table. 1. Totally, it is composed of 5 convolutional layers. No pooling operation is used in the network architecture for conserving the completeness the extracted features. The dropout rates for 2nd, 3rd, 4th, and 5th convolutional layers are 0.4.

Table 1. Network architecture of the proposed GCNN.

Table head	Layer						
	Conv	Conv	Conv	Conv	Conv	Conv	Classifier
Channels	32	32	64	64	128	128	2
K-order	9	9	9	9	9	90	N/A
Stride	1	1	1	1	1	1	N/A

The initial training rate of the proposed GNN is 0.001. The training is conducted with a fixed 600 steps. The learning rate would decrease by a factor of 0.5 once the validation accuracy drops in two consecutive rounds.

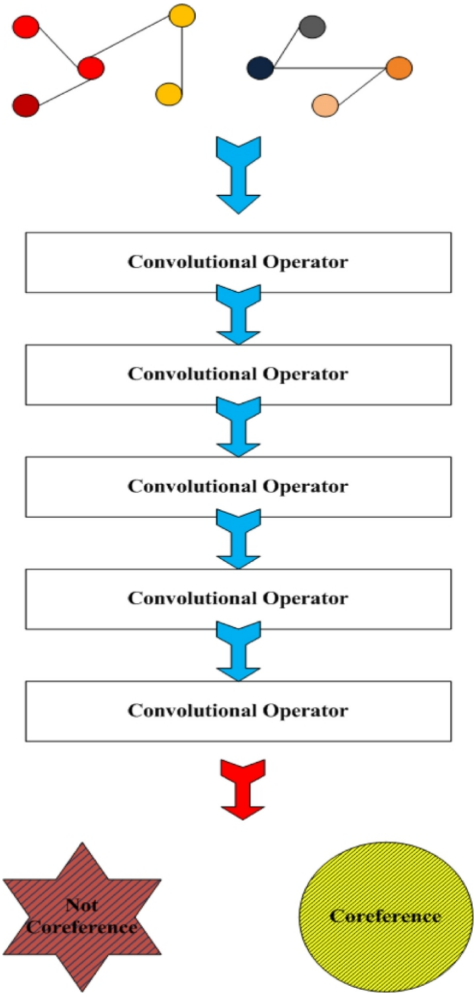

Fig. 1. The method of the presented GNN

3 Results and Discussion

The comparison experiments on the manually collated samples between latest techniques and the presented one to measure the performance of the presented GNN-based pipeline. And the results of the experiment as well as the analysis are provided in the following section.

3.1 Dataset

The proposed GNN is trained solely on samples data collected manually of course entities according to the syllabus in Universities of Shandong Province, China. In total, 1,312 pair of entities (600 of them are coreference) were manually collected from the raw materials.

Two educational experts were asked to perform the labeling tasks. Furthermore, none of the data augmentation techniques has been adopted to increase the diversity of the data samples due to the similarity of the course entities (only the course names). The adjacent matrix of the entities and the similarity of each pair of entities were both taken as the input the proposed GNN pipeline.

3.2 The Setting of the Hyperparamete

To determine the optimal setting of the hyperparameter as mentioned in Sect. 2.2, the classification experiments with different values of this hyperparameter from 0 to 1 with step of 0.1 were carried out and the corresponding accuracy is illustrated as Fig. 2.

Since the highest accuracy is achieved when we set λ at 0.5, the value of 0.5 is adopted in the following experiments. Accordingly, the value 0.5 is used during process of training, testing, and evaluation.

In total, 70% of the samples are taken as the training set, 20% as the evaluation set, and the remaining are used as the testing set. The presented GNN has been fine-tuned by back propagation mechanism. Graphics Processing Unit (GPU), which has high performance, is employed in the presented GNN, and the learning rate of the Tensorflow deep learning platform is set as 0.01.

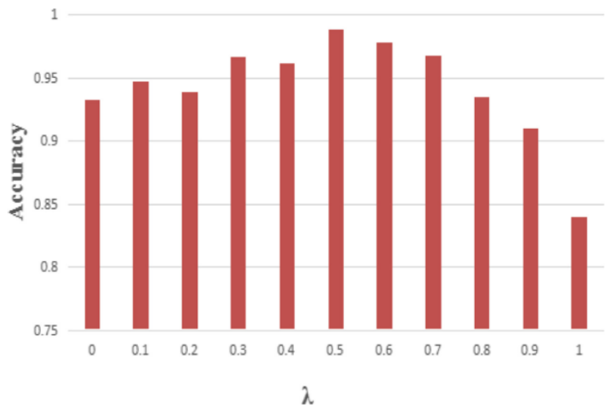

Fig. 2. Performance of the proposed GNN with different λ

3.3 Experiments

To measure the performance of the presented GNN-based pipeline, the comparison experiments between latest [10–13] and the proposed techniques were carried out on the data samples collected manually.

As illustrated in Table 2, our technique outperforms other coreference resolution techniques in accuracy significantly.

Table 2. Performance comparison between latest and the presented GNN-based approach.

Methods	Accuracy (%)
Lee et al. [10]	83.25
Meng et al. [11]	87.03
Pandian et al. [12]	86.47
Agarwal et al. [13]	90.13
Our method	98.56

3.4 Analysis

According to performance comparison between the latest and ours on the data samples collected manually, we could observe that effectiveness of the proposed GNN-based approach. Through transferring the coreference resolution tasks into the neighboring relationship between each pair of nodes in the non-Euclidean graph, the introduced GNN could reveal both the association between each pair of entities and the corresponding similarities. Meanwhile, the accuracy obtained could satisfy the practical requirement for course syllabus.

The proposed GNN could significantly enhance the classification of coreference. Since we set different λ to carry out the performance comparison experiments in Sect. 2.2, which is used to represent the similarity between the unknown similarity between one pair of entities.

4 Conclusion

The accurate identification of the coreference of a pair of course names is a potentially valuable tool for the automatic construction of course syllabus in Universities in China. A large amount of researches have paid attention to this area and have shown the effectiveness and efficiency of these works. However, most of the them did not aim at addressing the specific requirement of course syllabus. To bridge the gap, we propose a GNN-based network with transferring the coreference resolution issue into determining the node similarity in the graph. It offers an algorithm in an automatic manner.

This study offers at least the following contributions. First of all, a GNN designed for course syllabus scenarios is presented to implement the classification of coreference and non-coreference entities. Secondly, the original coreference resolution issue is transferred into a similarity measurement problem under the graph. Finally, the presented GNN outperforms other methods.

Next, we will go on study the extension of GNN and apply them in various fields, such as natural image processing [14], medical image processing [15] and [16].

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Micro-video Learning Resource Portrait and Its Application

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Abstract. The emergence of a large number of online learning platforms changes the learners' demands and learning styles, thus the society puts forward higher requirements for the personalization, intelligentization and adaptability of learning resource platforms. For large-scale, multi-source and fragmented micro-video learning resources and personalized education problems, based on micro-video online learning resources data, the paper studies the accurate, comprehensive and usable micro-video learning resources portrait method. And through the application of deep learning technology, it studies the theory and method of micro-video learning resource data analysis and personalized learning resource recommendation. It explores and forms the basic theories and methods of data-driven micro-video learning resources analysis to support the research of personalized education theories and methods.

Keywords: Micro-video · Learning resources · Resource portrait · Personalized recommendation

1 Introduction

Micro-video learning resources have the characteristics of multi-source, multi-dimensional and fragmentation. It can meet learners' ubiquitous, mobile and personalized learning characteristics and requirements in the age of intelligence. Especially because of the COVID-19 in 2020, micro-video learning resources online have attracted unprecedented attention. Massive micro-video learning resources promotes the teaching from "curriculum" to "knowledge point", and at the same time, the knowledge transfer has changed from the linear structure to the networked structure, and the traditional teaching methods and the recommendation of learning resources cannot fully meet the learning needs of learners. In addition, people's learning is based on knowledge points and its logical relationships, and learners' previous knowledge and experience will greatly affect the learning effect [1]. So it has great research significance to organize the existing micro-videos to explore the accurate, comprehensive and usable micro-video learning resources portrait method and personalized learning resource recommendation.

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2 Related Work

2.1 Learning Resource Portrait

In China, the study of resource portrait and its application is the research focus for both pedagogy and computer science researchers. Professor Yu Shengquan proposed the framework of international standards for learning meta-level from the perspective of basic education [2]. Professor Yu Ping and Zhu Zhiting put forward the content shareability standard of open education resources [3]. Professor Yang Jiumin studied various interaction designs in videos from the perspective of learning effects of video resources [4]. These studies focus on video learning resources portrait and its applications in the foundation education. There is a lack of research on fine-grained and fragmented micro-video learning resources in higher education.

2.2 Micro-video Learning Resource Portrait

Micro-video learning resource portrait refers to the use of consistent concepts, relationships and properties to describe micro-video learning resources under certain technical specifications. Jiang et al. [5] proposed a multi-modal LDA model to mine the content portrait of video learning resources. Minxin et al. [6] used the existing classification relationships in text mining and domain ontology to find candidate keywords that can represent semantic relationships. Yang et al. [7] proposed an attention mechanism based on relation representation to extract the directed relation information among elementary mathematical knowledge points. These existing researches focus on text, they only extract the low-level features, and They don't extract the relationship between multi-source network knowledge.

2.3 Personalized Learning Resource Recommendation

At present, the existing personalized learning resources recommended method which can be roughly divided into the following types: based on collaborative filtering (CFB) [8], based on the content (CB) [9], based on sequence mining (SMB) [10], mixing method. These researches didn't fully consider the semantic part of learning resources and paid little attention to the logical structure and the systematization of learning resources.

Therefore, based on unsolved problems in the above studies, this paper explores the portrait and application of micro-video learning resources, and proposes a method to carry out learning resources portrait and personalized recommendation.

3 Portrait and Application Analysis of Micro-video Learning Resources

The main system framework of this paper is shown in Fig. 1, which mainly includes the micro-video learning resources portrait of and the personalized recommendation.

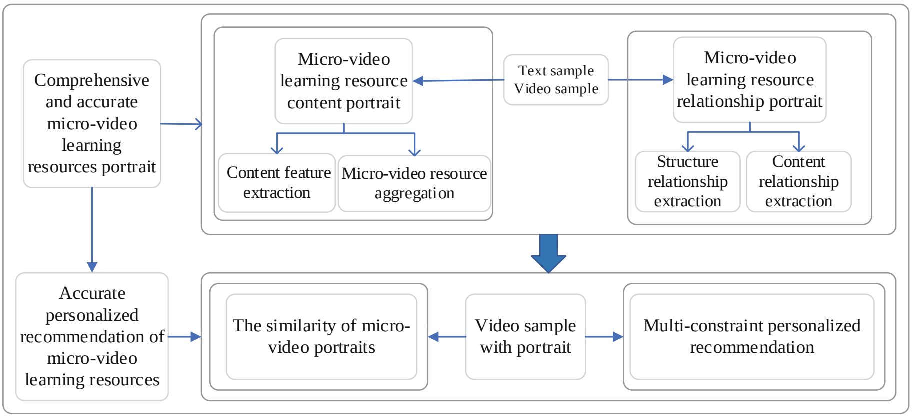

Fig. 1. System framework

3.1 Micro-video Learning Resource Portrait

Micro-video learning resource portrait mainly includes micro-video learning resource content portrait and micro-video learning resource relationship portrait.

1. Micro-video learning resource content portrait
Micro-video learning resource content portrait mainly includes the concept and properties of micro-video learning resources. When the content layer of micro-video learning resource is depicted, it is necessary to restore the source properties of the learning resource and label these properties. Specific as follows:
Firstly, we should extract the content feature of micro-video learning resource. Because of online learning resource covers all disciplines and fields and their content creators have different levels of knowledge, the same knowledge exist many different expressions, and it is not reality to determine the features of micro-video learning resources artificially. Therefore, we should study how to combine text, image and audio to mine the content features of micro-video learning resources. These features not only include low-level features such as keywords, but also contain a high-level feature, such as discipline, knowledge domain, knowledge unit, knowledge level, etc.
Secondly, we should aggregate micro-video learning resources. Different from basic education, which has standardized subject knowledge system, the knowledge system of higher education is open, the knowledge points are named according to their respective cultivation characteristics in higher education. Therefore, it is necessary to work out the domain knowledge point label system based on the above content features.
2. Micro-video learning resource relationship portrait.
It contains structural relationship and content relationship.

Firstly, we need to extract the structure relationship. The logical relationship between knowledge points may be different for different fields. A knowledge point may belong to a number of knowledge fields, and each knowledge field corresponds to a number of micro-videos. So the extraction of the micro-video learning resource relationship is a multi-dimensional problem. Therefore, we need to study how to combine text, image and voice data to mine relationship features. These features should not only include low-level features such as hierarchical relationship and association relationship, but also include high-level features such as co-reference and preorder.

Secondly, we need to extract the content relationship. Micro-video learning resources are based on the knowledge point granularity, it includes concept, principle, test questions and other types of content relations. Therefore, we need to study how to carry out transfer learning based on small sample data such as expert knowledge to accurately predict content relations.

3.2 Personalized Recommendation of Micro-video Learning Resources

It is implemented based on the above portrait and learner needs.

Firstly, the similarity of micro-video portraits is the basis of the recommendation algorithm. It has multi-dimensional characteristics, and the dimensions are not the same. Therefore, we need to study the measurement of the similarity of micro-video portraits.

Secondly, personalized recommend is based on micro-video portraits, and it is necessary to fully consider students' personalized learning needs and other constraints, such as the learner's professional background, previous knowledge, field experience, learning needs, learning objectives, and so on, so we need to study personalized micro-video recommendation under multiple constraints.

4 The Implementation of Micro-video Learning Resource Portrait and Application

Based on the problems that need to be solved, combined with the application analysis of current artificial intelligence and other technologies, this paper proposes the method of micro-video learning resource portrait and personalized recommendation system.

4.1 Micro-Video Learning Resource Portrait

The purpose of this paper is to study the iterative discovery method of the concepts of content layer and hidden properties in multiple fusion of text, image and audio. In this method, subjects, fields, knowledge level and relationships are taken as semantic annotation factors. This technology is an important technology to solve the problem of feature extraction of data-driven micro-video learning resources, and it is the basis of personalized guidance. According to the technical characteristics of deep learning, we think that a Convolutional Neural Networks (CNNs) data processing model can be adopted to solve this problem. As shown in Fig. 2, during the construction of a federation classifier for implicit properties, the system extracts the content features of multivariate learning resources data (such as text, image, audio, etc.), and combined with multivariate data fusion, the system extracts the common features of multivariate data as the important features of the classifier.

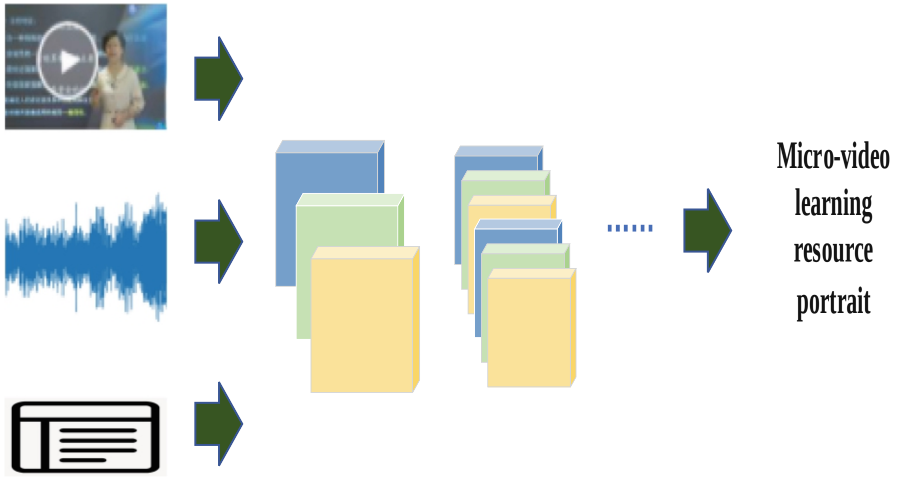

Fig. 2. Convolutional neural networks model

4.2 Personalized Recommendation System

This paper designed a micro-video learning resource portrait similarity method based on small sample. According to cognitive load theory, it provides appropriate methods to support the selection of micro-video learning resources. The collaborative filtering method can also be used to achieve the recommendation of micro-video learning resources, so it is necessary to calculate the portrait similarity of micro-video learning resources. In the definition of computational portrait similarity, we not only consider the content feature and structure feature, but also consider the timing factor of micro-video learning resources, and we use the latest change part of micro-video increment to calculate the result similarity. Different from other research similarities, in the field of education, whether the similarity of learning resources is accurate or not requires expert knowledge for final verification. Therefore, the sample micro-video data set needs to be reviewed online by corresponding experts and labeled as similar or not. Then, these labeled data are used as training sets to make accurate similarity prediction for micro-video learning resources. Multi-constraint personalized micro-video learning resource recommendation needs to consider the matching degree of students' personalized needs and micro-video learning resource portrait. According to the principle of homogeneity, we can match students who have similar personalized needs with micro-video learning resources which have similar portraits. Graph Convolutional Neural Network (GCN) is a neural network of learning graph structure, whose learning goal is to obtain the hidden state of graph perception of each node. We can take micro-video learning resources as nodes, and take their portrait as its characteristic value, then we can input this feature graph into graph convolution network for training and obtain corresponding similarity results.

5 Conclusion

This paper takes into account the disciplinary logic, domain and knowledge level of micro-video learning resource data, and proposes to use deep learning method to integrate multiple data such as text, image and audio to depict micro-video learning resources accurately. And it proposes a personalized recommendation method to calculate the similarity of micro-video learning resources by GCN. This paper explores and forms the basic theories and methods of data-driven micro-video learning resources analysis. In this paper, artificial intelligence technology is integrated into education, it provides a feasible way for micro-video learning resource portrait and its application.

Acknowledgment. Youth Innovative on Science and Technology Project of Shandong Province (2019RWF013), Postgraduate Education Reform Research Project of Shandong University of Finance and Economics (SCJY1911), Teaching Reform Research Project of Shandong University of Finance and Economics in 2020 (jy202011), Teaching Reform Research Project of Shandong Province (M2018X169, M2020283).

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Personalized Learning Service Based on Big Data for Education

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***Abstract*—According to modern educational thoughts and theories, the paper uses the new information technology to study the personalized learning service based on big data for education and artificial intelligence technology, so as to provide learners with intelligent services of personalized learning. Under the technical support represented by big data, the paper builds dynamic and diverse learning resources, continuously collects and analyzes learner-related data, and provides differentiated teaching, personalized learning and accurate services in real time. It can meet the individual social and autonomous learning needs of each learner, match learning requirements intelligently and provide adaptive learning services. It intelligently builds a learning model suitable for each learner and realizes personalized learning in a real sense.**

Keywords—personalized learning, big data for education, artificial intelligence

I. Introduction

In February 2019, “China's education modernization 2035” was issued by the CPC Central Committee and State Council, it proposed to accelerate the reform of education in the information age, accelerate talent training mode reform using modern technology, and finish the organic combination of personalized training and large-scale education. The characteristics of modern education: more open education, more emphasis on students' individuality and diversity, more pursuit of people-oriented and equality. Modern education emphasizes the development of learning ability and lifelong education, it is more sustainable education. The era of education modernization has brought about more and higher demands on people's knowledge, capacity and values. The large-scale education system in the era of traditional industrial revolution has been unable to meet the personalized requirements of education services in modern information society, and education reform and innovation is at a "crossroads".

This paper borrows the new generation of information technology(big data, artificial intelligence and so on) to provide personalized learning intelligent services. Under the technical support of represented by big data, we build dynamic and diverse learning resources, continuously collect and analyze learner-related data, and provide differentiated teaching, personalized learning and accurate services in real time. It can meet the individual social and autonomous learning needs of each learner, match learning requirements intelligently and provide adaptive learning services. It intelligently builds a learning model suitable for each learner and realizes a real sense of personalized learning.

II. Related Work

At present, all countries in the world are paying attention to personalized education, which is an important educational reform and innovation. The educational vision of achieving personalized learning in 2020 was described in British “Vision 2020: report of the teaching and learning review group in 2020”, which was published in January 2007. The goal of developing personalized learning was proposed by the US National Academy of Engineering, and it identified the 14 major scientific and technological challenges facing humanity in the 21st century[1]. In 2016, Science reported six future research frontiers which the National Science Foundation of the United States will develop, including the innovation of learning evaluation mechanism supported by big data and the innovation of learning environment based on the frontier of human-machine interaction[2]. “The outline of the national medium and long term education reform and development plan(2010-2020)” was released by the Chinese government in 2010, it put forward the idea of "paying attention to different characteristics and personality differences of students and developing the dominant potential of each student", it encouraged personalized development and it supported the idea of providing "suitable education" for each student. “The ten-year development plan of educational informatization (2011-2020)” also put forward the idea of "striving to provide information environment and services with personalized learning and lifelong learning for each student and learner and building a convenient, flexible and personalized learning environment for the learning needs of different groups in the whole society"[3].

In the field of personalized learning technology, foreign countries started earlier. Firstly, at the theoretical level, foreign countries have achieved abundant results on such issues as the model of personalized learning, key links, concept and structure of personalized adaptive learning system. It mainly involves five parts: personalized learning diagnosis, personalized learning path, personalized resource recommendation, learning status visualization and learning intervention[4]. Secondly, at the system level, foreign researchers have developed many adaptive learning systems that can provide personalized services. For example, Brusilovsky professor at the university of Pittsburgh[5-8] carried out the user model according to students' knowledge base, interest preference and education background. To satisfy the personalized learning demands in the process of the learner interacting with the system, he has developed the InterBook, ELM-ART, KnowledgeSea, AnnotatEd, TaskSieve adaptive learning system. And later many research results are the improvement and supplement based on it. Professor DeBra from Eindhoffen University of

Technology, professor Wolf from Rmit University and professor Papanikolaou from the University of Athens, et al also built separately AHA!, iWeaver, INSPIRE and other personalized educational hypermedia systems[9, 10]. Personalized learning research is still concentrated on the theoretical level and some small-scale attempts in China. At the theoretical level, Kehang He systematically discussed the theory, technology and method of "personalized learning" from the core theory of "learner modeling", the key technologies of "artificial intelligence" and "educational data mining"[11]. Shengquan Yu from Beijing Normal University studied adaptive learning earlier, and he focuses on dynamic organization of learning contents, learning strategy and learning diagnosis, and he studied the adaptive learning model based on these three key links[12]. Jianping Zhang from Zhejiang University had also done indepth research on support system about adaptive learning, and he finished some related academic achievements. He elaborated on the concept of knowledge visualization, learning ability, user model, and adaptive testing[13]. At the level of teaching system, the research group of Lu Wang from Capital Normal University built a primary school curriculum learning personalized courseware generation system in 2003. The scientific classification of students, the personalization of teaching strategies and the diversification of teaching activity sequences can be realized in this system. The research team of Wei Zhao from Northeast Normal University studied a personalized education adaptive learning system. The construction of cognitive level model and learning style model, the promotion of learning information to peers and recommendation of personalized learning path have been preliminarily realized in this system. At present, researches on personalized learning mainly focus on the learning process and seldom involve the learning situation of learners. This paper tries to introduce the learning situation into personalized learning[14].

III. Personalized Learning service based on Big Data for Education and Artificial Intelligence Technology

Research framework of personalized learning service based on big data for education and artificial intelligence technology is shown in Fig. 1.

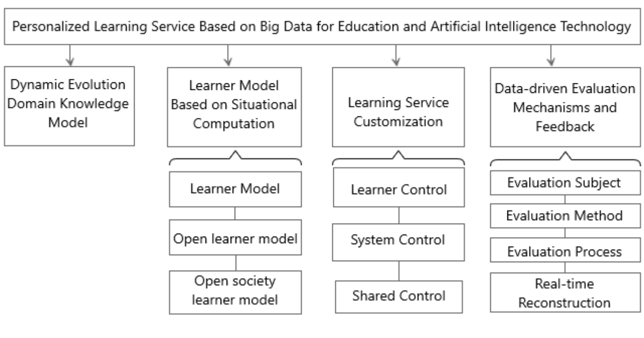

Fig. 1. Research on personalized learning service based on big data for education and artificial intelligence technology

A. *The Connotation of Personalized Learning in the Background of Educational Modernization*

Compared with traditional personalized learning, personalized learning in the context of education modernization has changed a lot. We multidimensional analysis the concept, characteristics, objectives and contents of personalized learning in the context of education modernization from the components of personalized learning, the process of personalized learning, the characteristics of personalized learning and the educational situation of learners.

B. *Personalized Learning Service under the Background of Educational Modernization*

Based on the connotation of personalized learning in education modernization, according to five elements in the general model of adaptive learning system (AEHS) proposed by Peter Brusilovsky (domain knowledge model, learners model, pedagogical model, adaptive engine and interface module), in the context of education modernization and in the new generation of information technology such as the artificial intelligence, big data analysis and other technical support, this paper studies the personalized learning service under the background of educational modernization from domain knowledge model and learner model, and the pedagogical model provides rules for the student model to access the domain model, as shown in Fig. 2.

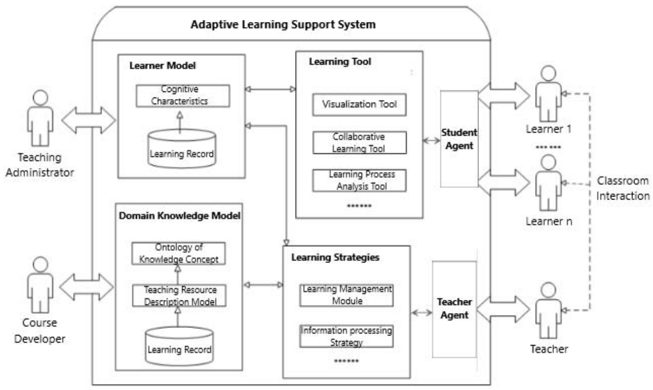

Fig. 2. Adaptive learning support system

1) Dynamic evolution domain knowledge model based on multidimensional and multi-level learning needs

This paper will deeply explore, comprehensively analyze and continuously understand learners' personalized learning needs, and build personalized learning on the basis of learners' personalized needs. Based on Maslow's hierarchy of needs theory and Bloom's classification of teaching objectives and He's deep learning theory, this research designs a questionnaire and analysis method for learners' individual and group learning needs and constructs multidimensional and multi-level learning needs. Based on the learning needs, this research constructs a dynamic evolution domain knowledge model. The basic characteristics of domain knowledge was presented from the ecology in this paper, such as generation, openness, evolution and intelligence, and uses the new information technology to realize the self-reorganization, growth, and evolution of domain knowledge.

2)Learner model based on situational computation

The learner model is an important basis for providing personalized learning services. This paper introduces learning situations into personalized learning. Learning situation refers to the environment, scene or background information of learners when they carry out learning activities, including the physical environment (such as classrooms, library, outdoor, etc.), virtual scene (such as online learning platform, mobile learning system, online social networking, etc.) and knowledge background (such as the knowledge unit or knowledge point that you are currently studying, and the position in the whole knowledge graph, etc.). The learners calculation model based on the situation can better cognitive education of the subject learners, enrich and improve the learner model. According to the constructivist learning theory, mixed learning theory and relevance learning theory, this paper constructs the learner model based on situational computing from the static model and dynamic model of learners, including the open learner model based on situational computing and the open social learner model based on situational computing. According to the learner model based on situational computing and the use of artificial intelligence, epc network and big data technology, this paper achieves accurate perception of educational situations and accurate prediction of learners' needs. It provides the premise and conditions for personalized and customized learning services.

3) Learning service customization

From the perspective of service, the essence of personalized education is the personalized learning service, and the customization of learning service is the basic strategy to improve the level of personalized learning service. The object of learning service is the learner. The content of the service includes knowledge, resources, teachers and partners.Based on the existing domain knowledge model and learner model, this paper adopts big data thinking and methods to study the personalized customization of learning services. This paper hope to carry out accurate matching of learners' learning services, realize personalized learning services and even higher level intelligent learning services. Specifically, the core theories and technical issues of customizable learning services include knowledge supply, precise services and intelligent guidance. According to the chapter 34 of "The educational communication and technology research manual(4th edition)", there are three types of customization: learner control customization, system control customization and combination customization(Shared control). This paper studies the personalized customization of learning service under the background of educational modernization from these three dimensions.

C. Evaluation of Personalized Learning Service based on Big Data for Education and Artificial Intelligence Technology

Evaluation is the most important factor to identify the success of any personalized learning service optimization strategy. The evaluation results can provide relevant feedback, which is an effective guarantee for the quality of personalized learning service. The construction of personalized learning service is constantly developing and improving in practice, and it is in the process of construction, feedback, adjustment and improvement. Based on the four dimensions proposed in the chapter 34 of the manual (4th edition), this paper constructs the evaluation strategies and indicators of the personalized learning system. The evaluation is carried out from two perspectives: subjective evaluation and objective evaluation, user process and user experience. The evaluation index comes from the learning process and the learning effect of learners using personalized learning system. Through the study of the difference analysis, correlation analysis and regression analysis on the learner's personalized learning data, this paper explores the key factors affecting learners' use of the system and the degree of interaction between them. And it provides an important reference for improving the use of personalized learning system and constructing other personalized learning support systems.

D. Data-driven multi-process Learning Performance Evaluation Mechanism and real-time Feedback Mechanism

This paper explores the evaluation mechanism and method of personalized learning performance based on data-driven technology. This personalized learning performance evaluation is guided by learners' personalized needs and learning characteristics. The multi-evaluation subject model including personalized learning system, teachers, learners and study partners is established. Comprehensive evaluation is made on the learning effects of learners' knowledge mastery and ability development. And under the technical support of big data, it can realize real-time feedback and monitoring of learners' personalized learning at any time, adjust the learning process in real-time, and intelligently provides adaptive learning services. Finally, a closed-loop teaching process of learning-evaluation-feedback-learning is formed, and the learning model of each learner is constructed intelligently.

IV. CONCLUSION

This paper studies the personalized learning service under the background of educational modernization and introduces education situation into the personalized learning services model. Under the background of educational modernization, it solved the problem that the physical space and the network virtual space coexist and the educational situation changes from the traditional preaching, teaching and solving of puzzles to the intelligent environment of intelligent perception and multi-dimensional interaction. This project uses the Internet of things, artificial intelligence, big data and other new generation of information technology to realize the education situation can be calculated. It further improves the learner model, constructs the dynamic evolution domain knowledge model, and realizes the self-reorganization, growth and evolution of domain knowledge. This project collects a large number of personalized learning data and related information through personalized learning system. And it uses the method of big data for education to analyze and diagnose the characteristics, preferences, processes and effects of learners' personalized learning and provides learners with appropriate and accurate personalized learning services. It has broken through the limitation of the original personalized learning and has new connotation and characteristics, which is an important topic in the current education study field. It is an active adjustment to the inevitable trend of educational technicalization brought by the upgrading of modern information technology, and it is deep cognition of personalized learning supported by educational technology. The personalized learning service proposed in this paper adheres to the learning needs of learners as the center. It emphasizes the openness and technical characteristics of personalized learning under the background of educational modernization. And it further enriches diversified resources, promotes the scale of data and improves the intelligence of computing. It catalyzed the integration of natural science in education. In addition, unlike the traditional empirical education research paradigm, it is transformed into a data-driven scientific research paradigm. It creates a new approach to make education precise and scientific. It accumulates the initial momentum of breakthrough in personalized learning. And this is a historic opportunity to realize the millennium dream of "teaching students based on their real aptitude".

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Video Knowledge Discovery Based on Convolutional Neural Network

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Abstract. Under the background of Internet+education, video course resources are becoming more and more abundant, at the same time, the Internet has a large number of not named or named non-standard courses video. It is increasingly important to identify courses name in these abundant video course teaching resources to improve learner efficiency. This study utilizes a deep neural network framework that incorporates a simple to implement transformation-invariant pooling operator (TI-pooling), after the audio and image information in course video is processed by the convolution layer and pooling layer of the model, the TI-pooling operator will further extract the features, so as to extract the most important information of course video, and we will identify the course name from the extracted course video information. The experimental results show that the accuracy of course name recognition obtained by taking image and audio as the input of CNN model is higher than that obtained by only image, only audio and only image and audio without ti-pooling operation.

Keywords: Knowledge discovery · TI-pooling · Convolutional nerve

1 Introduction

Online education platforms, forums, personal homepages, Weibo, various training groups, live broadcast platforms, etc. are all scattered with a large number of course video resources. Some of the course resources are normative, with course names, course knowledge points, and course evaluations. However, there are many video resources that are not standardized and are uploaded spontaneously by individuals on the Internet. Therefore, when searching for learning resources, the search may be incomplete due to the irregular description of the video resources, the irregularity or lack of naming, so it is

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increasingly important to identify the courses name from the video for us to effectively use the Internet learning resources.

Identifying course names from video is a category of knowledge discovery, and knowledge discovery is the process of identifying effective, novel, potentially useful, and ultimately understandable knowledge from the data [1]. At present, most researches on knowledge discovery focus on text documents. For example, Wang et al. [2] proposed a convolutional neural network event mining model using distributed features, which uses word embedding, triggering word types, part of speech characteristics and multiple features of topic model to conduct event mining in text. Li et al. [3] used gated recurrent neural network (GRU) with attention mechanism to identify events in texts. However, few people study video, audio and other multimedia files. Video and audio generally contain rich knowledge, especially courses video, which is not only rich in content but also related to knowledge. At present, there are a large number of courses video on the Internet, and these course resources have the phenomenon that the course name does not correspond to the content or lacks the course name. Research on how to identify the course name in video will help learners make better use of learning resources. In recent years, deep neural networks have made remarkable achievements in many machine learning problems, such as image recognition [4], image classification [5] and video classification. However, identifying course names from courses video is still a challenge.

Based on the above analysis, this study uses a deep neural network model to collect video fragments of different courses from MOOC of China University and input the pictures and audio of course video into the model for training. After the completion of convolution and pooling, a TI-pooling operation is added. The TI-pooling operation can automatically find the best "standard" instance for training input, reduce the redundancy of learning features, and reduce the parameters and training time of the model. Ti-pooling operation will be introduced in detail in Sect. 3.2. In terms of the selection of activation function, we choose FReLU activation function. Compared with traditional ReLU function, FReLU function has the advantages of rapid convergence, higher performance, low calculation cost and strong adaptability. To verify the effectiveness of the method we used, we compared it with only images, only audio, and with images and audio but no TI-pooling model. Experimental results show that the performance of our method is better than the other three methods. Generally, this study offers at least three contributions as follows.

1. The CNN is applied to the course name recognition of course video.
2. The images and audio of course video are used as the input of the model to identify the name of course video.
3. The course name is automatically recognized from the course video.

2 Related Work

Massive data and poor knowledge lead to the emergence of data mining and knowledge discovery research. Knowledge discovery originates from artificial intelligence and machine learning. It is a new interdisciplinary subject with strong adaptability formed by the integration of machine learning, artificial intelligence, database and knowledge base. There are two main branches of knowledge discovery research at present, namely knowledge discovery based on database (KDD) and knowledge discovery based on literature (KDT).

Knowledge discovery based on database (KDD) can be defined as using data mining methods to identify valid, potentially useful, and ultimately understandable patterns from the database [7]. Knowledge discovery technology based on database is very mature and has been applied in many industries. For example, Wu Dan [8] used database knowledge discovery technology to predict employee turnover based on the basic information database of employees, and identified important factors that affect employee turnover, including the company's equity ownership, monthly salary, work environment satisfaction, work participation and so on. Xu et al. [9] developed the PhenoPredict system, which can infer the therapeutic effects of therapeutic drugs for diseases with similar phenotypes on schizophrenia from the knowledge base. Li Xiaoqing [10] studied bank data mining and knowledge discovery, and pointed out that data mining and knowledge discovery provide a basis for bank decision-making and customer relationship management. Knowledge discovery based on database has its limitation that it can only deal with structured data.

However, in the real world, knowledge does not all appear in the form of structured data in traditional databases, and quite a lot of knowledge is stored and presented in various forms, such as books, journals, newspapers, research papers, radio and television news, WEB pages, E-mail and so on. There is also a large amount of valuable information in these unstructured data sources. Therefore, data mining from these unstructured data sources to extract useful knowledge for users has become a new research hotspot in data mining, which is knowledge discovery based on text. For example, Kerzendorf [11] has developed a tool that can find similar articles based entirely on the text content of the input paper. By mining Web server logs, Novanto Yudistira et al. [12] found the correlation knowledge in the indicators of e-learning Web logs. Strong typed genetic programming (STGP) is used as a cutting edge technique to find precise rules and summarize them to achieve goals. The knowledge displayed may be useful to teachers or scholars, and strategies can be improved according to course activities to improve the use quality of e-learning. Enrique Alfonseca et al. [13] describes a combination of adaptive hypermedia and natural language processing techniques to create online information systems based on linear text in electronic formats, such as textbooks. Online information systems can recommend information that users may want based on their interests and background. Text-based knowledge discovery can process a variety of unstructured data. However, the current social data volume is growing exponentially. Traditional knowledge discovery technology based on database and opportunity text has been difficult to process massive data.

In recent years, deep learning technology has achieved good results in image recognition, image classification and audio processing, and promoted the application of knowledge discovery in video and audio. We use a two-channel convolutional neural network model to process the pictures and audio in the course video, and realize the automatic recognition of the course names without naming or non-standard naming of video from a large number of course video.

3 Methodology

3.1 The Network Architecture

For video knowledge discovery, CNN-related technology usually adopts multi-channel network structure, and has the following three main characteristics: first, weight sharing, second, local reception field (LRF), and third, pooling operation. CNN generally uses local information rather than global information.

The CNN model we use consists of two channels, picture and audio, which share parameters, The model consists of five convolution layers, each of which is followed by a maximum pooling layer after convolution. After the five convolution layers, a TI-pooling operation is conducted, and then the full connection layer is connected. The CNN model is shown in Fig. 1:

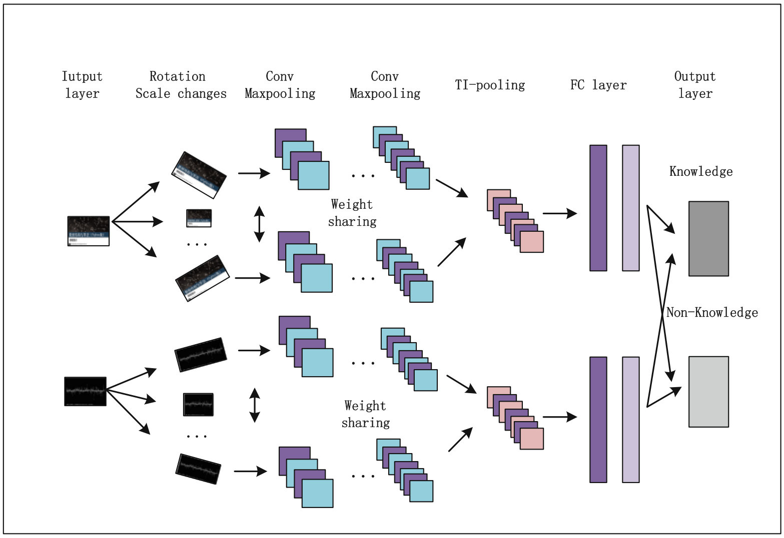

Fig. 1. CNN architecture

3.2 TI-Pooling Operation

In this study we represent features in a convolutional neural network as invariant transformations, which means that the machine learning algorithm only processes inputs that have not changed for some transformations. The most famous examples of general-purpose transformation-invariant features are SIFT (scale-invariant feature transform) [14] and its rotation-invariant modification RIFT (rotation-invariant feature transform) [15].

Because we did some processing on the sample before entering the data into the model, such as rotation, scaling and other changes to enhance the richness of the sample. The goal of TI-pooling is to carry out exhaustive search on the transformed samples to obtain the instance corresponding to the current response of the feature, and then only improve the performance of the feature with this instance.

As shown in Fig. 1, in the CNN model, the original sample and the transformed sample are input together. Instead of considering all the inputs as independent samples, but all the responses of the original sample and the transformed sample are accumulated and the maximum response is taken. Compared with data expansion, TI-pooling operation can learn fewer parameters without the disadvantage of losing relevant information after sample conversion, because it uses the most representative strength for learning.

Assume that, given a set of possible transformations Φ, we want to construct new features g_k (x) in such a way that their output is independent from the known in advance nuisance variations of the image x. We propose to formulate these features in the following manner:

$$g_k(x) = \max_{\phi \in \Phi} f_k(\phi(x)) \tag{1}$$

Where $\phi(x)$ is the input sample x according to a set of transform Φ transform after get the sample, $f_k \phi(x)$ is the input sample characteristics of the model, and TI-pooling ensures that we use the best instance $\phi(x)$ for learning.

3.3 Activation Function

ReLU is an activation function widely used in CNN, but due to the zero-hard rectification, it cannot obtain the benefits of negative values. ReLU simply restrains the negative value to hard-zero, which provides sparsity but results negative missing. The variants of ReLU, including leaky ReLU (LReLU) [16], parametric ReLU (PReLU) [17], and randomized ReLU (RReLU) [18], enable non-zero slope to the negative part. It is proven that the negative parts are helpful for network learning. In this paper we use a new activation function called flexible rectified linear unit (FReLU), FRELU extends the output state of the activation function, adjusts the output of the ReLU function by adjusting the rectifying point, captures negative information and provides 0 features. It has the advantages of fast convergence, high performance, low calculation cost and strong adaptability [19].

As shown in Fig. 2(a), the input is x and the ReLU function is:

$$relu(x) = \begin{cases} x & if\ x > 0 \\ 0 & if\ x < 0 \end{cases} \tag{2}$$

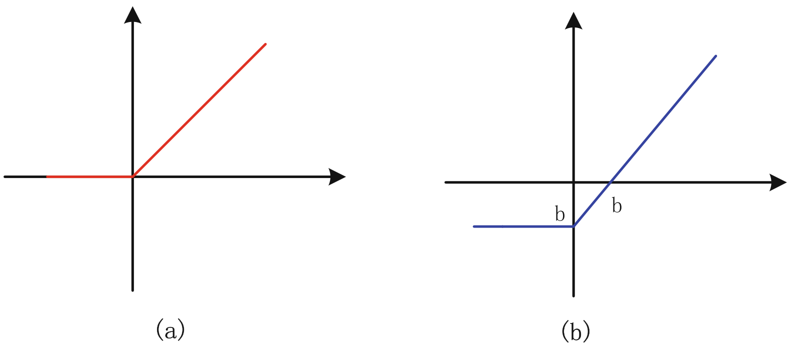

Fig. 2. ReLU and FReLU function images

The FReLU activation function we use is shown in Fig. 2(b). The function is:

$$frelu(x) = \begin{cases} x + b_l & if\ x > 0 \\ b_l & if\ x < 0 \end{cases} \tag{3}$$

where b_l is the l_{th} layer-wise learnable parameter, which controls the output range of FReLU. Note that FReLU naturaly generates ReLU when $b_l = 0$.

3.4 Loss Function

We choose the cross entropy function as the loss function of the training network. The specific function is:

$$\mathrm{C} = \frac{1}{n}\sum_{x}[yln a + (1-y)\ln(1-a)] \tag{4}$$

Where x is the input to the training, y is the output of the training, a is the actual output of each neuron, and n is the entire number of samples trained.

3.5 Back Propagation

Let $\nabla f_k(x)$ be the gradient of the feature $f_k(x)$ defined in Eq. 1 with respect to the outputs $\mathrm{O}(\cdot, \theta_j^{l-1})$ of the previous layer. This gradient is standard for convolutional neural networks and we do not discuss in details how to compute it [20]. From this gradient we can easily formulate the gradient $\frac{dg_k(x)}{df_k(x)}$ of the transformation-invariant feature $g_k(x)$ in the following manner:

$$\frac{dg_k(x)}{df_k(x)} = \nabla f_k(\phi(x)) \tag{5}$$

$$\phi = arg \max_{\phi \in \Phi} f_k(\phi(x)) \tag{6}$$

4 Experiments

The method we used is to input the images and audio of course video into the model. In order to verify the accuracy of the model, we conducted a comparative experiment with the model that only images, only audio, only images and audio but without TI-pooling. The detailed process of the experiment is shown below.

4.1 Data Set

We collected 15 video clips from MOOC of China University, processed the video into 324 pictures and 62 pieces of audio, and marked the picture and audio according to the course name. In order to increase the richness of the sample, we will make the picture and audio. After the rotation and scaling changes, 1296 pictures and 248 pieces of audio were obtained, and then 70% of the samples were selected into the training set, and 30% of the samples entered the test set.

4.2 Parameter Settings

The optimizer of the whole model uses the stochastic gradient descent method. The initial learning rate of the stochastic gradient descent method is set to 0.005, and the learning rate is attenuated by 1×10^{-6} after each update. The batch size of the data set read by the neural network during training is 16. The training data is transmitted to the neural network we use in the form of "sample-tag" for training the network model. The number of iterations is 10^3.

4.3 Experimental Result

To evaluate the effectiveness of the method we used, we compared the model using only images, using only audio, and using images and audio without increasing the TI-pooling operation. The experimental results show that the model we used is identified. Course names are more accurate than other methods. As shown in Table 1:

Table 1. Experimental result

Methods	Accuracy
Image only	61.3%
Audio only	57.7%
Image and Audio(without TI-pooling)	71.6%
Image and Audio(with TI-pooling)	77.4%

5 Conclusion

Identifying course names from a large number of non-naming or naming non-standard course videos can help learners improve the efficiency of resource retrieval and thus improve learning efficiency. In this paper we use a two-channel convolutional neural network model to process the image and audio signals of the course video. The framework adds a TI-pooling operation after all convolutional pooling layers. TI-pooling can Extract the most important features from the course video. The experimental results show that the CNN framework we use can better identify the course name from the course video, thus helping learners to better utilize the video learning resources on the Internet.

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Sparse Linear Method Based Top-N Course Recommendation System with Expert Knowledge and L_0 Regularization

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Abstract. In this paper, we propose an approach of course recommender system for the subject of information management speciality in China. We collect the data relative to the course enrollment for specific set of students. The sparse linear method (SLIM) is introduced in our approach to generate the top-N recommendations of courses for students. Furthermore, the L_0 regularization terms were presented in our proposed optimization method based on the observation of the entries in recommendation system matrix. Expert knowledge based comparing experiments between state-of-the-art methods and our method are conducted to evaluate the performance of our method. Experimental results show that our proposed method outperforms state-of-the-art methods both in accuracy and efficiency.

Keywords: Course recommender system · Sparse linear method
Expert knowledge

1 Introduction

The emergence and rapid development of Internet have greatly affected the traditional viewpoint on choosing courses by providing detailed course information. As the number of courses conforming to the students' has tremendously increased, the above-mentioned problem has become how to determine the courses mostly suitable for the students accurately and efficiently. A plethora of methods and algorithms [2, 3, 11, 15] for course recommendation have been proposed to deal with this problem. Most of the methods designed for recommendation system can be grouped into three categories, including collaborative [1, 8], content-based [7, 14], and knowledge-based [5, 8, 17], which have been applied in different fields such as [4] proposed a collaborative filtering embedded with an artificial immune system to the course recommendation for college students. The rating from professor was exploited as ground truth to examine the results.

Inspired by the idea form [4] and the optimization framework in [9], we propose a sparse linear based method for top-N course recommendation with expert knowledge as the ground truth. This method extracts the coefficient matrix for the courses in the

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recommender system from the student/course matrix by solving a regularized optimization problem. The sparseness is exploited to represent the sparse characteristics of recommendation coefficient matrix. Sparse linear method (SLIM) [9] was proposed to top-N recommender systems, which is rarely exploited in course recommender systems. Due to the characteristics of course recommendation system in Chinese University, our method focuses on the accuracy more than the efficiency. It is different form the previously proposed SLIM based methods [6, 9, 10, 18], which mainly addresses the real-time applications of top-N recommender systems. The framework of our proposed course recommender system is shown in Fig. 1.

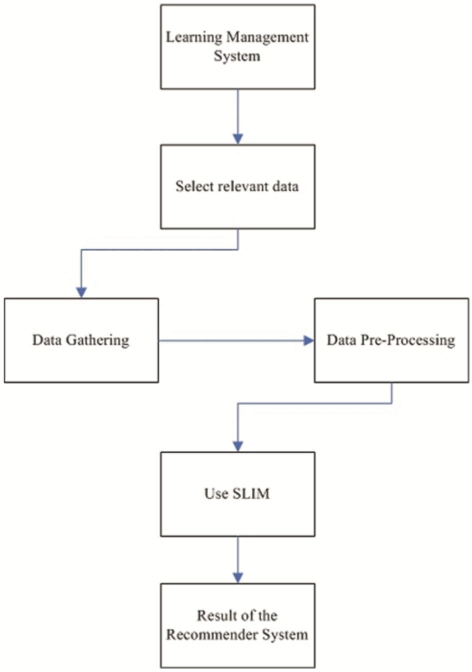

Fig. 1. The framework of our proposed course recommender system

According to our observation about common recommendation system matrix, most of the entries are assigned the same value (zero or one), and the gradients of neighboring entries also hold the same value (zero or one). Therefore, the sparse counting strategy of L_0 regularization terms [16] were included into the optimization framework of SLIM. The L_0 terms can globally constrain the non-zero values of entries and the gradients in the recommendation system matrix, which is the main contribution of our proposed method. Different from the previously proposed regularization terms (the L_1 and L_2 terms), the L_0 term can maintain the subtle relationship between the entries in recommendation system matrix.

After the process of data gathering as shown in Fig. 1, comparing experiments between state-of-the-art methods and our method are conducted. Consequently, both the experimental results of state-of-the-art methods and our method are evaluated with the course recommendations presented by seven experts with voting strategy.

The rest of the paper is organized as follows. In Sect. 2, we describe the details of our proposed method. In Sect. 3 the dataset that we used in our experiments and the experimental results are presented. In Sect. 4 the discussion and conclusion are given.

2 Our Method

2.1 The Formation of the Method

In the following content, t_j and s_i are introduced to denote each course and each student in course recommender system, respectively. The whole student-course taken will be represented by a matrix A of size $m \times n$, in which the entry is 1 or 0 (1 denotes that the student has taken the course, 0 vice versa).

In this paper, we introduce a Sparse Linear Method (SLIM) to implement top-N course recommendation. In this approach, the score of course recommendation on each un-taken student/course item t_j of a student s_i is computed as a sparse aggregation of items that have been taken by s_i, which is shown in Eq. (1).

$$\overline{a_{ij}} = a_i^T w_j \tag{1}$$

where $\bar{a}$ is the initial course selection of a specific student and w_j is the sparse vector of aggregation coefficients. The model of SLIM with matrix is represented as:

$$\bar{A} = AW \tag{2}$$

Where *overlineA* is the initial value of student/course matrix, A denotes the latent binary student-course item matrix, W denotes the $n \times n$ sparse matrix of aggregation coefficients, in which $j - th$ column corresponds to w_j as in Eq. (1), and each row of $C(c_i)$ is the course recommendation scores on all courses for student s_i. The final course recommendation result of each student is completed through sorting the non-taken courses in decreasing order, and the top-N courses in the sequences are recommended.

In our method, the initial student/course matrix is extracted from the learning management system of a specific University in China. With the extracted student/course matrix of size $m \times n$, the sparse matrix W size of $n \times n$ in Eq. (2) is iteratively optimized by alternate minimization method. Different from the objective function previously proposed in [9] shown in Eq. (3), our proposed method is shown in Eq. (4).

$$\min_{W \geq 0} \frac{1}{2} \|A - AW\|_2^2 + \frac{\beta_1}{2} |W\|_F^2 + \lambda_1 \|A\|_1 \tag{3}$$

$$\min_{W \geq 0} \frac{1}{2} \|A - AW\|_2^2 + \frac{\beta_2}{2} |W\|_F^2 + \lambda_2 \|A\|_0 + \mu |\nabla A|_0 \tag{4}$$

Where $\|.\|_F$ denotes the Frobenius norm for matrix, $\|W\|_1$ is the item-wise L_1 norm, $\|W\|_0$ denotes the entry-wise L_0 norm that stands for the number of entries with zero value. The data term $\|A - AW\|$ is exploited to measure the difference between the calculated model and the training dataset. The $L_F - norm$, $L_1 - norm$, and $L_0 - norm$ are exploited to regularize the entries of the coefficient matrix W, A, and ∇A, respectively. The parameters β_1, β_2, λ_2, and μ are used to constrain the weights of regularization terms in the objective functions.

In our proposed final objective function, the L_F norm is introduced to transfer the optimization problem into elastic net problem [19], which prevents the potential over fitting. Moreover, the L_1 norm in Eq. (3) is changed to L_0 norm in our proposed objective function. This novel norm L_0 [12, 13, 16] is introduced to constrain the sparseness of the A and ∇A.

Due to the independency of the columns in matrix W, the final objective function in Eq. (4) is decoupled into a set of objective functions as follows:

$$\min_{w_j \geq 0, w_j j=0} \frac{1}{2}\left\|a_j - a_j w_j\right\|_2^2 + \frac{\beta_2}{2}\left|w_j\right\|_F^2 + \lambda_2\left\|a_j\right\|_0 + \mu\left|\nabla a_j\right|_0 \tag{5}$$

where a_j is the *j-th* column of matrix A, w_j denotes *j-th* column of matrix W. As there are two unknown variables in each Eq. (5), which is a typical ill-posed problem. Thus, this problem need to be solved by alternate minimization method. In each iteration, one of the two variables is fixed and the other variable is optimized.

2.2 The Solver of Our Proposed Method

Subproblem1: computing w_j

The w_j computation sub-problem is represented by the minimization of Eq. (6):

$$\frac{1}{2}\left\|a_j - a_j w_j\right\|_2^2 + \frac{\beta_2}{2}\left\|w_j\right\|_F^2 \tag{6}$$

Through eliminating the L_0 terms in Eq. (5), the function Eq. (6) has a global minimum, which can be computed by gradient descent. The analytical solution to Eq. (6) is shown in Eq. (7):

$$w_j = F^{-1}\left(\frac{F(a_j)}{F(a_j) + \frac{\beta_2}{2}\left(F(\partial_x)^* \cdot F(\partial_x) + F(\partial_y)^* \cdot F(\partial_y)\right)}\right) \tag{7}$$

where $F(.)$ and $F^{-1}(\cdot)$ denotes the Fast Fourier Transform (FFT) and reverse FFT, respectively $.F()^*$ is the complex conjugate of $F(\cdot)$.

Sub-problem 2: computing a_j and ∇a_j

With the intermediate outcome of w_j, the a_j and ∇a_j can be computed by Eq. (8):

$$\frac{1}{2}\left\|a_j - a_j w_j\right\|_2^2 + \lambda_2\left\|a_j\right\|_0 + \mu\left\|\nabla a_j\right\|_0 \tag{8}$$

By introducing two auxiliary variables h and v corresponding to the column vector a_j and ∇a_j. The sub-problem can be transformed into Eq. (9):

$$\frac{1}{2}\left\|a_j - a_j w_j\right\|_2^2 + \lambda_2\left\|a_j - h\right\|_2^2 + \mu\left\|\nabla a_j - v\right\|_2^2 + \lambda\left(\|h\|_0 + \|v\|_0\right) \tag{9}$$

To testify the performance of our proposed method, comparing experiments between state-of-the-art methods and our method are carried out with gathered dataset and expert knowledge. In the following section, the experiments are described in detail.

3 Experimental Results

3.1 Datasets

In order to testify the performance of our proposed method and implement the method in practical scenarios, we gather the data from five classes of information management specialty for the learning management system of our University. The data records of the

Table 1. The initial dataset from the five classes

No.	SPSS	CH	Eng	LA	PT	DB	CC	PE	C	Acc	CS
1	1	1	1	0	1	0	1	1	0	1	0
2	0	1	1	0	1	0	1	1	1	1	0
3	0	1	1	0	1	1	0	1	0	1	0
4	0	1	1	0	1	1	0	1	1	1	0
5	1	1	1	1	1	0	0	1	1	1	0
6	1	1	1	1	1	0	0	1	1	1	1
7	0	1	1	1	1	0	0	1	1	1	1
8	1	1	1	1	1	1	0	1	0	1	1
9	1	1	1	0	1	1	1	1	0	1	0
10	1	1	1	0	1	1	1	1	0	1	0
11	0	1	1	0	1	0	1	1	0	1	0
12	0	1	1	0	1	1	0	1	0	1	1
13	0	1	1	1	1	0	1	1	0	1	1
14	1	1	1	1	1	1	1	1	0	1	1
15	1	1	1	1	1	1	1	1	0	1	1
16	0	1	1	0	1	1	1	1	0	1	1
17	1	1	1	1	1	1	1	1	0	1	1
18	0	1	1	1	1	0	1	1	0	1	0
19	1	1	1	0	1	1	1	1	0	1	0
20	0	1	1	1	1	0	1	1	0	1	1

courses and students were extracted from the Department of Management Information System, Shandong University of Finance and Economics and the Department of Electronic Engineering Information Technology at Shandong University of Sci&Tech. The most important information of the courses and students is mainly about the grades corresponding to the courses. All of the students from the information management specialty are freshmen in our University. Most of them have taken the courses of the first year in their curriculum except three students have failed to go up to the next grade. Thus, firstly we eliminate the records of the three students. Meanwhile, we collect the knowledge including the programming skill that they have mastered through a questionnaire. The courses that they have taken and the content that have grasped are combined in the final datset. A part of the dataset is shown in Table 1, where 1 denotes that the s_i student has mastered the t_j course, and 0 denotes the opposite.

After gathering the data of the students from the five classes, comparing experiments between state-of-the-art methods and our method are conducted. We choose several state-of-the-art methods including collaborative filtering methods itermkNN, userkNN, and the matrix factorization methods PureSVD.

3.2 Measurement

The knowledge from several experts on the courses in information management specialty are adopted as ground truth in the experimental process. To measure the performance of the comparing methods, we introduce the Hit Rate (HR) and the Average Reciprocal Hit-Rank (ARHR) in the experiments, which are defined as shown in Eqs. (11) and (12).

$$HR = \frac{\#hits}{\#students} \tag{11}$$

where *#hits* denotes the number of students whose course in the testing set is recommended by the expert, too. *#students* denotes the number of all students in the dataset.

$$ARHR = \frac{1}{\#students} \sum_{i=1}^{\#hits} \frac{1}{p_i} \tag{12}$$

Where p_i is the ordered recommendation list.

3.3 Experimental Results

In this section, the experimental results calculated from the practical dataset. Table 2 shows the experimental results of the comparing methods in top-N course recommendation.

Table 2. The performance of the comparing methods

Methods	HR_1	$ARHR_1$	HR_2	$ARHR_2$	HR_3	$ARHR_3$	HR_4	$ARHR_4$	HR_5	$ARHR_5$
itemkNN	0.18	0.13	0.19	0.14	0.20	0.13	0.18	0.13	0.19	0.14
Itemprob	0.21	0.15	0.19	0.16	0.21	0.14	0.19	0.12	0.17	0.13
PureSVD	0.09	0.11	0.10	0.12	0.12	0.12	0.17	0.14	0.18	0.15
SLIM	0.24	0.16	0.17	0.18	0.24	0.19	0.16	0.14	0.17	0.15
ours	0.27	0.17	0.19	0.17	0.25	0.18	0.20	0.14	0.19	0.15

Where HR_i, $ARHR_i$ denotes the performance for $class_i$, respectively. The experimental results shown in Table 2 demonstrate that our proposed method outperforms state-of-the-art methods in most of course recommendations both in the HR and ARHR. It shows that the sparse regularization term based on the prior knowledge from the observation in our method are suitable for solving the problem of course recommendation.

In order to illustrate the performance of our proposed method according to the number of courses and topics included in the experimental testing. It shows in Fig. 2 that a higher accuracy is obtained when the number of courses increases. Meanwhile, the courses included in our experiments are divided into 32 different topics, Fig. 3 shows that the accuracy is also higher when there are more relative courses.

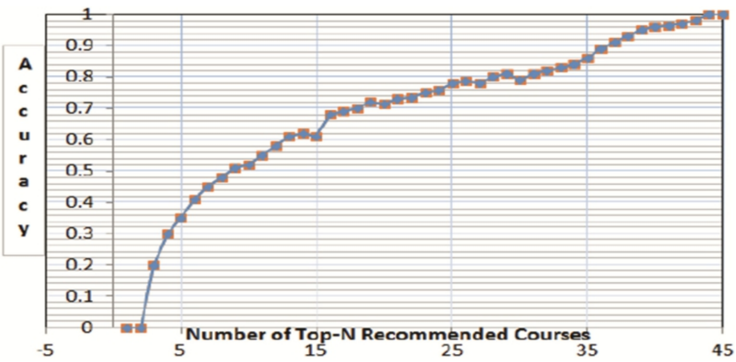

Fig. 2. Accuracy of our proposed recommendation system method due to the number of courses

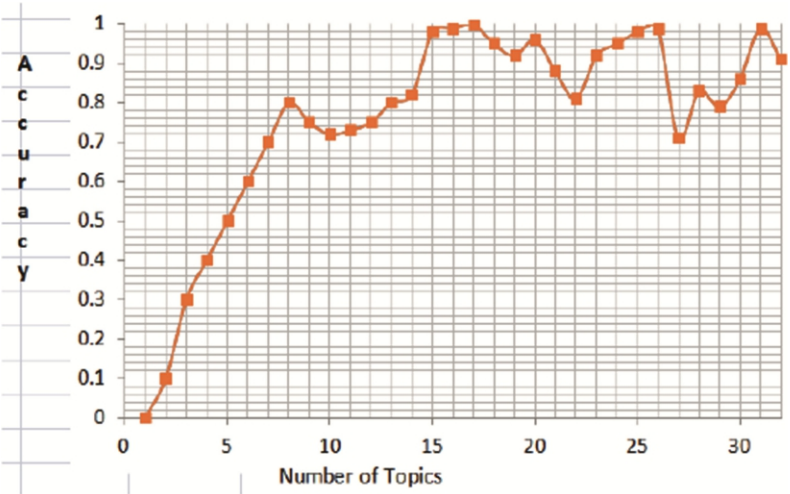

Fig. 3. Accuracy of our proposed recommendation system method due to the number of topics

4 Conclusion

In this paper, we propose an approach of course recommendation. In our method, the SLIM was introduced and a novel L_0 regularization term was exploited in SLIM. Meanwhile, the alternate minimization strategy is exploited to optimize the outcome of our method. To testify the performance of our method, comparing experiments on students from five different classes between state-of-the-art methods and our method are conducted. The experimental results show that our method outperforms the other previously proposed methods.

The proposed method was be mainly used to implement the course recommendation for the Universities in China. However, it also can b exploited in other relative fields. In the future, more applications of our approach would be investigated. Other future work includes the modification of the objective function in our method including the other regularization terms and different optimization strategy.

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Mobile Leaning knowledge architecture Construction and resource Integration in Information Management and Information System

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Abstract—**As a novel learning method, mobile learning will definitely become one of the most important part of learning based society. In this paper, we firstly analyze the disadvantage of the traditional in-class teaching pattern, aiming at Information Management System to research the mobile learning based knowledge architecture construction and related resource integration. According to the current curriculum architecture, we systematically review all of the subjective courses and relative knowledge modules, which contributes in organizing whole relationship among all of the modules, constructing the connections and improving the whole knowledge architecture. Our proposed plan would be beneficial in solving the problem existing in traditional in-class teaching pattern.**

Keywords- Mobile learning; Information Management and Information System; Knowledge Architecture

I. INTRODUCTION

According to the current curriculum architecture, we systematically review all of the subjective courses and relative knowledge modules, which contributes in organizing whole relationship among all of the modules, constructing the connections and improving the whole knowledge architecture. Our proposed plan would be beneficial in solving the problem existing in traditional in-class teaching pattern.

Along with the development of computer networking and wireless communication, intelligent mobile terminal has greatly changed our living style and working method [1-2]. Based on the mobile learning technique, learning with the mobile terminal has been paid attention by more and more people, and mobile learning has become one of the novel learning methods in learning based society. In 2000 [3], the report D-learning. E-learning. M-learning presented by remote learning expert Desmond•Keegan was introduced into China, after that mobile learning has been one of the most popular research hotspot in China. Mobile Learning means to implement the Anyone, Anytime, Anywhere, and Any style (4A) freely learning, which can supply the learners with time-oriented, place-oriented, and person-oriented learning environment, and dynamically construct the brand new learning and teaching pattern.

There have been various successful mobile learning cases, such as [4]the project of MOBILearn in EU, and[5] the mobile education project presented by Chinese Ministry of Education, which theoretically and practically explore the teaching design, content development, platform implementation, architecture evaluation and business pattern of mobile learning architecture, respectively. On the other hand, the hand hold augmented reality simulation game project by MIT, America and the butterfly observation live learning support system project by National Tsing Hua University, focus on specific content based virtual reality, simulated game scene, they emphasize on the natural fusion of learning and substantial scenario. Their research content aims at making use of the facility of the mobile devices in functionality such as information acquisition and mutual discussion. The project presented in China, including the mobile education by Ministry of Education stress on the implementation of teaching supportive system, the commercial project by corporation such as the family of mobile learning by Nokia Inc., focuses on informal learning or casual learning of English and other fashion design. At present, the researches and projects in China hardly relate to the formal educating activity, especially the fusion with the courses of in-school courses, the width and depth of the mobile learning based teaching and practicing researches and projects need to be extended in the next following phases.

The content of Information Management and Information System covers up management and computer science, etc. It has obvious characteristics of inter-discipline, following with the rapid development of networking technique and micro-electronic technique, management, computer software and theory are interconnected with each other deeply and broadly, which all contribute in changing the theory and technique in Information Management and Information System.

Currently, most of the Universities in China are exploring how to cultivate and raise the creative talents of Information Management and Information System under the new era. In recent several years, some Universities are carrying out applied talent raising and extraordinary engineer plan based teaching researches and projects of different levels, aiming at this problem and combining with self practical condition we perform similar teaching reform exploration. The reform includes the talent raising pattern in Information Management and Information System, Curriculum architecture construction, curriculum optimization, practical teaching arrangement, etc. Some of the projects put forward utilizing the modern teaching method and constructing

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network based teaching platform, such as online learning and mobile learning both are remote educational patterns. Mobile learning emphasizes on the personal learning, which is the extension and development of online learning, can help the learners to realize the learning process anytime anywhere. At present, there are rarely this kind of researches and explorations especially in Information Management and Information System.

Nowadays, the construction of Information Management and Information System in each University of China usually follows as: from fundamental to professional, from simple to difficult, based on which the curriculum architecture of Information Management and Information System is divided into Common Fundamental, Specialty Fundamental, Specialty Optional, and Practical Section, etc. The courses in raising plan are systematically related with each other, but in the implementation process we commonly observed that the students are lack of systematical understanding and acquiring, meanwhile they have no knowledge about the relationship among the courses and the fundamental requirements, and they always present the problems that the knowledge are discrete and what can they do after graduation or where to find the job.

In this paper, according to teaching and analyzing of the author, we confirm that the existing problems relates to the constraint of traditional teaching pattern. Thus, we firstly analyze the constraint of traditional teaching pattern in Information Management and Information System, researching on the knowledge architecture construction and resource integration based on mobile learning, according to the current curriculum architecture, we systematically review all of the subjective courses and relative knowledge modules, which contributes in organizing whole relationship among all of the modules, constructing the connections and improving the whole knowledge architecture. With the learning requirement of students, getting rid of the textbook-centered teaching method, constructing the mobile learning based specialty knowledge learning resource, we emphasize on the forming process of teaching knowledge. Aiming at the different emphasizing directions of this specialty, we construct the web based knowledge architecture. Based on the intactness and practicality of specialty knowledge, guiding the students to carry out self learning, leaving them with free space of thinking, cultivating the creative thought and creative ability of the students with inspiring teaching. The implementation of the project can effectively solve the problems existing in traditional in-class teaching pattern.

II. EXISTING PROBLEMS IN TRADITIONAL CLASSROOM

The problems include:

(1) Under the traditional in-class teaching pattern, the teachers utilize the instructing and experimenting to teach the students relative knowledge of specific specialty. According to the abstract theory, dynamical process description, integration, and designing experiments of specialty courses in Information Management and Information System. The students have difficulties in understanding the content, lacking of practicality. With the mobile learning pattern , the teachers and students all can make use of the resource platform with different multimedia materials (animation, simulation, audio and video, etc) to learn specific knowledge module, the students can utilize the mobile devices to learn anytime and anywhere, which can effectively enhance the learning result.

(2) In traditional in-class teaching pattern, according to the constraint of semester arrangement, the time interval of some courses is extensively long. There are disconnections of preliminary and successive courses, omitting of the important knowledge points, thus the teachers always need to review, retrospect consistently, which affects the learning efficiency. Otherwise, with the current evaluation and feedback mechanism, after completing the course the students can only clearly understand self learning situation with the score of final exam, which makes them ignoring the knowledge points if they pass the exam, without successive guidance and lack of knowledge points the student cannot comprehend enough content. On the other hand, with the mobile learning based specialty knowledge architecture resource, the students and teachers can communicate with the same learning platform, the teacher can teach the students online, and according to the different requirement of different specialty and employment they can elaborate the knowledge differently. The students can choose the learning resource optionally anytime and anywhere, breading the wall of before class, in-between class, and after class and barrier between preliminary course and successive course.

(3) In traditional in-class teaching pattern, in order to satisfy the covering of knowledge in determining the raising plan, there are various specialty courses. But the students did not get enough guidance of choosing optional courses, which makes them lack of systematical understanding of the specialty learning. Mobile learning based knowledge architecture should be constructed with different directions and webbed knowledge architecture, guiding the students to clarify their own learning direction and carry out systematical learning, and effectively extend their knowledge.

(4) Because the teachers have to think about the employment and graduation of the students at the same time, they usually require the students to comprehend the knowledge points similarly, which is lack of personal guidance and unbeneficial to teaching according to personal requirement and condition. With the mobile learning platform, the teachers can broadcast the knowledge modules according to the different specialty and employing requirement, and the students can choose voluntarily. Exploiting the mutuality of the platform, the students and teachers can execute one by one learning and teaching procedures, which can realize the personal teaching and customizing teaching.

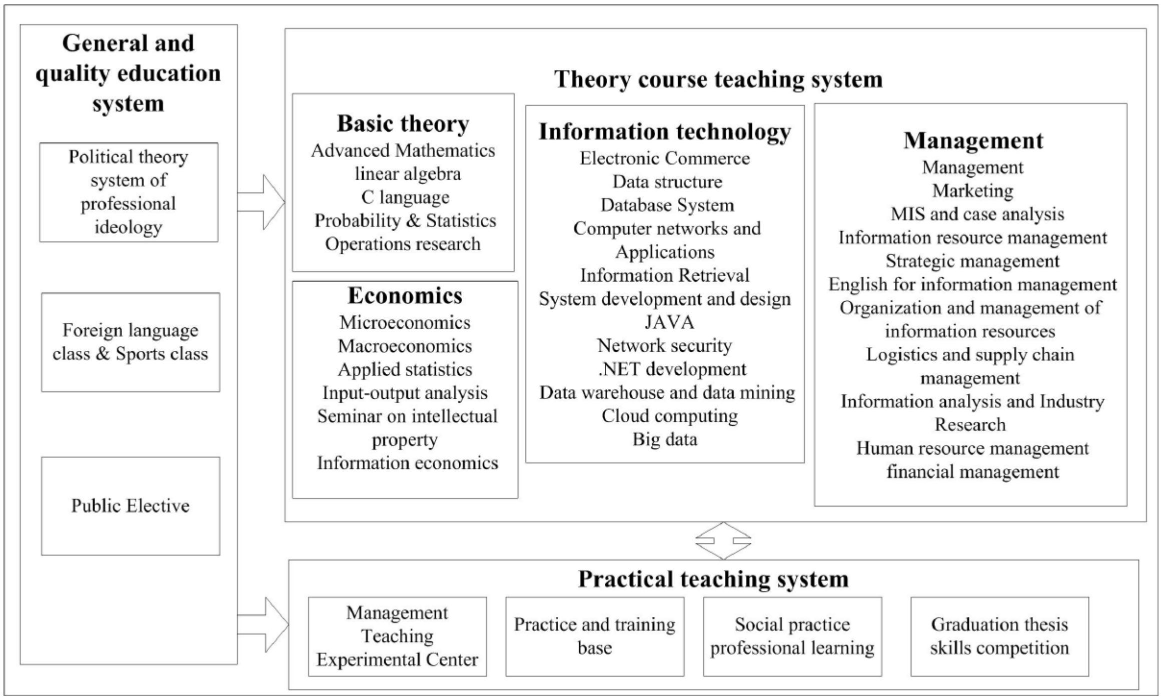

Figure 1. Information Management and Information System specialty teaching architecture.

Meanwhile, mutual learning and collaborative learning with the mobile terminals can transfer the passive learning into active learning, which can stimulate the interest and enthusiasm of the students, would be beneficial to the cooperation and creativity of the students. Through the research and exploration of this project, we can implement the fusion of foreign advanced teaching methods and resources, which can enhance the comprehensive ability of the student and the teaching research level of our University, finally it can improve the educating quality entirely.

III. Information Management and Information System Specialty mobile learning based resource construction

Our University began to enroll the students of Information Management and Information System from 2005. According to the requirement of Shandong Province High School and social economy development, as a provincial school our University clearly presented that we should raise advanced practical and creative talents in our planning. Therefore, aiming at Information Management and

Information System we should stand up on the localization of our University, fully make use of the characteristics and advantage of our specialty, effectively utilize the inter-discipline characteristics of Information Management and Information System, to cultivate the students with ability of information technique and management, advanced practical talents for the area economy development would be our optimal arrangement and position.

During about one decade of development, we insist on the specialty construction guiding thought, which is based on cultivating the talent, integrating the knowing with practicing,

teaching researching, and serving the society in harmony. Oriented with the social requirement, organizing openly, creating talent raising pattern, based on the persons, chasing the personal development and fully development of the students, we continually accumulate and cultivate the specialty characteristics of Informative society requirement oriented, practical teaching and practical information system developing ability of the students emphasized, and the fusion of information technique and management. Figure 1 shows the specialty teaching architecture of Information Management and Information System in our University.

Figure 1 can demonstrate that the knowledge in Information Management and Information System is broad, meanwhile the development of information technique is rapid, the teaching tasks and quantity are heavy, and the time of teaching specialty courses is short. Therefore, aiming the shortage of in-class teaching pattern, combing with the specialty teaching architecture of Information Management and Information System, we research on the specialty talent raising objective of Information Management and Information System under new situation, and construct the mobile learning based specialty knowledge architecture. In above-mentioned architecture, the fundamental theory platform can construct mobile learning resource, which are chosen from foreign famous teachers, combined with traditional in-class teaching, increase the diversity of learning and decrease the dullness of theory learning for the students. For the information technique platform part, the updating of corresponding knowledge is rapid, so we should construct the resource as much as possible and not constrained by the above listed content, we also should construct the resource based on the interest of the students, which would contribute to solve the problem that there is not enough individual teaching. The students can acquire the resource following their own requirement. We would increase practical cases of learning resource, which can impress the students directly and can benefit them further. Management and Economics platforms can construct the mobile learning resource with fundamental theory platform, but they all must combine with the traditional in-class teaching, if the mobile learning resource is independent there would be not good effect. Above all, the resource we construct is mainly exploited to support the in-class learning of the students.

The front-mentioned learning resource can be effectively used by the students. Under the traditional in-class teaching pattern, the students mainly make use of paper textbook, the material supplied by teachers, PPT, Flash and other video materials to learn. But in the mobile learning based pattern, the brand of the terminal, platform, monitor, processing ability and battery life time are different from each other, thus the mobile learning resource has the characteristics of intactness, conciseness, short but completeness, real time mutuality, and personality. Therefore, after fully researching and analyzing the characteristics of mobile learning based terminal and the requirement of mobile learning, with the fundamental units of knowledge module of mobile learning, adopting and introducing current foreign teaching methods and resource, we develop the knowledge module based visualized mobile learning resource, The content of very knowledge module is relatively complete and independent, they also have interior connection and logic. The mobile learning resources are diverse, including text, picture, audio, video, animation, document, experimental case, and learning app, etc.

To enhance the interest and enthusiasm of students, we supply them with online seminar, forum, group discussion, importance and difficulty analysis, online test, kinds of mutual learning, the students can communicate with the teachers about specific problem under one by one tutoring, the students can discuss, co-assistant, co-evaluate with each other, which all play important roles in the feedback during teaching and leaning.

IV. CONCLUSION

In this paper, after analyzing the existing problems in traditional in-class teaching and exploiting state of the art Internet and other relative techniques, we transfer the traditional Information Management and Information System education to Internet. First of all, According to the current curriculum architecture, we systematically review all of the subjective courses and relative knowledge modules, which contributes in organizing whole relationship among all of the modules, constructing the connections and improving the whole knowledge architecture. Secondly, focusing on the difference among individual mobile resource, we render the learning resources in diverse ways. And to motivate the interest and enthusiasm of the students, we supply them with multiple mutually learning methods. Our proposed plan would be effectively and efficiently in solving the problem existing in traditional in-class teaching pattern.

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The Construction and Implementation of Seminar Teaching Model for Information Management and Information System Specialty

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ABSTRACT: In our project, we focus on the information management and information system subject in our University, we propose the Seminar teaching model, the scientific definition of this model, the implementation principles of this model and we are practicing this model in reality. It should play an vital role in raising specialized talents with high quality and creative skill, and render important standardization meaning.

1. INTRODUCTION

Chinese higher education has already stepped into the Era of the Missification with rapid and overall development; Meanwhile, along with the development of national construction and economy, we do need more specialized talents with higher quality and ability (Lin, et al. 2014a, b, c）. Thus, how to reform the talents raising model under such development situation, and to seek advanced teaching skills have become one of the most important aspects that we should focus on. And exploring the raising model and teaching methods are playing vital roles in current time, they are valuable and meaningful for all of us.

In “Shi Shuo” from HanYu, it says “What are the main functions of teachers? They should at least consist of teaching, transmitting, and exploring.” It is simple but deep explanation of what a teacher should be and should do. It is also the refined summary of Chinese traditional teaching model from thousands of years ago. This model exists in modern Chinese education. It has played an crucial role in raising the socialism constructors with comprehensive knowledge in China. To understand this model fully, we can conclude that good teachers should speak out and speak well, and good students should learn well thoroughly. Above all are the fundamental requirements of our traditional education (He, 2002; Haidi, et al. 2008), they are also the basic content of current evaluation of teaching quality. We should not deny the advantages of this model, but we also can not avoid talking about the disadvantages of this model, either. And with the development of modern education, the disadvantages are affecting more severely. In this mode, the functions and roles of teaching are emphasized too much, and the activities of students have been neglected. Especially, with the development of modern society, more and more knowledge is accumulated to even explosion level. The knowledge that the students can learn in limited time has fallen behind the development of knowledge. And traditional education can not solve the inherent contradiction of itself. For example, teachers always complaining about insufficient time, incomplete content, meanwhile students complaining about overloaded content and fast teaching speed, tedious, and boring process, etc. But, somebody has done relative experiments and the results show that there is only 20 percent time of the students has been used to concentrate on learning the content from the teachers, and the results also tell us that the students can not tolerate the one direction teaching model, they are not interested in this kind of teaching any more, which is the main source of the above mentioned contradiction between teaching and learning. Specially, as the settlement of raising plan in our University, and the guideline to all subjects in our University, this is kind of contradictions would be more obvious than ever before. It is the important issue that we are facing to eliminate the contradiction. And the improvement and exploration of teaching model should be one of the effective ways to us. So in this paper, we propose one teaching model based on Seminars, and corresponding teaching plans for Information management and information system subject, the proposed model would render powerful meaning to raising talents with high quality, creative ability, and teaching standardization such as Figure1.

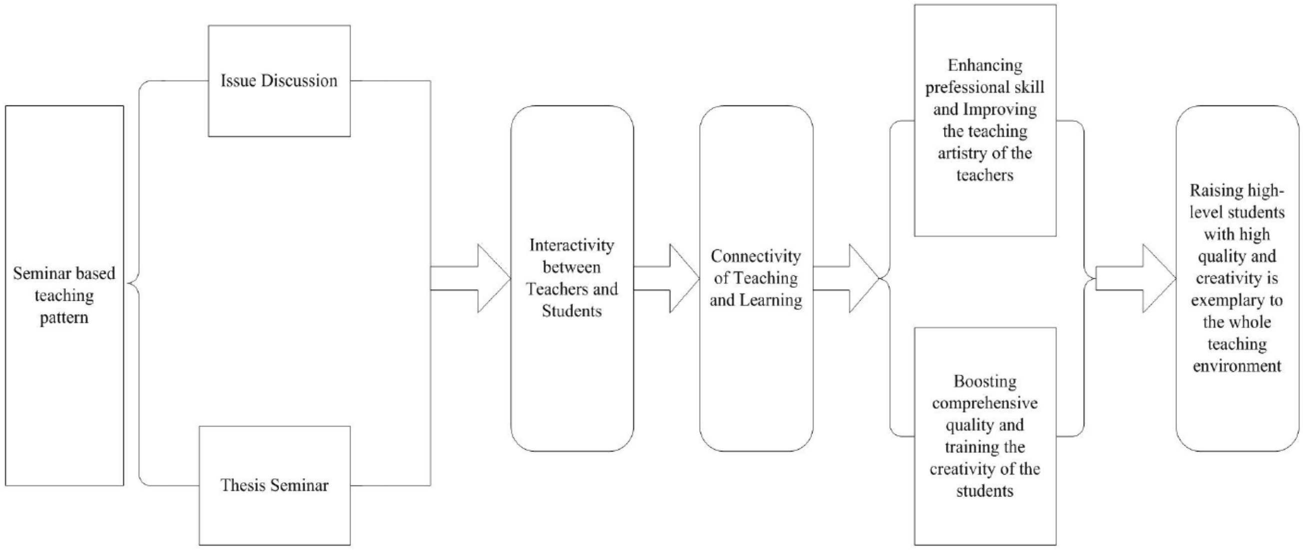

Figure 1. The powerful meaning to raising talents with high quality, creative ability, and teaching standardization.

2. GETTING STARTED RELATED WORKS

Among the teachers and students in Harvard, US, there is one famous saying, "the one real object of education is to have a man in the condition of continually asking questions (Zhu, 2008)." In China, because of the impacts of traditional education ideas, the teachers over emphasize on the teaching of knowledge itself. They turn the active, dynamic, interacting language related activities into tedious, boring broadcasting of knowledge. They do not encourage the students to bring problems, they also do not advocate the students to think or discuss independently, and finally they make the teaching into embarrassing situation. Under the dominance of this mode, the students are reluctant to raise new problems or discussion. In contrary, teaching model based on Seminars do encourage the students to ask questions, to think, to discuss, to explore, which all contribute to develop the students' talents and abilities, and it can help to form the active scenes of classrooms.

This mode is not one new teaching method. It had been adopted by western Europe from 17 century. Bruback (American Educator) presented that the most fabulous teaching art is encouraging the students to raise their own problems. From 50's of 20 century, Seminar has been adopted in China education system, but affected by the traditional education idealism, this model has not been utilized widely and thoroughly. In current years, plenty of primary school and middle school students of literature and history subjects have began to explored and practiced this mode, have achieved great effect, including some papers and practical experience, but the implementation of this model in Universities and colleges is still rare to see (Kirschner, et al. 2006).

Thus, how to effectively promote the application in Universities still need much more experiments and experiences, the effects also need to be evaluated in the future.

In our project, we focus on the information management and information system subject in our University, we propose the Seminar teaching model, the scientific definition of this model, the implementation principles o this model and we are practicing this model in reality. It should play an vital role in raising specialized talents with high quality and creative skill, and render important standardization meaning. After exploration, practicing of last two years, we have achieved considerable teaching experiences and operative teaching results, and it would achieve more satisfactory effect, meanwhile it would also help to guide relative teaching processes, and contribute in raising the learning interests, enhancing the creative ability, and comprehensive quality of the students.

3. CONSTRUCTION AND IMPLEMENTATION PLANING OF SEMINAR TEACHING MODEL - FOR INFORMATION MANAGEMENT AND INFORMATION SYSTEM SPECIALTY

Seminar based teaching model should include researching topics from the teachers or students, discussion, self-exploration, implementing the research plans, completing the objectives and learning plans, satisfying the requirements, enhancing the practical ability. In this paper, we propose two ways to implement the teaching model:

3.1 *Topic based Seminar: students into groups—assigning the topics by the teachers—browsing the relative materials by students(including learning and summarizing the relative knowledge, and writing out the topic reports)—discussion in groups—topic seminar—evaluating the students by the teachers.*

The teachers mush firstly analyze and plan the teaching content at macro level based on studying the curriculum and textbooks in prior, and they should be familiar with the corresponding theories and materials, based on the researching topics they can bring the advance researching results into teaching process, they must also determine the topic problems used in the Seminar scenarios, give out the subtle problems, assign the topic content, above mentioned issues all need plenty of energies and spirits. The teachers should create well designed contextual environments, and stimulate the students to explore actively with self motives, and help to supply with the supporting materials to the students. Discussion is the main stem of learning, it consists of three aspects: (1) learning relative content from the textbooks, to understand the problems through observing, analyzing, and experimenting. (2) exploring according to topics till satisfactory answers to the problems are found out. (3) practicing according to topic, including topic reports and self discussion. In the seminars, the group leader should pay attention to take the records. After the group leader(in turns) give the conclusion, the teachers can give supplement, based on the seminar process, the teachers can give conclusion and emphasis furthermore, and try to find out the inherent relationship among the discussions from higher level, and finally the teachers evaluate the topic reports and presentations of the students.

3.2 *Problem based Seminar: students into groups—teaching simply and instructing by the teachers—self learning the relative materials by students and proposing the relative problems—discussion in groups—concluding by the teachers—evaluating the students by the teachers.*

In this paper, we propose a novel teaching method, which theoretically is based on the constructivism of teaching-learning theory and cognitive tool theory, whose principal part is the students and guided by the teachers, it encourages independent researching and problem solving of the students. This method is comprised of following six aspects: a great deal of preliminaries taught by the teachers, sufficient considering time given to the students, problems raised by the students, the discussion with or without conclusion, the evaluation of the problems and the group members given by the academic advisor or teachers.

Thus our proposed teaching pattern not only pays attention to "what to know", it also concentrates on "how to know", it is mainly about teaching the students to mastering the knowledge and learning skills. Through the Initiative participation practical experience of the students to promote the dynamical construction of the science knowledge. The flow chart of our proposed teaching pattern is illustrated in Figure 2.

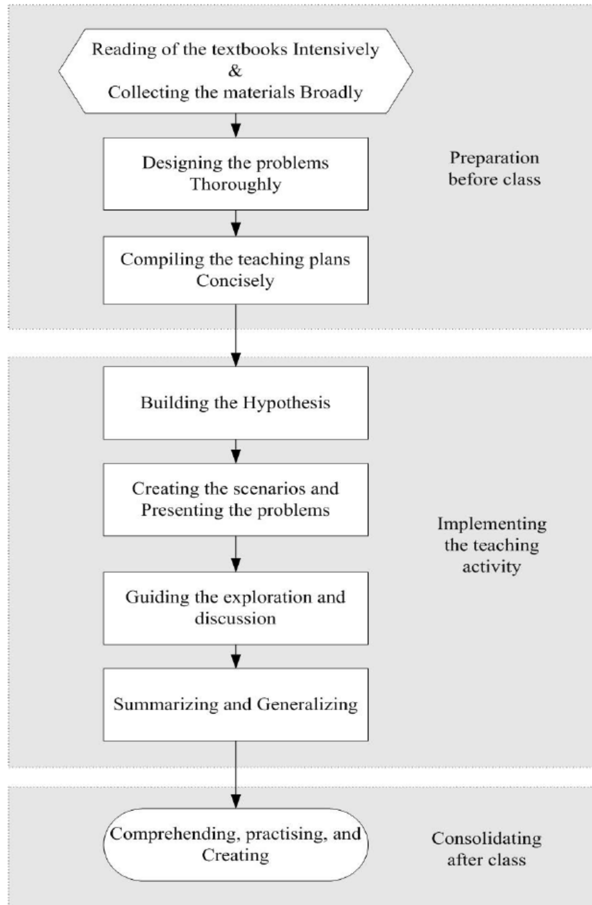

Figure 2. The flow chart of our proposed teaching pattern.

4. CONCLUSION

Problem based seminar teaching model is one teaching method that can be used to stimulate the interests and motives of the students to learn by themselves. The keynote of this model is to reform the framework of traditional teaching by innovations of curriculum and teaching processes, form one brand new teaching idealism, i.e. to instruct the students to explore and discuss by themselves. It emphasizes the interactions between teachers and students, guarantee the students to join in the teaching activities actively, it can develop the enthusiasm of the students and the teachers. In this paper, we try to explore the bilateral process of teaching and learning, we give specific implementation plans, which all can effectively enhance conscious activities of the students, subjective initiatives of the teachers and activate the classroom atmosphere.

5. ACKNOWLEDGEMENTS

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An Information Professional Personnel Training Mode Based on Social Requirement of Independent Colleges

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***Abstract*—In recent years, whether the graduate are needed by the society has become more and mor concerns. In this paper, combining the students of independent colleges and our education practice, the social requirement oriented training mode is proposed. we construct and improve the pattern both conforming the practical needs of current economic society and reflecting the training characteristics based on the social requirement for Information Management and Information System talents of different majors and levels.**

Keywords-information management and information system, personnel training mode, social requirement, independent college

I. INTRODUCTION

Personnel training mode, which determines the basic characteristics of the trained object, is the specific implement way of colleges and universities to train the students' knowledge, ability and quality structure. Personnel training mode based on social requirement enhances the pattern with social requirement oriented education construction and talent management, meanwhile implement the suitable principles and flexibility in the whole process.

In recent years, the employment for graduates has become one of the major concern of the society. Essentially, the problem is related to structure rather than quantity. And the main reason is that for these years, the major setup and training mode always follows the supply oriented principle, which causes the divorce between major setup and market requirement. Traditional Personnel training mode, knowledge structure and quality structure cannot satisfy the practical needs of our economic development. Therefore in order to solve the problem we should focus on making use of the information from labor market, construct and create the requirement oriented personnel training mode according to social requirement principle and improved high education system. In other words, the education department should adjust the content of subject, major and course in time, which can satisfy the market requirement, based on the dynamical market demand. Obviously, to construct the market signal generation mechanism, transmission mechanism and adjustment mechanism, we need the construction of requirement oriented education mechanism and creative personnel training mode.

At present, knowledge economy trains and develops rapidly with brand new gesture, and goes through explosive expansion. Following the hierarchically development of new technology revolution and continuous change of economy structure, even in rapidly developed information management field the employment situation of graduates is terrible now, and intense competition, overall quality and society adaptability have become the most important factors in information management talent requirement and competition[2]. Under the situation discussed above, the overall information management major talents who has complete knowledge structure, acute creative consciousness and spirit, perfect personality and strong society adaptability, can be competent the corresponding position and be accepted by the market. Therefore, in the education practice in financial colleges, we should pay attention to the economic development frontier and grasp the market requirement direction, which can help us to construct and improve the pattern in order to conform the practical needs of current economic society, reflect the training characteristics based on the social requirement for Information Management and Information System talents of different majors and levels.

II. RESEARCH STATUS

Currently, there have been plenty of discussion and researches relative to personnel training mode [3,4]. In general, the pattern includes three main factors: teaching principle, teaching pattern and culture environment. Most of the researches insist that the talent training in colleges and universities should focus on following aspects: to face the society reality, to stress interdisciplinary and ability, to enhance practice, to cultivate team spirit and creativity.

At present the problems in researches on information management and information system personnel training mode are:

A. Fuzzy professional positioning

In "Specialty catalog and introduction of undergraduate course of common colleges and universities" presented by Chinese Ministry of Education[1], the training objectives of information management and information system have been given thoroughly, but the content is highly generalized and broadly. Many professional teachers in universities would misunderstand the content in the making process of major training plan and teaching outline, which makes the students of this major especially the freshmen confused about the subject development and future occupation direction. At the same time, many teachers in information management and information system originally are from management major or computer major, so they usually they would start from the original major stand and divide the new major into management and computer parts. But practically, information management major not only needs computer based information technique courses but also stress the ability of management information system design and implementation.

In the professional talent training process, most of the plan and course architecture in colleges and universities have flaws. Firstly, the courses arrangement, most of which have not arranged the guide courses and subsequent courses as knowledge acquirement behavioral habit. Secondly, they do not pay attention to practice teaching, and neglect the interdisciplinary features of the major, which all make the students lack of the ability of knowledge application and necessary means of comprehensive ability. Thirdly, the connection between the major courses is not deep enough, especially between the fundamental theory and information technique courses, which make the students hard to apply their knowledge in design and implementation, confines the enhancement of their ability.

Analyzing from the practical perspective, information technology has been applied broadly in modern enterprise management, and the management concept, ideas and means have changed totally. Information technology has also deeply affected every aspect of the current economic society. So how to train students, who have rapid adaptability to science and technology development and conform to the society requirement, is one of the important projects in information management major talent train.

B. Chaos pattern

Now the information management major positioning mainly relates to three kinds of courses: the first kind is general education courses, such as: higher mathematics, foreign languages and political courses; the second kind is economy management courses, such as: Management, Economics, Accounting and Financial Management; the third kind is information technology courses, such as Programming, Operating System, Networking and Database, etc. And in this pattern there is no effective interdisciplinary professional course architecture, but the courses are simply meld, the connection between them is not solid and the knowledge architecture is incomplete, too. And the information management and information system major train plans of the colleges and universities are different from each other, and the perspective differs, too. In "Specialty catalog and introduction of undergraduate course of common colleges and universities" of 1998, the courses includes: Economics, Accounting, Marketing, Operation Management , Organizational strategy and behavior, Principle of Management, Application of mathematical statistics, Operation research , Computer system and software, Data structure and Database, Computer networking, Information Management, Information Organization, Information storage and retrieval, Management Information System analysis and design, etc[1]. And the courses should be divided into following modules: economics knowledge module, management knowledge module, computer knowledge module and information management knowledge module, each college and university has their own opinion to the plan.

In the plans, the colleges and universities have agreed that there should be fundamental quality knowledge module, modern information knowledge module, information management and information system major knowledge module and major background knowledge module in the final plan, through which we can understand that the main objective of major training is to construct the systematic structure of major knowledge.

C. Lack of laboratory fundamental condition and insufficient of labs and practical training

Information management and information system major has the characteristics of binding of theory and practice, which demands practical experience of the teachers. But nowadays most of the teachers graduating from University directly have no practical engineering experience. Because most of the teachers have no way to attain information implementation means in practice, and they can only carry our theory teaching, which makes the students lack of practical experience, either. And they cannot understand the importance information technology. Therefore, major teachers without knowledge renovation and practical experience are the most terrible problem now. And most of the persons incorrectly assume that the information management major belonging to management science, and misunderstand the major laboratory of the major. Actually, comparing to Science and engineering laboratory, lab of management major has more input and less output. Therefore, the University prefers to construct the former labs instead of management major labs. And, some of the Universities treat the theory teaching staff and experiment staff differently in salary and other aspects, which severely damage the working enthusiasm of the lab staff. Because of the existing problems above, the construction of the information management labs obviously lags behind the society requirement to talent training, which makes it hard to carry out in talent training.

D. Reform plan design

We can find that the information management and information system major relates to many different fields, and because of the rapid development, hard work of teaching tasks and insufficient time of major courses, which all make creative major teaching reform and construction important.

1) Reform courses in information technology module

To carry out corresponding reform to courses in information technology module, this can help the students to make use of information technology effectively. Meanwhile we should adapt the knowledge learned from management courses into practical scenarios such as: reflecting the running situation of enterprise, management and decision, and combine the knowledge learned in mathematics courses within. And the combination of the several modules can be used to analyze and solve the problems.

2) Reform practical teaching segment

Surrounding the industry background and professional training objectives to build all kinds of practice teaching link，and combine them into practical teaching link, which can be used to enhance the basic practical ability, professional adaptability and creativity of the students, to improve and reform the present information management and information system major practical teaching objective architecture, practical teaching content architecture, practical teaching management architecture and practical teaching quality evaluation architecture.

3) Reform and create teaching methods

We should renovate teaching concept, motivate the students to think more, analyze more and enhance the practical ability of them. Making use of modern teaching methods and tools, we would attract initiative of the students. In course teaching process, we should pay more attention to foster self learning ability, creativity ability and independent thinking ability of the students. In class teaching process, we should insist on the combination of theory and engineering cases to enhance the comprehensive ability to apply the knowledge in practice of the students.

E. Solution methods

We present the following methods based on the reform plan above

1) Select the textbooks and reference books.

We should choose one set of textbooks and reference books which are suitable for the situation of our University and pay attention to the connection between the textbooks themselves. The selection of textbooks is important, and they would affect the students a lot in a course.Reform courses in information technology module

2) Emphasize on fundamental theory teaching , arrange curriculum schedule reasonably.

We should emphasize the fundamental courses, major core courses and lab courses, enhance the coaching answering s and paper correction, and choose the experienced teachers to teach the fundamental courses. According to decades of teaching experience, whether the student would become the talent that the market and society needs the first year is rather important. Besides public courses, the subject characteristics determines the freshmen should put most of the energy on fundamental courses such as mathematics, rather than computer operations, programming design, etc. Listening to the teachers carefully, reading, thinking hardly and experiencing deeply, which all need repeatedly boring learning, are the main parts of the freshmen. Many students have not gone through systematical and hard fundamental learning and training, which leads to Infineon when they enter higher grade. But once one student finish the fundamental learning process, even if his entrance scores is lower than other students, he would catch up the others definitely and he would feel easier in the following courses. The reason is that this kind of students have followed the requirement of the major and gone through fundamental training hardly.

3) Reform evaluation means. Information management and information system major has dual characteristics of theory and application, and the evaluation of core courses is important to students.

We should advocate better learning atmosphere, relying on scientific credit management principle, to embody the theory learning and knowledge application and make sure the fairness, objectivity and credibility.

4) Enhance the lab teaching process and standardize the experiment teaching process.

Based on fundamental courses teaching, targeted and scheduled to enhance the lab teaching in the major, and foster the combination ability of theory and practice.

III. CONCLUSION

Information Management and Information System is one of most necessary major in our information-base society, because we need information in all walks of life. In this paper we propose the personnel training mode for Information Management and Information System major through theory and practice. We hope that the pattern can enhance the society adaptability of students from this major.

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Research on Information-based Talent Cultivation Mode in New Zealand

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Abstract: At present the world higher education is developing rapidly. Guaranteeing the quality of talent cultivation is one of the important issues that the Universities widespread care. In this paper it firstly analyzes the concept of talent cultivation in New Zealand, then introduces the majors, curriculum, teaching structure, students and teachers of Information-based talent cultivation in Unitec. Finally it points out the impacts of Information-based talent cultivation mode in New Zealand on the Information-based talent cultivation of independent colleges in China.

Keywords: Information-based Talent cultivation; Higher Education in New Zealand; Students-centered; Social Demand

1 Introduction

At present the world higher education is developing rapidly. Guaranteeing the quality of talent cultivation is one of the important issues that the Universities widespread care[1-2]. Today, our country's higher education are experiencing great changes from elite education to popular education. On the one hand, plenty of graduates step into the society every year and cannot find appropriate jobs, one the other hand the talents gap increases, too. Hence the quality of talent cultivation is more important than before. It should be studied that how to construct one set of up and down through qualification architecture and quality assurance architecture[3]. To review New Zealand, although the political system and culture background is different from China, it plays the important role in New Zealand education development especially the higher education development. In this paper, starting from the practical problems of independent colleges Information-based talent cultivation in China, with the main researching objects of information talent cultivation education quality assurance architecture in unitec, through the systematical analysis of quality assurance architecture, it summarizes the successful experience and supplies with reference to information talent cultivation development in China.

In New Zealand, higher education talent cultivation not only supplies with professional education and training to students of different age levels, raises the qualified talents that the enterprises demand, and promotes the local economy development; it also supplies with life training opportunities to the people in New Zealand following the situation that the Information-based development of science and technology, more high school graduates and adults of different age levels choosing higher education to accept their learning and training; finally, with the enhancement of international communication, higher education in New Zealand is becoming more market oriented and internationalized, which helps to attract plenty of students from abroad and promotes the higher education internationalized.

Unitec institution of science and technology is one unique higher education organization, which demands the students to grasp one obvious prominent skill[4]. The teaching methods of the institution is to combine the academic standards, theories with technology and professional advantages in higher institution together. At present, the talent cultivation of independent colleges in China is researching on the same issue and how to enhance the social competition and suit the social demand of students. Thus, it is meaningful to research on the impact of the talent cultivation mode of Unitec institution of science and technology to the talent cultivation mode of independent colleges in China.

As visiting scholar the author experiences the Information-based talent cultivation mode in school of computing, Unitec. Therefore, in this paper it introduces and analyzes the four layers of majors, curriculum, students and teachers. Finally it gives the reference of Information-based talent cultivation mode to Information-based talent cultivation of independent colleges in China.

2 Major setup of information-based talent cultivation in unitec

2.1 The basis of major setup

The majors of information talent cultivation in Unitec keep up with the development of industry and enterprises, which is the basis point of economy development and society service, and is also one of the basic factors of institution of science and technology enrollment. Major setup is market oriented, it should accord to the market requirement to set up the majors and set

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up the integrated majors to realize the communication and integration of relative and different subjects. The major setup should also satisfy following requirement, such as: firstly, it must be examined and approved by corresponding departments and organizations; then, it should satisfy the needs of industry and enterprises; finally, it should satisfy the interests of the students. Therefore, it is to say that the major setup of Information-based talent cultivation in Unitec is totally determined by the social requirement.

2.2 The characteristics of major setup

According to the basis of major setup we can get that the characteristics of major setup in Information-based talent cultivation process are as follows:

First, market oriented

The major setup of Unitec all are based on the tight communication with industry and enterprises, it has characteristic of pertinence, applicability and practicalness and should follow the market requirement to set subjects and courses.

Second, to raise the applied skill talents

The raising objective of Information-based education in Unitec is clear, is to raise applied skill talents. In order to realize the raising objective, the industry, enterprises all should join in the process of subjects and courses planning, implementation, and evaluation. And the main objective should be realize the talent cultivation of the industry and enterprises need through subject setup and form the industry oriented education system.

Third, strong regional

The programs and internship units of school of computing, Unitec locates in every areas of New Zealand, and the objective is to satisfy practical requirement of the local economy development and industry talent cultivation.

3 The curriculum setup of information talent cultivation in unitec

3.1 The concept of curriculum setup-competence based view

The competence based view of curriculum reflects the transition from traditional teaching process to learning process. The center of curriculum is not the teachers but the students, the teachers become part of students' learning resource and the promoter and organizer of the students' learning. According to the individual difference of students to offer different courses, acknowledge the former knowledge that the students learned(formal or informal courses). The curriculum is totally customers' requirement oriented, the curriculum content contains the knowledge, skills and attitudes for competence, it also reflects ability requirement to practitioners of occupation post and professional role directly, it would form ability standards through professional ability analysis and transform the ability standards into courses. Adopting the module curriculum structure, professional ability centered, and according to ability unit or ability element to develop the learning modules. The ultimate curriculum objective focuses on cultivating competent workers, problem solvers, and life learners.

3.2 The structure of curriculum setup-module

The curriculum in school of computing, Unitec fits the practical requirement of business industry, and must pass the evaluation or authorization of New Zealand Qualification Association. And the institution adopts Unit&Module curriculum operation way, the students would choose different modules and make different curriculum programs according to their own ability and requirement.

One module is one relatively independent but intact learning unit, it relates to certain credits, the certification training and diploma education of every level correspond to one group of modules and corresponding credits. Independent and intact module is the basic unit of the whole module curriculum, the direct objects of students would elect, and the basic unit of students examination and evaluation.

The module is not absolutely isolated but relatively independent, it relates with other modules in corresponding learning fields, would point to bigger raising objective of composing intact module curriculum, and link up with corresponding professional certification. The curriculum includes the core modules and elective courses, the modules that the students would choose should conform to the requirement of the curriculum.

In order to assure the integration of flexibility and systematicness, all the students must learn the core modules, the students' elective module should be instructive to the students, should help to the students to formulate the learning plan, the module curriculum stipulates that only the qualified students can learn the module, and they can only get corresponding credits through finishing one module. The teaching adopts small class size, and one by one individual tutoring and group discussion forms. With students' interests centered, teachers oriented and the students as the subject in the teaching process, it pays attention to individual development of students and the teachers would support the students with service. In the classroom teaching process, the teachers' explanation is mainly adopted, the teachers instructs the students how to learn, but most time the students learn study independently and the learning time is relatively flexible, but the students must finish every module in required time.

3.3 The characteristics and examination standards of curriculum

The curriculum setup focuses on praticalness and implementation, most courses relate intensely to Information-based talents education or training, and usually there is no culture fundemental courses and P.E. kinds of public courses. The teaching of courses combine theory with practice, and it focuses on practical application and professional training.

Besides the independent practical teaching steps, the theory teaching and learning integrates with the practical training, especially the strongly practical courses, basically the courses are carried out with the combination of scene teaching, speaking, doing, and practising in practice classrooms or corresponding major classrooms. There are strict standards to the curriculum in the institution. Firstly, every course has detailed examination standards, such as, through this course, what should you know? What should you do? What extent should you reach? All of them have corresponding standards, which should be satisfied. Secondly, examination process runs through the learning process, the ordinary homework, paper, report and design has strict examination, and should be record and taken as accordance of final score.

4 Information talent cultivation teaching staff in unitec

The recruitment of new teachers in Unitec adopts competitive mechanism and public oriented, the recruitment is carried out by the human resource department, the hiring is appointed by the council and sign the contraction finally. For cultivating applied talents with strongly practical skills, the school of computing is responsible for the appointment qualification of the teachers.

Besides common degree requirement, full time teachers must satisfy following conditions: 3 to 5 years major working experience, appropriate skill qualification especially the teaching qualification(adult education diploma), University degree attained, through specific training, sophisticated teaching and cultivatting methods. Before the teachers are hired, they must pass probation period of one year to gradually enrich academic attainments, major knowledge background and abundant teaching experience. The teacher team is composed of full time teachers and part time teachers, and the part time teachers are more that the full time teachers.

The school of computing, Unitec also focuses on hiring part time teachers from the talent market to remedy the deficiency of full time teachers. The main standards of hiring part time teachers are: three or more years of major working experience, appropriate major skill qualification, strong ability of producing operation. Because the part time teachers have higher society status, generous material treatment, and the hiring process is fair and public, it attracts plenty of sophiscated professional skillers of enterprises and industry to apply for the positions. They not only have solid professional knowledge and abundant practical experience but also integrate the newest situaton producing, operating, managing technology improvement with the content that students learned and timely teach the students to relate the theory with practice. The hiring of part time teachers makes up the deficiency of teachers because of major transition, which contributes the exchange of full time and part time teachers and enhances the quality of the talents that the institution raised.

5 The information-based talent cultivation students in unitec conclusion

New Zealand requires that the students from scholl of science and technology should insist “easy in and hard out”. During the enrollment, the enrollment age is flexible, besides the current graduate from middle school, there are plenty of adults. For age, most of the students are 18 years old, but generally there are still more adults in the campus. It can be seen that the enrollment age requirement is loose, the college considers that the high education is life education, which also reflects that the update of knowledge and skill is rapid, and the requirement of workers’ knowledge and skill. Many graduates from middle school enter the society to look for jobs, because that the employers in New Zealand regard experience as important factor, after the students have accumulated specific working experience, according to working or personal knowldege development, the students go back to school of science and technology to carry out further learning to increase their own knowledge skill and attain education certificate. Thus, the part time students are dominant in the school of science and technology. Many students are working students, some of the take part time job and the others take full time work and studey only in their spare time. The graduation process is strict, usually the qualification examination is adopted(it is kind of combining academic achievement test with professional qualification certificate), which means that the students not only need to attain the education certificate but also the skill level certificate or professional qualification that could reflect the corresoponding professional ability and skill level.

The core of student quality assurance is the framework of education qualification certificate in New Zealand, through which the knowledge that student has learned and the experience that the student has earned both can attain authorized qualification certificte. In 1991, New Zealand formally issued and executed the national unified qualification framework and the qualification certificate system. The qualification certificate is the authorization of learning result and ability coming from personal learning, training, and working experience, it can prove the personal knowledge and skill. The school of science and technology, Unitec adopts the credit accumulation way, which is convinient for students to choose the appropriate qualification certificate level according to their own condition and quality, flexiblely satisfies the needs of students of different level and type, and makes the students would achieve the quality standard of talent culitivation. The special agency in New Zealand divides the different academic education, training, and corresponding adademic and professional qualification after Grade 11 into 10 levels according to knowledge skill, professional ability, education level, basic education length, education degree that the students should attain. Every level has corresponding national qualification standard, meanwhile it should accrod with nationally authorized certificate and diploma. 1 to 4 level are certificate training, 4 to 6 level are diploma education(corresponding to junior college), 5 to 8 level are degree education(corresponing undergraduated and bachlor degreee), 8 to 10 level are postgraduate education. The professional education in New Zealand equals to 1 to 8 level area, among which 1 to 4 level training are corresponding to junior professional education in China, 4 to 8 level are corresponding to senior professional education in China. The school of science and technology, Unitec is the principal part of executing professional education, basically it carries out the degree education and different certificate training of 3 to 8 level.

6 The reference of information-based talent cultivation quality assurance system to information-based talent cultivation of independent college in china

6.1 To establish the diversified quality assurance system

Independent college, in which the cultivated talents must contact with the market with zero distance, is one special form of higher education, it must satisfy the employment requirement of zero distance, its cultivation objective, subject setup, facility should follow the development rule of higher education, meanwhile follows the development of times, science, and technology to continuely update the professional skill and knowledge. It is to say that the independent college should not only meet the quality indexes that the government education department requires but also satisfy the requirement of industry enterprises, changing talent market, and the college it self. Therefore, the education quality of independent college need to show the requirement of society, industry, and the college itself, but in China the government is the subject of quality assurance form, and relects the quality assurance requirement of the government which can not adapt to the development requirement of independent college now. Therefore the subject of diversely cooperative quality assurance should be established by government, society, and the college, and it is also the development trend of establishing quality assurance subject in developed countries. During the establishment of quality assurance system, the government, society, and college should become independent and related subjects, among which the government is the guidance, the society is the evaluation basement, and the college locates in the core position of self monitoring. The subject of diversely cooperative quality assurance not only enhances the popularity and transparency of social participation and education management, increases the social acceptance to independent college, also gives the college more self adjusting space, and increases the self quality control consciousness, which would more effectively assures the quality of the independent college education.

6.2 To establish the professional evaluation authority

Comparing with New Zealand the levels and types of Chinese higher education are more complicated, and the evaluation organization in New Zealand still has no such sub evaluation organization to evaluate so many kinds of college. Therefore, the establishment of different evaluation organization to evaluate the different type of college is one effective assurance way. The establishment of specialized evaluation organization should take the concept of diverse higher professional quality as the guidance, according to the practical situation of Information-based talent education development in China, through establishing national standard of different types of independent colleges to form independent third party evaluation organization and industry quality qualification organization and form the all-dimensional quality assurance network architecture integrated with nation, areas, and independent colleges. In order to assure the scientificity and authority of evaluation, different types of specialized evaluation organizations or associations lead by government, organized by famous people, experts, and industry representatives from specialized field to execture the evaluation, and effectively makes use of the evaluation result, which would make the relative persons(students, parents, enterprises) to understand the Information-based talent education quality of independent college and satisfy their own needs.

6.3 To improve the quality assurance mechanism of teacher

At present the teachers of independent college in China mainly are graduates from ordinary higher school, there are few teachers can satisfy the social requirement of Information-based talent education, which severely affects the education quality of independent college.

There has been improved teacher quality assurance mechanism in developed countries. We can learn the successful experience from them to establish strict, appropriate teacher qualification way of independent college, widen the source channel of professional teachers, execute the open teacher cultivation system, carry out training to different teachers, and generally evaluate the teachers' work regularly.Firstly, to carry out the pre-employment training of the new teachers, including teaching and skill practice. The teaching practice adopts tutoring, observing. The skill practice is used to examine the practical operation ability of teacher, through the process the teachers can attain specific skill certificate and corresponding practical skill, and it could enhance the establishment of double certificate teachers. Secondly, following the development of society, science, technology, and knowledge, the Information-based talent cultivation of independent college must update to follow the development, so it must support the professional training and further education of the working teachers. The whole evaluation of the teacher not only includes the theroy teaching evaluation, practice teaching evaluation, and assessment of scientific research, but also includes the self moral evaluation of the teacher, through the evaluation they can find out the ineffeciency and adjust themselves in time.

6.4 To establish and improve the professional qualification system

At present in China, there is no scientific qualification evaluation system, and there are same certificates from different department, which makes the responsibility confusing. Thus the professional qualification system should be established in China. Firstly, The specialized management organization should be established by the country, and the organization should take charge of the mangement of all the qualification certificates. Secondly, the specialized organizaiton should establish the framework architecture of national professional qualification to wholy manage the classification of education background and certificate as well as the corresponding relationship of every professional qualification. Thirdly, there should be specialized organization to take charge of the national professional qualification authorization. Fourthly, the labor access system should be executed strictly, and gradually step into professional qualification certificate. Fifthly, the professional qualification system should dock with the international system, and pass the international authorization.

6.5 To give full play of professional organization

The professional organizations can play more practical role in management of professional education and training, which has been adopted by New Zealand and other developed courtries. We should encourage and promote to establish this kind of organizations, to which the functional departments should authorize more responsibilities of professional qualification, organization training, subject and curriculum development and quality evaluation, and allow them to work effectively in professional qualification standard establishment, policy survey, and human resource development.

7 Conclusion

Although New Zealand is only one island country, its education system is considered as one of the best education systems in the world. In New Zealand, every citizen has his own right to enjoy approriate way of education that would release their abilities, and has the chance of life education. The school of science and technology, Unitec in New Zealand, which insists life education concept, regards ability as standard, employment as guidance, according to requirement of local development, it sets up various types of subjects and courses, which relate with market and enterprises, it also cultivates applied skill talents of different levels that the society and market requires. The most important part of education process is subjective initiative of the students, who follow their situation to learn and truly integrate professional education with life education. At present the development of independent colleges in China are facing new chanllenges and opportunies, during the development process we need to learn and imitate the foreign anvanced experience, and the successful experience of school of science and technology, Unitec in New Zealand should be one of our choices.

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The Adaptation of Mobile Learning System Based on Business Rules

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Abstract—**In the mobile learning system, it is important to adapt to mobile devices . Most of mobile learning systems are not quickly suitable for mobile devices. In order to provide adaptive mobile services, the approach for adaptation is proposed in this paper. Firstly, context of mobile devices and its influence on mobile learning system are analized and business rules based on these analysis are presented. Then, using the approach, the mobile learning system is constructed. The example implies this approach can adapt the mobile service to the mobile devices flexibly.**

***Keywords* —Mobile Learning System; Mobile Devices; Business Rules**

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1 Introduction

The rapid adoption of mobile computing devices with Internet capabilities, such as computers, smart phones and handheld devices, makes us work or study at any time, at any place. And mobile learning will complement and add value to the exiting learning models [1].

It is important for mobile learners to get education information and service, which meet their needs in an adaptive manner. However, in the mobile learning system, different mobile devices have different CPU speeds, memory capacity and power. This means that a mobile learning system created needs to adapt to different mobile devices.Currently, some researches about device independence in mobile learning system have been proposed. Xinyou Zhao proposed a device-independent architecture for mobile learning, which is composed of device detector and adapted content model [2][3]. That system detects the features by using user agent and analyzing the head of request. Anastasios A. Economides presented a framework for adaptive mobile learning in order to stimulate and support providing service [4]. The adaption engine is the core of the adaptive mobile learning system. By employing the learner's state L(t), the educational activity's state A(t), the infrastructure's state I(t) and the environment's state E(t), the system has the ability to detect the characteristics of device and learners. By employing the learning automata to reinforce a good decision and penalize a bad one, this system can provide the most appropriate service. But all before-mentioned system frameworks are not extended easily, because the formal model of context and adaption is not presented. When more and more new-style devices are used to mobile learning system, this shortage will be obviously.

In this paper, business rule approach is proposed to construct mobile learning system. It can detect mobile devices' context and adapt the service to the device, by considering the influence of context on service parameters.

2 Business rule

2.1 Context and its influence

Mobile learning system is composed of one server and mobile devices which access the server via different types of networks, for example, GSM, 3G, internet, Wi-Fi, or other networks. Mobile devices maybe are PDA, computer, mobile phone, laptop, digital TV, or other devices which have the ability to access the network, play audio and video program, and access the system server using browser which support standard communication protocol.

Mobile devices communicate with the mobile learning system server interactively. The device sends the request of service to the server. Then the server provides the mobile service, such as video on demand, to the learners' devices. The learner's devices can communicate with others through the server.. When providing the service, in order to adapt itself to several kinds of devices, the mobile learning system should adjust the parameters of information communication according to the context of devices. In this way, every user can obtain the mobile service automatically with the quality matching the ability of his device.

2.2 Business rule

Based on the analysise above, there are some rules in the mobile learning system. These rules have the same structure as 'IF conditions THEN adaption policy' in the codes. While the context match the condition, this rule will be triggered immediately, and the adaption policy will be implemented.
BR=(id; width, networktype; speed, size,color)
In this depiction,
BR is the symbol of an business rule.

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Id is the rule identity,which is exclusive.
Width is the width of the mobile device.
Networktype is networktype of the mobile device.
Speed is the transmission speed to the mobile device.
Size is the displaying size in the mobile device.
Colour is the displaying colour in the mobile device.
For example:
BR=(001; 0.6×2Mbps,0.4×ADSL;15f/s)

3 The approach

On the basis of the discussion above, we utilize business rules to implement the dynamic part in the mobile learning system.Figure 1 shows the mobile learning system architecture based on business rules.

The context management module in the architecture employs the approach proposed by Henricksen in [5]. The context repository management module is responsible for collecting context, maintaining a set of context models and their instantiations. This module additionally provides the reasoning capacity between the low-level and high-level context and implements the query interface. The other modules in the architecture are our own work and will be discussed as follows. At present, the reasoning procedure has not been included in the business rules.

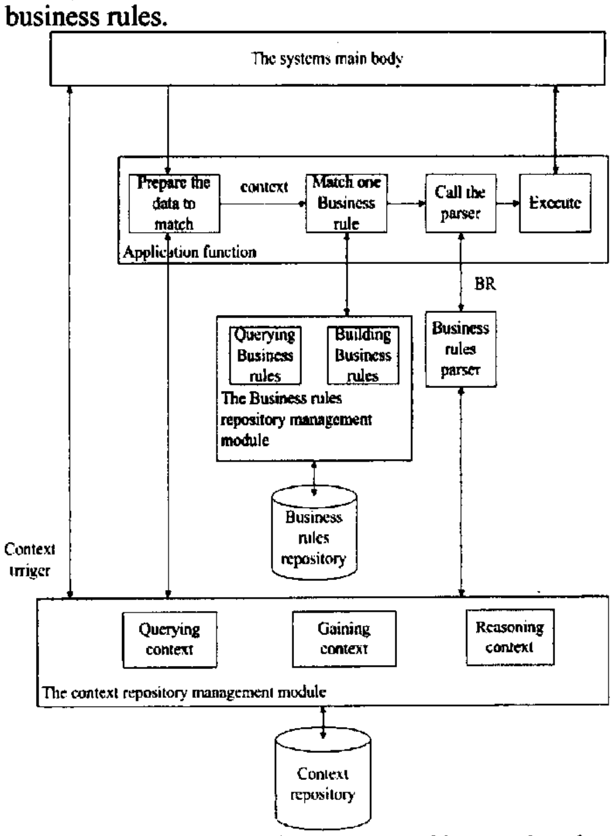

Figure 1 the mobile learning system architecture based on business rules

The traditional mobile learning system architecture consists of the system's main body and the context repository management module. The dynamic elements of the system's main body are encoded in the traditional architecture. In the new architecture shown in Fig.1, the system consists of the main body, the context repository management module and the implementation module for the dynamic element separated from the program code. When the system executes the dynamic element, a functionis invoked and implemented. Moreover, the variables of the invoked function are the parameters, their values easily being modified to suit the changing situation.

4 Example

In the mobile learning system,learners can get the video courseware resource by VOD service provided by this mobile learning system. They can get these video resources by many kinds of device, such as PDA, mobile phone, laptop and computer. The mobile learning system must apperceive the context of terminal device, and adjust the transmission policy to the different context.

In this example, the bandwidth, type of link, the vender and model of terminal, the size of screen are considered as the context of device.

Business rules are show in follow:
BR=(001; 0.6×2Mbps,0.4×ADSL;15f/s)
BR=(002; 0.6×1Mbps,0.4×ADSL;10f/s)
BR=(003; 0.6×10Mbps,0.4×LAN;25f/s)
BR=(004; 0.6×20Kbps,0.4×GPRS;5f/s)
BR=(005; 0.6×120Kbps,0.4×HSDP;7f/s)

The contexts of mobile device are detected by the context information server, and then according to the business rules above, some information transmission policy is carried out to ensure the quality of mobile learning,. Moreover, when more and more new-style devices are used to mobile learning system, we only add some business rules instead of modifying the codes.

5 Conclusion and expectation

In mobile learning environment, system should detect the context of mobile devices, and then adapt the service parameters to the context. In order to construct the mobile learning system that can adapt to mobile devices, business rule approach is presented. Using the approach, the mobile learning system is constructed. The example implies this approach can detect the contextual environment of mobile computing and adapt the mobile service to the mobile devices flexibly.

In future, the business rules repository will be researched and optimized, employing the method and theory of artificial intelligence.

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Research on University Information System Oriented Business Adaptability

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Abstract

University information systems should flexibly and quickly adapt to variable requirements. This paper proposed an university information system implementation method based on business rule to achieves information systems adaptability. Based on steady business pool consisting of business granules and business objects, variable factors on the business object aggregate business granule operates are separated from information systems codes and stored as business rule, which is implemented through the corresponding business rule engines. Therefore, university information systems based on this method can adapt to variable requirements flexibly and quickly through configuring business rule. Experiments and examples are provided to evaluate the feasibility of the proposed method.

Keywords: *University Information System; Adaptability; Business Rule*

1. Introduction

In information society and knowledge economy era,it is the construction hot of university at home and abroad to build an information and digital campus. Nowadays, many of large and middle software corporations at home and abroad implemented university information systems. But, there is no system to adapt to many of university at home and abroad. The reason for this situation is the strong university regional, different management schema and very difficut containing all of functional department. According to above university difference and complex and variable university business, it is required that university information system implemented by information technology can support the difference and variable.

This paper proposed a business rule approach to implement university information systems. At present,business rule-oriented methodology to implement the information system attracts more and more attention in recent years. Irma Valatkaite [1-3] presented a conceptual graphs approach for business rule model, represented business rule in UML use case diagrams, and enforced automatically business rule as ADBMS triggers from conceptual graphs model. Based on above, the BR-Centric IS development framework was then presented. P. Kardasis[4] and W. M. N. Wan-Kadir[5] provided business rule elicitation, representation, mapping and implementation. Sequentially, they proposed MBRM development frame. All of these approaches proposed the structuring of business rule according to the ECA (Event Condition Action) paradigm or IF Else Then paradigm. As a result, these approaches had a limitation that they couldn't represent complex business rule. Besides, there are some commercial business rule management systems productions, such as Ilog's Jrules[6] and Fair issac's Blaze advisor[7]. It is a pity these productions are too complex for enterprise level. Accordingly, it is necessary for enterprises to abstract and implement their business rules in terms of their variable requirements.

This paper proposed a business rule approach to implement the configurable complex business logic of university information systems. Based on steady business pool consisting of business granules and business objects, variable factors on the business object aggregate business granule operates are separated from information systems codes and stored as business rule, which is implemented through the corresponding business rule engines. Therefore, university information systems based on this method can adapt to variable requirements flexibly and quickly through configuring business rule.

2. Information system framework based business rule

The information systems based on business rule consist of three components including business granule, business object and business rule[8].

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2.1. Business granule

Business granule is business atomic unit of business operations or operations sequence with the business goal in the special application domain. It has attributes, such as atom, independence and multi-instance. No subdivided business embodies the business granule atomic attribute and the least business executing unit embodies its independence. Its independence shows it couldn't depend on other business granules. Since the business granule is relatively stable, business functions can consist of these business granule sets by accumulation. Different accumulation or assembling styles represent different business logic.

2.2. Business object

Business object is the object that business granule operates. To the relatively stable business granule, its operating object is also relatively stable. But, the operating object instance set may be change. These variations come from user's requirements and represent the variable business logic.

2.3. Business rule

There are various classifications of business rule given by different researchers. Von Halle, Ron Ross and business rule group have their categories. Based on the variable requirements influencing business object instance set the business granule operates, we classify three categories: (1) constraint relations among variables (Variable Relation Constraint Rule VRCR); (2) the variable attribute value mandatory constraint (Attribute Mandatory Constraints Rule AMCR); (3) constraint relations among the variable attribute values(Attribute Relation Constraints Rule ARCR).

VRCR abstracts the related variables and joint relations among these variables. This class business rule can meet these variations: (1) the number of variables; (2) the name of variables (3) the joint relations among all variables; (4) the order of the variable attribute values. Following is its representation.

VRCR1=(Id, Application, Task, Rulesetname, Table, Variable, Order, Level)

VRCR2=(Id, Application, Task, Customed, Table, Variable, Value, Order1，Order2)

VRCR1 is the symbol of VRCR.

'Id' is the rule identity, which is exclusive.

Application is that the VRCR is applied.

Task is the business granule where the VRCR is valid.

Rulesetname is the name of the rule set that the VRCR belongs to.

Table is the operated table in the database by the VRCR.

Variable is the influencing factor the VRCR involved.

Order indicates the order of the influencing variable attribute value in the VRCR. Its value may be descending, ascending, random and customed. If the value is customed, there will be some new VRCRs which are represented by VRCR2. In VRCR2 expression, Value is the attribute value that the user customs, Order1 indicates the customed order of the attribute value and Order2 indicates the order of multi-attribute-value in the same order1.

Level indicates the joint relations among the influencing variables the VRCR involves.

AMCR abstracts mandatory attribute value constraint on business object set that business granule operates. Following is its representation.

AMCR=(Id, Application, Task, Rulesetname, Condition, Valid, Sequrence)

AMCR is the symbol of AMCR.

'Id' is the rule identity, which is exclusive

Application is that the AMCR is applied.

Task is the business granule where the AMCR is valid.

Rulesetname is the name of the rule set that the AMCR belongs to.

Condition is the mandatory constrain condition.

Valid indicates that the AMCR is valid

Sequence indicates the order the AMCR executes.

ARCR abstracts the constraint relation among the variable attribute values. The external user's requirements lead to the constraint relation among the business object instance sets consisting of all variable attribute values. Therefore, the ultima business object instance set makes up of these sets dependent on set operations. Following is its expression.

ARCR=(Id, Application, Task, Rulesetname, Condition, Setaction,)

ARCR is the symbol of ARCR.

'Id' is the rule identity, which is exclusive

Application is that the ARCR is applied.

Task is the business granule where the ARCR is valid.

Rulesetname is the name of the rule set that the ARCR belongs to.

Condition is the pre-condition that set actions execute.

Setaction is the set actions when condition is true.

3.University information system framework based on business rule

University information system framework based on business rule consists of three parts including business rule management system(BRMS), database management system(DBMS) and function modules of university information system. In this framework, function modules of university information system implement basic functions university information system provided and DBMS manage the data of university information system. However, BRMS manage variable business requirement in the university information system. Its functions include:

·business rule repository definition

It includes business rule definition of logic structure, storing structure, secrecy and corresponding information format, etc.

·business rule repository management

It includes system control, rule storage, update and rule integrity, security control etc.

·business rule execution engine

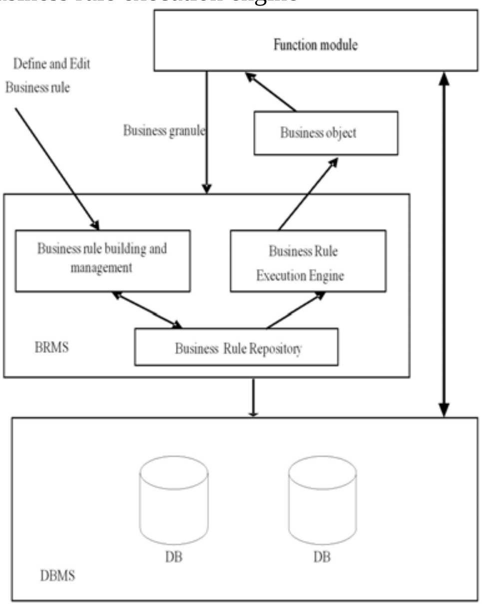

Figure 1 University information system framework based on business rule

This is a mechanism program that searches and implements business rule.

·business rule repository building and maintenance

This is a component that builds and updates business rule repository and maintains and restores structure of business rule repository.

Therefore, BRMS includes following components:

·business rule representation language and compiler

·business rule operation language and compiler

·business rule repository management program

Flow that university information systemexecutes is following: function modules of university information system provide BRMS with the requirement of business granule. Then BRMS picks up relevant rules from business rule repository, and business rule execution engine implements this rule set. At last, BRMS provides business object for the function modules of university information system to use. The specification is shown in Figure 1.

4.Example

The approach presented in this paper has been used in developing teaching affairs system of one university. During education, one student couldn't have two classes at the same time. Moreover, because teacher need tutor students and a teacher has limited energy, the number of tutored students must be limited. So, we need group teacher and students based on some constraints to form a suitable education grouping. This grouping can form automatically in terms of courses selected by students. So, we only consider that students select courses. What are analyzied in selecting courses are showed as follows:

Business granule: selecting courses

Business object:students, teacher, courses

Business rules:

(1)Student must be a student in this university

(2)course that student didn't select or pass before

(3)number of registered students of course is less than capacity of course

(4)course that student has pass its prerequisite course

(5)students haven't selected any course during this course

Above business rule can be expressed:

AMCR=(001, teachingaffair, selectingcourses, selectingcourses, xh=student.xh,valid,1)

AMCR=(002, teachingaffair, selectingcourses, selectingcourses, course<>student.selectedcourse,valid,2)

AMCR=(003, teachingaffair, selectingcourses, selectingcourses, registrationlist.size()<course.getminimum(),valid,3)

AMCR=(004, teachingaffair, selectingcourses, selectingcourses, course.getprerequisite()=student.haspassedcourse(),valid,4)

5.Conclusion

The above example shows that the implementation method based on business rule improve the flexible configuration and the expansibility of university information systems. At the same time, it also shows that the university information systems implemented by this method more adapt to the variable environment. Moreover, business rule is separated from the codes and stored in the repository, which reduces many codes and the complexity of the codes. The future work should be done on the issues how to manage these business rules.

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RESEARCH ARTICLE

WILEY

Evaluation of MOOCs based on multigranular unbalanced hesitant fuzzy linguistic MABAC method

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Abstract

Massive open online courses (MOOCs) are very popular in China, and it is very important to evaluate and improve them. In this paper, a new evaluation method for MOOCs based on multi-attribute group decision-making is proposed. First, an evaluation index system of MOOCs is constructed, which contains six elements and 16 indicators, and multigranular unbalanced hesitant fuzzy linguistic term set (MGUHFLTS) is adopted to describe these indicators. Then based on MGUHFLTS, the aggregation operators are developed, including the multigranularity unbalanced hesitant fuzzy linguistic weighted averaging operator and the multigranularity unbalanced hesitant fuzzy linguistic order weighted averaging operator, moreover, a novel multi-attributive border approximation area comparison model based on MGUHFLTS is proposed. This model is testified validity and superiority by comparison with other three methods and is applied in evaluation of MOOCs. After ranking five MOOCs, each indicator is analyzed to show how they influenced each element and suggestions are given.

KEYWORDS

MABAC method, MOOCs evaluation, multigranular hesitant fuzzy linguistic term set, multiple attribute group decision-making, unbalanced linguistic term set

1 | INTRODUCTION

With the rapid development of the internet, higher education is undergoing a new revolution. The learning way of the courses is changing from offline to online. Massive open online courses (MOOCs) are primary means of online education and have been greatly promoted,[1] with the feature of "anytime, anywhere to learn." In 2011, China's Ministry of Education launched the "national quality open curriculum construction and sharing" project, which promoted the development of MOOCs in China. In March 2019, the China government work report clearly put forward the development of "internet plus education" to promote the sharing of high-quality resources. At the beginning of 2020, the COVID-2019 has spread worldwide, the majority of offline courses had been transformed into MOOCs. Thus, how to evaluate the quality of MOOCs and establish an effective quality assurance system has attracted much attention. However, the evaluation of MOOCs' quality faces many problems, one of which is how to put forward scientific and effective evaluation methods to guarantee and improve MOOCs' quality.

Many researches have been made on evaluating the quality of MOOCs, and the evaluation criteria are diversified. Gil-Jaurena et al.[2] put forward seven undergraduate education evaluation indexes, including encouraging teacher–student interaction, promoting cooperation among learners, encouraging learners to study actively, providing timely feedback, emphasizing task time, communicating high expectations, and learning style. These principles have been using as the standards to improve the implementation of MOOCs by some educators and researchers.[3] La Garza et al.[4] put forward five indicators and Margaryan et al.[5] focused on the teaching quality of MOOCs. However, the existing researches failed to put forward scientific and effective MOOCs evaluation methods. In fact, the evaluation of MOOCs is a typical multi-attribute group decision-making (MAGDM) problem. Because the evaluation process is a complex system, most of the influencing factors are fuzzy and the decision-making is usually made by a group of decision makers (DMs) rather than one DM. Due to the fuzziness of DMs and the complexity of MOOCs' evaluation, it is difficult for DMs to express the evaluation value with crisp values. For this reason, fuzzy value is a better choice to describe fuzzy information. Since the evaluation of MOOCs is a MAGDM problem, two aspects should be considered in solving this problem, one is the expression of the fuzzy information, and the other is the choice of the evaluation method.[6,7]

The first important item is how to express the fuzzy information for MOOCs' evaluation. Obviously, linguistic variables (LVs) are more convenient to represent the preference values of DMs in a qualitative environment. At the same time, there also exists hesitation of DMs in the evaluation process of MOOCs, because every DM is limited by his cognition and experience. In such a situation, the hesitant fuzzy linguistic term set (HFLTS) is proposed.[8,9] However, the evaluation information of MOOC is generally not given by one DM, but by different DMs, so different DMs will put forward different linguistic evaluation sets according to their personal preferences, that is, they may give the linguistic information by multigranularity.[10–13] Both the different knowledge backgrounds and decision-making habits of DMs can be taken into consideration in multigranularity HFLTSs (MGHFLTSs), which allow the DMs to give linguistic evaluation with different linguistic term sets (LTSs). For instance, there are three DMs in a group, DM1 considers one course of MOOCs is "general" with granularity 3 of "bad, general, good," DM2 considers its "good" with granularity 3 of "bad, general, good," and DM3 considers its "good" with granularity 5 of "very bad, bad, general, good, very good." The different considerations of three DMs above results are expressed by MGHFLTSs, which supposed the linguistic descriptors and semantics are balanced and symmetrical. However, in the process of

MOOCs evaluation, unbalanced linguistic information often appears, that means, with the increase of the subscripts of LTs, the absolute value of deviation between the subscripts of adjacent linguistic terms (LTs) also changes.[14–16] A good way to solve unbalanced linguistic information is to use the 2-tuple linguistic representation model initiated by Herrera and Martínez,[17] by means of matching the elements in the initial LTs. By defining the concept of numerical scale (NS), Dong et al.[18] proposed the NS model (NSM) based on traditional linguistic 2-tuples to deal with unbalanced LTSs (ULTSs) directly without matching the elements in the initial LTs. These studies provided a solid theoretical basis for MGHFLTSs expanding to ULTSs. On the basis of selecting appropriate linguistic information forms to evaluate MOOCs, multigranular unbalanced HFLTSs (MGUHFLTSs) are adopted to solve this problem.[19]

After selecting MGUHFLTSs to express the fuzzy information for MOOCs' evaluation, another important item is choosing an appropriate evaluation method for MOOCs. Multi-attributive border approximation area comparison (MABAC) method is very effective and reliable in solving the MAGDM problem, which is proposed by Pamucar and Cirovic.[20] The reason why MABAC method has been used wildly is that it has many advantages. The most noticeable one is the stability of the solution, when such changes happened in the nature and character of the criteria, its stability is always first concerned. Another apparent advantage is that the number of steps never changes no matter how many alternatives and criteria are. On the basis of these advantages, many scholars have expanded MABAC method and have applied it in different fields,[21–25] including supply chain management,[20] university web pages evaluation,[26] and risk management.[27] In addition, many scholars have done researches on the combination of MABAC and other methods, including ELimination Et Choix Traduisant la REalité (ELECTRE) method,[28] Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method,[29] and decision making trial and evaluation laboratory (DEMATEL) method.[20] With the development of MABAC method, the form of evaluation information can be expressed in many ways, including triangular fuzzy numbers,[20] interval rough number,[26] intelligent fuzzy rough numbers,[30] linguistic neutrosophic numbers,[31] and hesitant fuzzy LTSs.[22] In this paper, MABAC method is applied to evaluate MOOCSs based on MGUHFLTSs environment.

The objective of this article is to construct a novel evaluation index system of MOOCs, and to propose a new concept of MGUHFLTSs to fully express the evaluation information of MOOCs, then to develop a new effective MAGDM method based on MABAC for evaluating MOOCs, and fill the gap that exists in the methodology for MOOCs evaluation.

The contributions of this paper are shown as follows: (1) propose MGUHFLTSs and its operations, this novel linguistic information form can effectively express uncertain information from the MAGDM problem; (2) develop multigranularity unbalanced hesitant fuzzy linguistic weighted averaging (MGUHFLWA) operator and its ordered weighted form (MGUHFLOWA); (3) build a novel evaluation index system of MOOCs; (4) construct MGUHFLTSs–MABAC model, which extends MABAC method to new linguistic environment; (5) analyze the effect of each indicator on the MOOCs based on the evaluation results, and the suggestions for improvement are proposed.

The paper is composed of seven sections. Section 2 introduces basic knowledge of MGUHFLTSs, including LVs, the 2-tuple fuzzy linguistic model (2TFLM), and ULTS. Section 3 proposes the concept of MGUHFLTSs and its operators are introduced. Section 4 presents a novel MGUHFLTSs–MABAC model and its steps in detail. Section 5 applies this MGUHFLTSs–MABAC model in evaluating five MOOCs courses with the help of the evaluation index system of MOOCs. In Section 6, by analysis of the five MOOCs courses, influence factors are found out which will promote the quality of MOOCs. Section 7 is conclusion.

2 | PRELIMINARIES

In this section, the basic knowledge of MGUHFLTSs is introduced, which includes LVs (Section 2.1), 2TFLM (Section 2.2), and ULTS (Section 2.3).

2.1 | NS of LVs

Definition 1 (Zadeh[32]). Let $S_g = \{s_i | s_0, s_1, ..., s_g\}$ be an ordered LTS, g is finite even number, generally $g < 14$. $s_i \in S_g$ is called LV, $i \in \{0, 1, ..., g\}$. S_g needs to satisfy the following properties:

1. Negative operator: if $j = g - i$, $neg(s_i) = s_j$.
2. Minimization operator: if $s_i \leq s_j$, then $min(s_i, s_j) = s_i$.
3. Maximization operator: if $s_i \geq s_j$, then $max(s_i, s_j) = s_i$.

$g + 1$ is the granularity of S_g, different LTSs may have different granularities.

Example 1. Suppose that LTS S_2 consists of three LVs and LTS S_4 consists of five LVs:

$$S_2 = \{s_0 = bad, s_1 = medium, s_2 = good\},$$

$$S_4 = \{s_0 = very\ bad, s_1 = bad, s_2 = medium, s_3 = good, s_4 = very\ good\}.$$

In the process of decision-making in real life, different DMs may use the LTSs with different granularities to describe their preferences to form MGLTSs. In Example 1, LTS S_2 is with granularity 3 and LTS S_4 is with granularity 5, which are composed of S_2 and S_4.

The semantics of LVs are quantitative expression of linguistic evaluation by mathematical method, and they can make a connection between linguistic evaluation and numerical values.

Definition 2 (Dong et al.[33]). Let $S_g = \{s_i | s_0, s_1, ..., s_g\}$ be an LTS, and R be a set of real numbers. The function: $NS : S_g \rightarrow R$ is defined as an NS of S_g, and $NS(s_i)$ is called the numerical index of s_i. If the function NS is strictly monotone increasing, then NS is called an ordered NS.

2.2 | 2-Tuple fuzzy linguistic model

The 2TFLM is proposed by Herrera and Martinez,[17] which matches the elements in the initial LTSs, being used to deal with the LTSs of uniform symmetrical distribution.

Assuming that $A = (A_1, A_2, ..., A_m)$ is a set of alternatives, $C = (C_1, C_2, ..., C_n)$ is a set of attributes, and $G = (G_1, G_2, ..., G_q)$ is a set of DMs.

Definition 3 (Herrera and Martínez[17]). Let $S_g = \{s_i | s_0, s_1, ..., s_g\}$ be an LTS, $\alpha \in [-0.5, 0.5)$, then (s_i, α) is called 2TFLM, which defines a transformation between linguistic 2-tuples and numerical values. Let $\eta \in [0, g]$ be a value of the symbol aggregation operation. Then, the

2-tuple that expresses the equivalent information to η is obtained by means of the following function:

$$\Delta : [0, g] \rightarrow S_g \times [-0.5, 0.5), \tag{1}$$

$$\Delta(\eta) = (s_i, \alpha), \quad \text{with} \begin{cases} s_i, & i = round(\eta), \\ \alpha, & \alpha = \eta - i, \alpha \in [-0.5, 0.5), \end{cases} \tag{2}$$

where Δ is a one-to-one mapping function. For convenience, its range is denoted as $\overline{S}_g$. Accordingly, Δ has an inverse function with $\Delta^{-1} : \overline{S}_g \rightarrow [0, g]$ and $\Delta^{-1} : ((s_i, \alpha)) = i + \alpha$.

A computational model has been developed for the Herrera and Martínez model, in which the following exists:

Theorem 1 (Herrera and Martínez[17]). *Let (s_i, α) and (s_j, β) be two 2-tuples LVs, the computational model has been developed as follows:*

1. *The comparison operator:*
(i) *If $i < j$, then (s_i, α) is smaller than (s_j, β).*
(ii) *If $i = j$, then*
(a) *if $\alpha = \beta$, then (s_i, α) and (s_j, β) represent equivalent information, that is, $(s_i, \alpha) = (s_j, \beta)$;*
(b) *if $\alpha < \beta$, then (s_i, α) is smaller than (s_j, β).*
2. *The negation operator:*

$$Neg((s_i, \alpha)) = \Delta(g - \Delta^{-1}((si, \alpha))). \tag{3}$$

Definition 4 (Dong et al.[34]). Let $S_g = \{s_i | s_0, s_1, ..., s_g\}$ be an LTS, $\overline{S}_g$ be the 2-tuple model of S_g and NS be the numerical scale on S_g. For $(s_i, \alpha) \in \overline{S}_g$, the numerical scale $\overline{NS}$ on $\overline{S}_g$ is defined by

$$\overline{NS}((s_i, \alpha)) = \begin{cases} NS(s_i) + \alpha(NS(s_{i+1}) - NS(s_i)), & \alpha \geq 0, \\ NS(s_i) + \alpha(NS(s_i) - NS(s_{i+1})), & \alpha < 0. \end{cases} \tag{4}$$

Remark 1. In this paper, $\overline{NS}$ will be denoted as NS, and $NS((s_i, 0))$ will be denoted as $NS(s_i)$ for notation simplicity. In the same way, the following $\Delta^{-1}((s_i, 0))$ will be short for $\Delta^{-1}(s_i)$.

Definition 5 (Dong et al.[34]). Let (s_i, α) and (s_j, β) be two 2-tuples LVs, the deviation measure between (s_i, α) and (s_j, β) is as follows:

$$d((s_i, \alpha), (s_j, \beta)) = \frac{| NS^{-1}((s_i, \alpha)) - NS^{-1}((s_j, \beta)) |}{g + 1}. \tag{5}$$

Dong et al.[34] simplified formula (5) to (6) when existing only one pre-established linguistic label set:

$$d((s_i, \alpha), (s_j, \beta)) = | NS^{-1}((s_i, \alpha)) - NS^{-1}((s_j, \beta))|. \tag{6}$$

2.3 | Unbalanced LTS

On the basis of existing researches,[17,35] Dong et al.[18] proposed a novel definition of ULTSs in the form of the 2-tuple linguistic representation, which based on the concept of NS.

Definition 6 (Dong et al.[18]). Let $S_g = \{s_0, s_1, ..., s_g\}$ be an LTS, NS be the numerical scale on S_g, and $s*$ be the middle term in S_g. S_g is an LTS that is uniformly and symmetrically distributed, if the following two conditions are satisfied:

1. There exists a unique constant $\delta > 0$ such that $NS(s_i) - NS(s_j) = \delta(i - j)$ for all $i, j = 0, 1, ..., g$.
2. Let $S^R = \{s|s \in S_g, s > s*\}$ and $S^L = \{s|s \in S_g, s < s*\}$. Let $\#(S^R)$ and $\#(S^L)$ be the cardinality of S^R and S^L, respectively. Then, $\#(S^R) = \#(S^L)$.

Otherwise, it is a ULTS. It is of convenience that S denotes ULTS in this paper.

$$S = \{s_k | k = 0, 1, ..., l\}, \tag{7}$$

where the granularity is $(l + 1)$, and s_k satisfies $s_i > s_j$, iff $i > j$.

3 | MULTIGRANULAR UNBALANCED HESITANT FUZZY LINGUISTIC TERM SETS AND THEIR AGGREGATION OPERATORS

In this section, the concept of MGUHFLTS is introduced and the novel CW methodology based on the NSM is proposed. Then, two aggregation operators are developed.

3.1 | MGUHFLTS

Generally, an MGUHFLTS is referred to a set of ULTSs with distinct granularities.

Definition 7 (Liu and Rong[19]). Let $S^{MG} = \{S^t | t = 1, ..., T\}$ be a set of ULTSs, $S^t = \{s_0^t, s_1^t, ..., s_\tau^t\}$ be a ULTS, then the granularity of S^t is $(\tau + 1)$. Let X be a reference set, $x_i \in X, i = 1, 2, ..., N$, then the mathematical form of an MGUHFLTS on X is denoted by

$$\overline{H}_S = \{<x_i, \overline{h}_s(x_i)>|x_i \in X\}, \tag{8}$$

where $\overline{h}_s(x_i) : X \to S^t$ is a function defined on set X, for any element $x_i \in X$, there is a unique $\overline{h}_s(x_i)$ corresponding to it. $\overline{h}_s(x_i) = \{S_{\delta_j}(x_i)|S_{\delta_j}(x_i) \in S^t, j = 1, ..., L\}$, L is the cardinal number of $\overline{h}_s(x_i)$, which represents the number of elements in set $\overline{h}_s(x_i)$, and $\delta_j \in \{0, 1, ..., L\}$. Then $\overline{h}_s(x_i)$ is called multigranularity unbalanced hesitate fuzzy linguistic element (MGUHFLE), so MGUHFLTS is the set of all MGUHFLEs.

Example 2. About the evaluation on the teaching design of MOOCs in a university, three groups of experts (G_1, G_2, G_3) are invited to evaluate five MOOCs $(A_1, A_2, A_3, A_4, A_5)$. Among them, G_1 is composed of three presidents (E_1, E_2, and E_3), G_2 is composed of 3 deans (E_4, E_5, and E_6), and G_3 is composed of three teachers (E_7, E_8, and E_9). $S^1 = \{s_0^1, s_1^1, s_2^1, s_3^1, s_4^1\}$ and $S^2 = \{s_0^2, s_1^2, s_2^2, s_3^2, s_4^2, s_5^2, s_6^2\}$. The semantics of S^1 and S^2 are represented by NS as follows:

$NS(s_0^1) = 0$, $NS(s_1^1) = 4$, $NS(s_2^1) = 6$, $NS(s_3^1) = 7$, $NS(s_4^1) = 8$.
$NS(s_0^2) = 0$, $NS(s_1^2) = 5$, $NS(s_2^2) = 6$, $NS(s_3^2) = 7$, $NS(s_4^2) = 8$, $NS(s_5^2) = 10$, $NS(s_6^2) = 16$.

Three groups of experts give evaluation information for five MOOCs according to their own experience and preference, in which the evaluation information of G_1 is given from S^1; the evaluation information of G_2 and G_3 is given from S^1 and S^2. The evaluation information given by the three groups of experts for A_1 and A_2 is shown as

$\overline{h}_{S_1}^1 = \{s_0^1, s_1^1, s_2^1\}$, $\overline{h}_{S_2}^1 = \{s_0^1, s_1^2, s_1^2\}$, and $\overline{h}_{S_3}^1 = \{s_1^1, s_1^2, s_2^2\}$, so $\overline{H}_S^1 = \{\{s_0^1, s_1^1, s_2^1\}, \{s_0^1, s_1^2, s_2^2\}, \{s_1^1, s_1^2, s_2^2\}\}$.
$\overline{h}_{S_1}^2 = \{s_3^1, s_3^1, s_4^1\}$, $\overline{h}_{S_2}^2 = \{s_3^1, s_3^2, s_4^2\}$, and $\overline{h}_{S_3}^2 = \{s_4^1, s_3^2, s_4^2\}$, so $\overline{H}_S^2 = \{\{s_3^1, s_3^1, s_4^1\}, \{s_3^1, s_3^2, s_4^2\}, \{s_4^1, s_3^2, s_4^2\}\}$.

Here $\overline{H}_S^1$ and $\overline{H}_S^2$ are two MUHFLTSs, and $\overline{h}_{S_1}^1 = \{s_0^1, s_1^1, s_2^1\}$, $\overline{h}_{S_2}^1 = \{s_0^1, s_1^2, s_1^2\}$, and $\overline{h}_{S_2}^1 = \{s_1^1, s_1^2, s_2^2\}$ are three MGUHFLEs of $\overline{H}_S^1$; $\overline{h}_{S_1}^2 = \{s_3^1, s_3^1, s_4^1\}$, $\overline{h}_{S_2}^2 = \{s_3^1, s_3^2, s_4^2\}$, and $\overline{h}_{S_3}^2 = \{s_4^1, s_3^2, s_4^2\}$ are three MGUHFLEs of $\overline{H}_S^2$.

Remark 2. In Example 2, $\overline{h}_{S_1}^1 = \{s_0^1, s_1^1, s_2^1\}$ is an ordered finite subset of the consecutive LTs of S^1. With further study of the HFLTS,[18] the continuous HFLTS has been expanded to discontinuous, so $\{s_0^1, s_1^1, s_3^1\}$ is also in line with the concept of MGUHFLEs.

3.2 | MGUHFLTSs and 2-tuple set

After introducing the concept of MGUHFLTSs, a reliable linguistic model should be found to simplify this complex linguistic information form. The 2-tuple linguistic model can be regarded as a connection between MGUHFLTSs and numerical data, with the character of accurate expression of discrete elements.

Theorem 2. *Let $S^{MG} = \{S^t \mid t = 1, ..., T\}$ be a set of ULTSs, $S^t = \{s_0^t, s_1^t, ..., s_\tau^t\}$ be a ULTS, $s_i^t \in S^t$, $t = 1, ..., T$, $i = 0, ..., \tau$. Let* NS *be an ordered numerical scale, that is, $NS(s_i^t) < NS(s_{i+1}^t)$. For $\forall\, y \in [NS(s_0^t), NS(s_\tau^t)]$, if $NS(s_i^t) \le y \le NS(s_{i+1}^t)$, then the inverse operation of between MGUHFLTSs and 2-tuple set based on* NS *is*

$$NS^{-1}(y) = \begin{cases} \left(s_i^t, \dfrac{y - NS(s_i^t)}{NS(s_{i+1}^t) - NS(s_i^t)}\right), & y < \dfrac{NS(s_{i+1}^t) + NS(s_i^t)}{2}, \\ \left(s_{i+1}^t, \dfrac{y - NS(s_{i+1}^t)}{NS(s_{i+1}^t) - NS(s_i^t)}\right), & y \ge \dfrac{NS(s_{i+1}^t) + NS(s_i^t)}{2}. \end{cases} \tag{9}$$

Proof. For any $(s_i^t, \alpha) \in S^t$, $NS^{-1}(NS(s_i^t, \alpha)) = (s_i^t, \alpha)$. So, the inverse operation of NS is Equation (9).

3.3 | The aggregation operators of MGUHFLTS

In MAGDM problems, it is an important step to aggregate assessments from different sources into a whole. The aggregation principle of MGUHFLTS is consistent with that of HFLTSs, which means all the possible combinations of the elements should be aggregated first.

Let $\{\overline{H}_{S_1}, \overline{H}_{S_2}, \ldots, \overline{H}_{S_n}\}$ be a collection of MGUHFLTS on $S^{MG} = \{S^t | t = 1, \ldots, T\}$, and $W = (w_1, w_2, \ldots, w_n)^T$ be the associated weighting vector of $\overline{H}_{S_j}$, $j \in J = \{1, 2, \ldots, n\}$, such that $0 \le w_j \le 1$, $\sum_{j=1}^n w_j = 1$. Let $h_{S_j} \in \overline{H}_{S_j}$, $j \in J$, then these MGUHFLTSs are initially aggregated as

$$\oplus_{j=1}^n w_j \overline{H}_{S_j} = \cup_{\overline{h}_{S_j} \in \overline{H}_{S_j}, j \in J} \{\oplus_{j=1}^n w_j \overline{h}_{S_j}\}. \tag{10}$$

Obviously, there are $V = \prod_{j=1}^n \#(\overline{H}_{S_j})$ elements in $\oplus_{j=1}^n w_j \overline{H}_{S_j}$. $\oplus_{j=1}^n w_j \overline{h}_{S_j}$ can be expressed in the form of linguistic 2-tuple as

$$\oplus_{j=1}^n w_j \overline{h}_{S_j} = NS^{-1}\left(\sum_{j=1}^n w_j NS(\overline{h}_{S_j})\right). \tag{11}$$

Here, the result derived by formula (11) is also a linguistic 2-tuple. By formula (9), the aggregation result can be obtained that

$$\begin{cases} \left\{\left(s_{j_i}^t, \frac{\sum_{j=1}^n w_j \overline{h}_{S_j} - NS\left(s_{j_i}^t\right)}{NS\left(s_{j_i+1}^t\right) - NS\left(s_{j_i}^t\right)}\right) \middle| \overline{h}_{S_j} \in \overline{H}_{S_j}, j \in J\right\}, & \sum_{j=1}^n w_j \overline{h}_{S_j} < \frac{NS\left(s_{j_i+1}^t\right) + NS\left(s_{j_i}^t\right)}{2}, \\ \left\{\left(s_{j_i+1}^t, \frac{\sum_{j=1}^n w_j \overline{h}_{S_j} - NS\left(s_{j_i+1}^t\right)}{NS\left(s_{j_i+1}^t\right) - NS\left(s_{j_i}^t\right)}\right) \middle| \overline{h}_{S_j} \in \overline{H}_{S_j}, j \in J\right\}, & \sum_{j=1}^n w_j \overline{h}_{S_j} \ge \frac{NS\left(s_{j_i+1}^t\right) + NS\left(s_{j_i}^t\right)}{2}. \end{cases} \tag{12}$$

Definition 8. Let $\{\overline{H}_{S_1}, \overline{H}_{S_2}, \ldots, \overline{H}_{S_n}\}$ be a collection of MGUHFLTS on $S^{MG} = \{S^t \mid t = 1, \ldots, T\}$ and $W = (w_1, w_2, \ldots, w_n)^T$ be the associated weighting vector of $\overline{H}_{S_j}$, $j \in J = \{1, 2, \ldots, n\}$, such that $0 \le w_j \le 1$, $\sum_{j=1}^n w_j = 1$. Let $\overline{h}_{S_j} \in \overline{H}_{S_j}$, $j \in J$, then the MGUHFLWA operator can be shown as

$$\begin{aligned} MGUHFLWA(\overline{H}_{S_1}, \overline{H}_{S_2}, \ldots, \overline{H}_{S_n}) = \{NS^{-1}(w_1 \times NS(\overline{h}_{S_1}) + w_2 \times NS(\overline{h}_{S_2}) + \cdots \\ + w_n \times NS(\overline{h}_{S_n})) \mid \overline{h}_{S_j} \in \overline{H}_{S_j}\}. \end{aligned} \tag{13}$$

Definition 9. Let $\{\overline{H}_{S_1}, \overline{H}_{S_2}, \ldots, \overline{H}_{S_n}\}$ be a collection of MGUHFLTS on $S^{MG} = \{S^t \mid t = 1, \ldots, T\}$ and $W = (w_1, w_2, \ldots, w_n)^T$ be the associated weighting vector of $\overline{H}_{S_j}$, $j \in J = \{1, 2, \ldots, n\}$, such that $0 \le w_j \le 1$, $\sum_{j=1}^n w_j = 1$. Let $\overline{h}_{S_j} \in \overline{H}_{S_j}$, $j \in J$, then the multigranularity unbalanced hesitant fuzzy linguistic order weighted averaging (MGUHFLOWA) operator can be shown as

$$\begin{aligned} MGUHFLOWA(\overline{H}_{S_1}, \overline{H}_{S_2}, \ldots, \overline{H}_{S_n}) = \{NS^{-1}(w_1 \times NS(\overline{h}_{S_{\sigma(1)}}) + w_2 \times NS(\overline{h}_{S_{\sigma(2)}}) + \cdots \\ + w_n \times NS(\overline{h}_{S_{\sigma(n)}})) \mid \overline{h}_{S_{\sigma(j)}} \in \overline{H}_{S_{\sigma(j)}}\}, \end{aligned} \tag{14}$$

where $(\sigma(1), \sigma(2), \ldots, \sigma(n))$ is the permutation of $(1, 2, \ldots, n)$ such that $\overline{h}_{S_{\sigma(j-1)}} \succ \overline{h}_{S_{\sigma(j)}}$ for $j = 2, 3, \ldots, n$.

Theorem 3. *Let $\{\overline{H}_{S_1}, \overline{H}_{S_2}, \ldots, \overline{H}_{S_n}\}$ be a set of MGUHFLTS on $S^{MG} = \{S^t \mid t = 1, \ldots, T\}$. Then the MGUHFLWA and MGUHFLOWA operators based on* NS *satisfy the following properties:*

1. (Boundedness) $min\{\overline{H}_{S_j}|j=1,2,...,n\} \le MGUHFLWA(\overline{H}_{S_1},\overline{H}_{S_2},...,\overline{H}_{S_n}) \le max\{\overline{H}_{S_j}|j=1,2,...,n\}$, and $min\{\overline{H}_{S_j}|j=1,2,...,n\} \le MGUHFLOWA(\overline{H}_{S_1},\overline{H}_{S_2},...,\overline{H}_{S_n}) \le max\{\overline{H}_{S_j}|j=1,2,...,n\}$.

Proof. $min\{\overline{H}_{S_j}|j=1,2,...,n\}=\overline{H}_{S_\alpha}$ and $max\{\overline{H}_{S_j}|j=1,2,...,n\}=\overline{H}_{S_\beta}$, then

$$MGUHFLWA(\overline{H}_{S_1},\overline{H}_{S_2},...,\overline{H}_{S_n}) = \{NS^{-1}(w_1 \times NS(\overline{h}_{S_1}) + w_2 \times NS(\overline{h}_{S_2}) + \cdots + w_n \times NS(\overline{h}_{S_n}))|\overline{h}_{S_j} \in \overline{H}_{S_j}\}$$

$$\le \{NS^{-1}(w_1 \times NS(\overline{h}_{S_1}) + w_2 \times NS(\overline{h}_{S_2}) + \cdots + w_n \times NS(\overline{h}_{S_n}))|\overline{h}_{S_j} \in \overline{H}_{S_\beta}\} = \overline{H}_{S_\beta}.$$

So, $min\{\overline{H}_{S_j}|j=1,2,...,n\} \le MGUHFLWA(\overline{H}_{S_1},\overline{H}_{S_2},...,\overline{H}_{S_n}) \le max\{\overline{H}_{S_j}|j=1,2,...,n\}$.

Similarly, we can get

$$min\{\overline{H}_{S_j}|j=1,2,...,n\} \le MGUHFLOWA(\overline{H}_{S_1},\overline{H}_{S_2},...,\overline{H}_{S_n}) \le max\{\overline{H}_{S_j}|j=1,2,...,n\}.$$

2. (Idempotency) $MGUHFLWA(\overline{H}_{S_1},\overline{H}_{S_2},...,\overline{H}_{S_n}) = MGUHFLOWA(\overline{H}_{S_1},\overline{H}_{S_2},...,\overline{H}_{S_n}) = \overline{H}_{S_\rho}$, when $\overline{H}_{S_j}=\overline{H}_{S_\rho}$ for $j=1,2,...,n$.

Proof. Since $\overline{H}_{S_j}=\overline{H}_{S_\rho}$ for $j=1,2,...,n$, it follows that

$$\begin{aligned} MGUHFLWA(\overline{H}_{S_1},\overline{H}_{S_2},...,\overline{H}_{S_n}) &= \{NS^{-1}(w_1 \times NS(\overline{h}_{S_1}) + w_2 \times NS(\overline{h}_{S_2}) + \cdots + w_n \times NS(\overline{h}_{S_n}))| \\ &\qquad \overline{h}_{S_j} \in \overline{H}_{S_j}\} \\ &= \{NS^{-1}(w_1 \times NS(\overline{h}_{S_1}) + w_2 \times NS(\overline{h}_{S_2}) + \cdots + w_n \times NS(\overline{h}_{S_n}))| \\ &\qquad \overline{h}_{S_j} \in \overline{H}_{S_\rho}\} = \overline{H}_{S_\rho}, \end{aligned}$$

$$\begin{aligned} MGUHFLOWA(\overline{H}_{S_1},\overline{H}_{S_2},...,\overline{H}_{S_n}) &= \{NS^{-1}(w_1 \times NS(\overline{h}_{S_{\sigma(1)}}) + w_2 \times NS(\overline{h}_{S_{\sigma(2)}}) + \cdots + w_n \\ &\qquad \times NS(\overline{h}_{S_{\sigma(n)}}))|\overline{h}_{S_{\sigma(j)}} \in \overline{H}_{S_{\sigma(j)}}\} \\ &= \{NS^{-1}(w_1 \times NS(\overline{h}_{S_{\sigma(1)}}) + w_2 \times NS(\overline{h}_{S_{\sigma(2)}}) + \cdots + w_n \\ &\qquad \times NS(\overline{h}_{S_{\sigma(n)}}))|\overline{h}_{S_{\sigma(j)}} \in \overline{H}_{S_{\sigma(\rho)}}\} = \overline{H}_{S_\rho}, \end{aligned}$$

hence, $MGUHFLWA(\overline{H}_{S_1},\overline{H}_{S_2},...,\overline{H}_{S_n}) = MGUHFLOWA(\overline{H}_{S_1},\overline{H}_{S_2},...,\overline{H}_{S_n}) = \overline{H}_{S_\rho}$, when $\overline{H}_{S_j}=\overline{H}_{S_\rho}$ for $j=1,2,...,n$.

3. (Commutativity) If $(\overline{H}'_{S_1},\overline{H}'_{S_2},...,\overline{H}'_{S_n})$ is any permutation of $(\overline{H}_{S_1},\overline{H}_{S_2},...,\overline{H}_{S_n})$, then $MGUHFLOWA(\overline{H}'_{S_1},\overline{H}'_{S_2},...,\overline{H}'_{S_n}) = MGUHFLOWA(\overline{H}_{S_1},\overline{H}_{S_2},...,\overline{H}_{S_n})$.

Proof. According to Definition 6, let

$$MGUHFLOWA(\overline{H}_{S_1},\overline{H}_{S_2},...,\overline{H}_{S_n}) = \{NS^{-1}(w_1 \times NS(\overline{h}_{S_{\sigma(1)}}) + w_2 \times NS(\overline{h}_{S_{\sigma(2)}}) + \cdots + w_n \times NS(\overline{h}_{S_{\sigma(n)}}))|\overline{h}_{S_{\sigma(j)}} \in \overline{H}_{S_{\sigma(j)}}\},$$

$$MGUHFLOWA(\overline{H}'_{S_1}, \overline{H}'_{S_2}, ..., \overline{H}'_{S_n}) = \left\{NS^{-1}\left(w_1 \times NS(\overline{h}'_{S_{\sigma(1)}}) + w_2 \times NS\left(\overline{h}'_{S_{\sigma(2)}}\right) + \cdots + w_n \times NS\left(\overline{h}'_{S_{\sigma(n)}}\right)\right) \middle| \overline{h}'_{S_{\sigma(j)}} \in \overline{H}'_{S_{\sigma(j)}}\right\}.$$

Because $(\overline{H}'_{S_1}, \overline{H}'_{S_2}, ..., \overline{H}'_{S_n})$ is any permutation of $(\overline{H}_{S_1}, \overline{H}_{S_2}, ..., \overline{H}_{S_n})$, so

$$MGUHFLOWA(\overline{H}'_{S_1}, \overline{H}'_{S_2}, ..., \overline{H}'_{S_n}) = MGUHFLOWA(\overline{H}_{S_1}, \overline{H}_{S_2}, ..., \overline{H}_{S_n}).$$

4. (Monotonity) If $\overline{H}'_{S_j} > \overline{H}_{S_j}$ for any $\forall j \in \{1, 2, ..., n\}$, then

$$MGUHFLWA(\overline{H}'_{S_1}, \overline{H}'_{S_2}, ..., \overline{H}'_{S_n}) > MGUHFLWA(\overline{H}_{S_1}, \overline{H}_{S_2}, ..., \overline{H}_{S_n}),$$

$$MGUHFLOWA(\overline{H}'_{S_1}, \overline{H}'_{S_2}, ..., \overline{H}'_{S_n}) > MGUHFLOWA(\overline{H}_{S_1}, \overline{H}_{S_2}, ..., \overline{H}_{S_n}).$$

Proof. Let

$$MGUHFLWA(\overline{H}'_{S_1}, \overline{H}'_{S_2}, ..., \overline{H}'_{S_n}) = \left\{NS^{-1}\left(w_1 \times NS(\overline{h}_{S_1}) + w_2 \times NS\left(\overline{h}'_{S_2}\right) + \cdots + w_n \times NS\left(\overline{h}'_{S_n}\right)\right) \middle| \overline{h}'_{Sj} \in \overline{H}'_{S_j}\right\}$$

and

$$MGUHFLWA(\overline{H}_{S_1}, \overline{H}_{S_2}, ..., \overline{H}_{S_n}) = \{NS^{-1}(w_1 \times NS(\overline{h}_{S_1}) + w_2 \times NS(\overline{h}_{S_2}) + \cdots + w_n \times NS(\overline{h}_{S_n}))|\overline{h}_{S_j} \in \overline{H}_{S_j}\},$$

since $\overline{H}'_{S_j} > \overline{H}_{S_j}$, then there must exist the probability of $\overline{h}'_{S_j} > \overline{h}_{S_j}$, then, if $\overline{H}'_{S_j} > \overline{H}_{S_j}$

$$MGUHFLWA(\overline{H}'_{S_1}, \overline{H}'_{S_2}, ..., \overline{H}'_{S_n}) > MGUHFLWA(\overline{H}_{S_1}, \overline{H}_{S_2}, ..., \overline{H}_{S_n}).$$

Similarly, if $\overline{H}'_{S_j} > \overline{H}_{S_j}$, we can get

$$MGUHFLOWA(\overline{H}'_{S_1}, \overline{H}'_{S_2}, ..., \overline{H}'_{S_n}) > MGUHFLOWA(\overline{H}_{S_1}, \overline{H}_{S_2}, ..., \overline{H}_{S_n}).$$

5. $MGUHFLWA(\overline{H}_{S_1}, \overline{H}_{S_2}, ..., \overline{H}_{S_n}) = \overline{H}_{S_j}$, when $w_j = 1$. $MGUHFLOWA(\overline{H}_{S_1},\overline{H}_{S_2}, ..., \overline{H}_{S_n}) = \overline{H}_{S_j}$, when $w_i = 1$ and $j = \sigma(i)$.

Proof. If $w_j = 1$, then

$$\begin{aligned} &MGUHFLWA(\overline{H}_{S_1}, \overline{H}_{S_2}, ..., \overline{H}_{S_n}) \\ &= \{NS^{-1}(w_1 \times NS(\overline{h}_{S_1}) + w_2 \times NS(\overline{h}_{S_2}) + \cdots + w_j \times NS(\overline{h}_{S_j}) + \cdots + w_n \times NS(\overline{h}_{S_n}))|\overline{h}_{S_j} \in \overline{H}_{S_j}\} \\ &= \{NS^{-1}(1 \times NS(\overline{h}_{S_j}))|(\overline{h}_{S_j}) \in \overline{H}_{S_j}\} = \overline{H}_{S_j}. \end{aligned}$$

Similarly, if $w_i = 1$ and $j = \sigma(i)$, then

$$
\begin{aligned}
&MGUHFLOWA(\overline{H}_{S_1}, \overline{H}_{S_2}, \ldots, \overline{H}_{S_n}) \\
&= \{NS^{-1}(w_1 \times NS(\overline{h}_{S_{\sigma(1)}}) + w_2 \times NS(\overline{h}_{S_{\sigma(2)}}) + \cdots + w_i \times NS(\overline{h}_{S_{\sigma(i)}}) + \cdots \\
&\quad + w_n \times NS(\overline{h}_{S_{\sigma(n)}})) | \overline{h}_{S_{\sigma(i)}} \in \overline{H}_{S_{\sigma(i)}}\} \\
&= \{NS^{-1}(1 \times NS(\overline{h}_{S_{\sigma(i)}})) | \overline{h}_{S_{\sigma(i)}} \in \overline{H}_{S_{\sigma(i)}}\} = \overline{H}_{S_j} = \{NS^{-1}(1 \times NS(\overline{h}_{S_j})) | \overline{h}_{S_j} \in \overline{H}_{S_j}\} = \overline{H}_{S_j}.
\end{aligned}
$$

This completes the proof of Theorem 3.

4 | NOVEL MGUHFLTS–MABAC MODEL

4.1 | Construction of the novel MGUHFLTS–MABAC model

The MABAC is a reliable approach to solve MAGDM problems. To deal with different granularity linguistic evaluation information, it is necessary to apply the MABAC method to the MGUHFLTS environment. Thus, a novel MGUHFLTS–MABAC model is established.

Seven steps of this model are shown as follows:

Let $S^{MG} = \{S^t | t = 1, \ldots, T\}$, $S^t = \{s_0^t, s_1^t, \ldots, s_\tau^t\}$, $s_\alpha^t \in S^t$ be the ULTS. The ULTS used by the kth DM group is $S^k = \{s_0^k, s_1^k, \ldots, s_{g(k)}^k\}$ and the NS function on S^k is NS^k, $k = 1, 2, \ldots, q$. Suppose that the evaluation value of group G_k under attribute C_j of alternative A_i is expressed as $\overline{h}_{ij}^k$, then, the decision matrix given is $\overline{H}^k = [\overline{h}_{ij}^k]_{m \times n}$, $i = 1, 2, \ldots, m$; $j = 1, 2, \ldots, n$; $k = 1, 2, \ldots, q$. m is the number of alternatives and n is the number of criteria.

Step 1. Set a basic ULTS S^B.

Select a basic ULTS S^B form $\{S^1, S^2, \ldots, S^q\}$. S^B can be chosen freely by DMs, because it cannot influence the ranking results.

Step 2. Construct the weighted aggregated decision matrix X of different DMs.

Assuming that $A = (A_1, A_2, \ldots, A_m)$ are a set of alternatives, the attributes are $C = (C_1, C_2, \ldots, C_n)$ and groups of DMs $G = (G_1, G_2, \ldots, G_q)$ provide their evaluations.

First, transform the assessment information MGHFLTEs to the linguistic 2-tuple elements in terms of formula (2).

Second, get the aggregated decision matrix X. Elements of aggregated decision matrix X can be calculated based on S^B by formula (10).

$$
X = \begin{array}{c} \\ A_1 \\ A_2 \\ \cdots \\ A_m \end{array}
\begin{array}{c}
\begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\
\begin{bmatrix}
\overline{h}_s(x_{11}^B) & \overline{h}_s(x_{12}^B) & \cdots & \overline{h}_s(x_{1n}^B) \\
\overline{h}_s(x_{21}^B) & \overline{h}_s(x_{22}^B) & \cdots & \overline{h}_s(x_{2n}^B) \\
\cdots & \cdots & \cdots & \cdots \\
\overline{h}_s(x_{m1}^B) & \overline{h}_s(x_{m2}^B) & \cdots & \overline{h}_s(x_{mn}^B)
\end{bmatrix}
\end{array} \quad (15)
$$

Step 3. Normalize the aggregated decision matrix N.

Normalized the aggregated decision matrix X into N as follows:

$$N = \begin{array}{c} \\ A_1 \\ A_2 \\ \cdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} \bar{h}_s\left(n_{11}^B\right) & \bar{h}_s\left(n_{12}^B\right) & \cdots & \bar{h}_s\left(n_{1n}^B\right) \\ \bar{h}_s\left(n_{21}^B\right) & \bar{h}_s\left(n_{22}^B\right) & \cdots & \bar{h}_s\left(n_{2n}^B\right) \\ \cdots & \cdots & \cdots & \cdots \\ \bar{h}_s\left(n_{m1}^B\right) & \bar{h}_s\left(n_{m2}^B\right) & \cdots & \bar{h}_s\left(n_{mn}^B\right) \end{bmatrix} \end{array} \quad (16)$$

where $\bar{h}_s(n_{ij}^B)$ is still a linguistic 2-tuple element, if $\bar{h}_s(n_{ij}^B)$ is a benefit criterion, $\bar{h}_s(n_{ij}^B) = \bar{h}_s(x_{ij}^B)$; or $\bar{h}_s(n_{ij}^B) = NS^{-1}(NS(s_\tau^B) - NS(\bar{h}_s(x_{ij}^B)))$, $s_\tau^B \in S^B = \{s_0^B, s_1^B, ..., s_\tau^B\}$.

Step 4. Calculate the weighted matrix V.

The elements are calculated by

$$\bar{h}_s(v_{ij}^B) = w_i \bar{h}_s\left(n_{ij}^B\right), \quad (17)$$

where $\bar{h}_s(n_{ij}^B)$ is the element of the normalized matrix N, and w_i is the weight of the criteria. The weighted matrix V can be obtained by using formula (13).

$$V = \begin{bmatrix} \bar{h}_s\left(v_{11}^B\right) & \bar{h}_s\left(v_{12}^B\right) & \dots & \bar{h}_s\left(v_{1n}^B\right) \\ \bar{h}_s\left(v_{21}^B\right) & \bar{h}_s\left(v_{22}^B\right) & \dots & \bar{h}_s\left(v_{2n}^B\right) \\ \dots & \dots & \dots & \dots \\ \bar{h}_s\left(v_{m1}^B\right) & \bar{h}_s\left(v_{m2}^B\right) & \dots & \bar{h}_s\left(v_{mn}^B\right) \end{bmatrix} = \begin{bmatrix} w_1 \cdot \bar{h}_s\left(n_{11}^B\right) & w_2 \cdot \bar{h}_s\left(n_{12}^B\right) & \dots & w_n \cdot \bar{h}_s\left(n_{1n}^B\right) \\ w_1 \cdot \bar{h}_s\left(n_{21}^B\right) & w_2 \cdot \bar{h}_s\left(n_{22}^B\right) & \dots & w_n \cdot \bar{h}_s\left(n_{2n}^B\right) \\ \dots & \dots & \dots & \dots \\ w_1 \cdot \bar{h}_s\left(n_{m1}^B\right) & w_2 \cdot \bar{h}_s\left(n_{m2}^B\right) & \dots & w_n \cdot \bar{h}_s\left(n_{mn}^B\right) \end{bmatrix}$$

Step 5. Determine the border approximation area (BAA) matrix G.

The BAA for each criterion is determined by using formula (18).

$$g_i = \frac{1}{m} \sum_{i=1}^{m} \bar{h}_s\left(v_{ij}^B\right), \quad (18)$$

where $\bar{h}_s(v_{ij}^B)$ is the element of the weighted matrix V, and m is the total number of alternatives.

After calculating the value g_i for each criterion, a BAA matrix G is formed as follows:

$$\begin{array}{cccc} & C_1 & C_2 & \cdots & C_n \\ G = & \Big[h_s\left(g_1^B\right) & h_s\left(g_2^B\right) & \cdots & h_s\left(g_n^B\right) \Big]. \end{array} \quad (19)$$

Step 6. Compute the distance matrix Q.

Elements of the distance matrix Q can be calculated by

$$Q = \bar{h}_s\left(q_{ij}^B\right) = \begin{cases} d\left(\bar{h}_s\left(v_{ij}^B\right), \bar{h}_s\left(g_j^B\right)\right) & \text{if } \bar{h}_s\left(v_{ij}^B\right) \succ \bar{h}_s\left(g_j^B\right), \\ 0 & \text{if } \bar{h}_s\left(v_{ij}^B\right) = \bar{h}_s\left(g_j^B\right), \\ -d\left(\bar{h}_s\left(v_{ij}^B\right), \bar{h}_s\left(g_j^B\right)\right) & \text{if } \bar{h}_s\left(v_{ij}^B\right) \prec \bar{h}_s\left(g_j^B\right), \end{cases} \quad (20)$$

where $d(\bar{h}_s(v_{ij}^B), \bar{h}_s(g_j^B))$ denotes the distance between $h_s(v_{ij}^B)$ and $h_s(g_j^B)$. $h_s(v_{ij}^B)$ is the element of the weighted matrix V, and $h_s(g_j^B)$ is the BAA of the criterion.

There are three situations of alternative A_i, the first is belonging to the BAA(G), the second is upper the BAA(G^+), and the third is lower the BAA(G^-), which could be shown as follows:

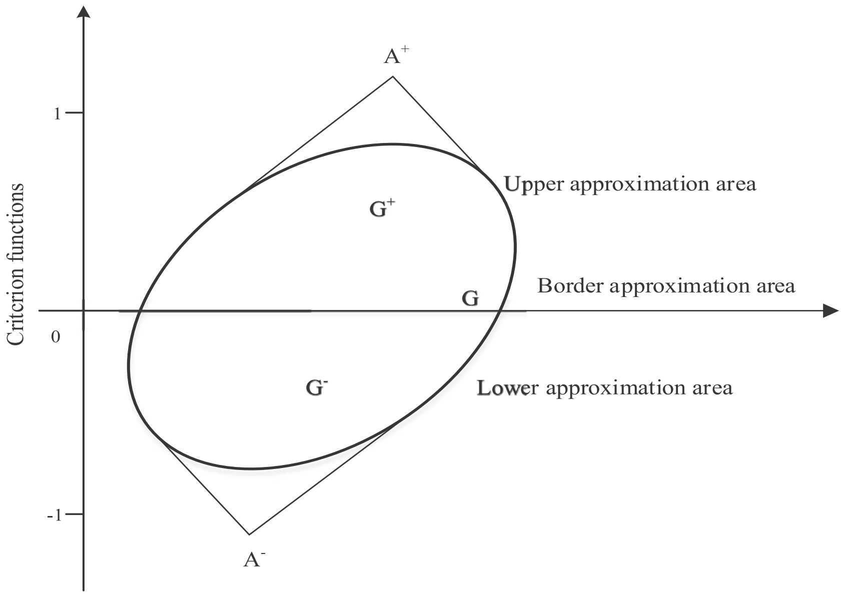

FIGURE 1 Presentation of the upper (G^{+}), lower (G^{-}), and border (G) approximation areas

$$A_i \in \begin{cases} G^{+} & \text{if } \overline{h}_s\left(v_{ij}^{B}\right) \succ \overline{h}_s\left(g_j^{B}\right), \\ G & \text{if } \overline{h}_s\left(v_{ij}^{B}\right) = \overline{h}_s\left(g_j^{B}\right), \\ G^{-} & \text{if } \overline{h}_s\left(v_{ij}^{B}\right) \prec \overline{h}_s\left(g_j^{B}\right), \end{cases} \tag{21}$$

where G^{+} is the area which contains the ideal alternative (A^{+}), while G^{-} is the area which contains the anti-ideal alternative (A^{-}) (Figure 1).

To select the best alternative A_i, there should be as many criteria as possible belonging to G^{+}. If $\overline{h}_s(v_{ij}^{B}) > \overline{h}_s(g_i^{B})$, that is, $A_i \in G^{+}$, then alternative A_i is near or equal to A^{+}; if $\overline{h}_s(v_{ij}^{B}) < \overline{h}_s(g_i^{B})$, that is, $A_i \in G^{-}$, then alternative A_i is near or equal to A^{-}.

Step 7. Rank the alternatives.

The final values of the alternatives are obtained by the following calculation:

$$S_i = \sum_{j=1}^{n} \overline{h}_s\left(q_{ij}^{B}\right), \quad j = 1, 2, \ldots, n, \quad i = 1, 2, \ldots, m, \tag{22}$$

where n is the number of criteria, and m is the number of alternatives.

The larger the value of S_i is, the better the alternative is.

4.2 | The comparative analysis

In this subsection, an existing example is applied by the novel MGUHFLTS–MABAC model, which is proposed in the previous subsection. And the validity and superiority of our proposed method are verified by comparing it with the other three methods.

4.2.1 | Validity analysis of the proposed method

To verify the validity of the proposed method, the multi-granular unbalanced hesitant fuzzy linguistic Choquet integral average (MGUHFLCA) method[19] is applied under the MGUHFLTS environment. The data are from online course evaluation of Open University of China in Liu and Rong's paper.[19] The slight difference of the data depends on whether DMs and attributes are independent of each other. In this paper, we suppose both DMs and attributes are independent. The weights of DMs are {0.2, 0.3, 0.5}, the weighs of attributes are {3/9, 1/9, 2/9, 3/9}. The semantics of the ULTSs S^1, S^2, S^3 are the same. Let $S^{MG} = \{S^t \,|\, t = 1, \ldots, T\}$ be a set of ULTSs, $S^t = \{s_0^t, s_1^t, \ldots, s_\tau^t\}$ be a ULTS, $s_i^t \in S^t$, $t = 1, \ldots, T$, $i = 0, \ldots, \tau$. $NS(s_i^t) = CCV(s_i^t)$.[18]

Therefore, our method and MGUHFLCA method are applied to solve this problem. The specific results are as follows:

The steps of our method are as follows:

Step 1. Set a basic ULTS S^B. S^3 is selected as S^B.

Step 2. Transform the assessment information MGHFLTEs to the linguistic 2-tuple elements and then get the aggregated decision matrix X of different DMs.

Formula (10) is used to calculate the data of the three DMs groups, and get the aggregated decision matrix X.

$$X = \begin{bmatrix} \{(s_3^3, 0.1438)\} & \{(s_3^3, 0.1313)\} & \{(s_3^3, 0.1375)\} & \{(s_4^3, -0.4222)\} \\ \{(s_2^3, 0.1179)\} & \{(s_2^3, 0.0393)\} & \{(s_2^3, -0.2449)\} & \{(s_2^3, -0.3237)\} \\ \{(s_3^3, 0.0169)\} & \{(s_3^3, -0.5000)\} & \{(s_3^3, -0.2375)\} & \{(s_3^3, 0.0313)\} \\ \{(s_1^3, -0.0671)\} & \{(s_1^3, -0.1762)\} & \{(s_1^3, 0.1204)\} & \{(s_1^3, -0.0654)\} \end{bmatrix}.$$

Here we take aggregation of $\{\overline{H}_{S_1}^{11}, \overline{H}_{S_2}^{11}, \overline{H}_{S_3}^{11}\}$ as an example to demonstrate the process. By formula (10) the linguistic 2-tuple elements are initially aggregated as

$$\begin{aligned} \oplus_{z=1}^{3}\lambda_z \overline{H}_{S_z}^1 &= \cup_{\overline{h}_{S_z}\in \overline{H}_{S_z}^1, j=1,2,3}\{\oplus_{z=1}^{3}\lambda_z \overline{h}_{S_z}\} \\ &= \{NS_B^{-1}(0.2\times 0.95 + 0.3\times 0.7 + 0.5\times 0.95), NS_B^{-1}(0.2\times 0.95 + 0.3\times 0.7 \\ &\quad + 0.5\times 0.7), \\ &\quad NS_B^{-1}(0.2\times 0.95 + 0.3\times 0.7 + 0.5\times 0.95), NS_B^{-1}(0.2\times 0.95 + 0.3\times 0.7 \\ &\quad + 0.5\times 0.7)\} \\ &= \{NS_B^{-1}(0.875), NS_B^{-1}(0.75), NS_B^{-1}(0.875), NS_B^{-1}(0.75)\}. \end{aligned}$$

The four elements of $\oplus_{z=1}^{3}\lambda_z \overline{H}_{S_z}^1$ are aggregated by the MGUHFLWA operator, and get $x_{11} = \{(s_3^3, 0.1125)\}$.

Step 3. Normalize the aggregated decision matrix N.

All the indicators are benefit criteria, so $\overline{h}_s(n_{ij}^B) = \overline{h}_s(x_{ij}^B)$, the normalized matrix N is the same as the aggregated decision matrix X.

Step 4. Calculate the weighted matrix V.

The weight of the attribute is shown as follows, according to formula (10), we get the weighted matrix V.

$$w = (3/9, 1/9, 2/9, 3/9),$$

$$V=\begin{bmatrix}\left\{\left(s_1^3,\text{-}0.2416\right)\right\} & \left\{\left(s_0^3,0.2586\right)\right\} & \left\{\left(s_1^3,\text{-}0.4788\right)\right\} & \left\{\left(s_1^3,\text{-}0.4565\right)\right\}\\ \left\{\left(s_1^3,\text{-}0.4563\right)\right\} & \left\{\left(s_0^3,0.1641\right)\right\} & \left\{\left(s_0^3,0.2894\right)\right\} & \left\{\left(s_0^3,0.2824\right)\right\}\\ \left\{\left(s_1^3,\text{-}0.3308\right)\right\} & \left\{\left(s_0^3,0.1867\right)\right\} & \left\{\left(s_0^3,0.4060\right)\right\} & \left\{\left(s_0^3,0.4551\right)\right\}\\ \left\{\left(s_0^3,0.3020\right)\right\} & \left\{\left(s_0^3,0.0915\right)\right\} & \left\{\left(s_0^3,0.2597\right)\right\} & \left\{\left(s_0^3,0.4944\right)\right\}\end{bmatrix}.$$

Step 5. Determine the BAA matrix G.

The BAA for each criterion is determined by using formula (18).

$$G=\left(\left\{\left(s_1^3,-0.4317\right)\right\},\left\{\left(s_0^3,0.1752\right)\right\},\left\{\left(s_0^3,0.3691\right)\right\},\left\{\left(s_0^3,0.3721\right)\right\}\right).$$

Step 6. Compute the distance matrix Q.

Elements of the distance matrix Q can be calculated by formula (20) and shown in Table 1.

Step 7. Rank the alternatives.

The final values of the alternatives are calculated by formula (22), and get $S(A_1)=0.2143$, $S(A_2)=-0.0722$, $S(A_3)=-0.0840$, and $S(A_4)=-0.2217$. Since $S(A_1)>S(A_3)>S(A_2)>S(A_4)$, then $A_1\succ A_3\succ A_2\succ A_4$, and the best alternative is A_1.

The steps of MGUHFLCA method[19] are as follows:

Step 1. S^3 is chosen as the basic LTS S^B.

Step 2. The assessment information provided by DMs groups with MGUHFLEs is transformed to the proportional 2-tuple sets.

Step 3. Determining the fuzzy measure (weight) of each DM group. The fuzzy measure of each DM group is as follows:

$\mu(\varnothing)=0$, $\mu(G_1)=0.2$, $\mu(G_2)=0.3$, and $\mu(G_3)=0.5$. In this example, the DM groups are independent of each other, $\lambda_G=0$, we get

$\mu(G_1,G_2)=0.5$, $\mu(G_1,G_3)=0.7$, $\mu(G_2,G_3)=0.8$, and $\mu(G_1,G_2,G_3)=1$.

Step 4. Integrating each DM group's assessment by *MGUHFLCA* operator to obtain the comprehensive information. Utilizing the *MGUHFLCA* operator, $\overline{H}^B=\overline{h}_{ij}^B$ $(i=1,2,3,4;j=1,2,3,4)$.

For example,

$$\overline{H}_{12}^B=\left\{\left(0.7158s_3^3,0.2842s_4^3\right),(0.5676s_3^3,0.4324s_4^3)\right\}.$$

The other results are omitted here.

Step 5. Determining the fuzzy measure of each attribute and attribute set. The fuzzy measure of each attribute is as follows:

$\mu(\varnothing)=0$, $\mu(C_1)=3/9$, $\mu(C_2)=1/9$, $\mu(C_3)=2/9$, $\mu(C_4)=3/9$, and $\lambda_C=0$. We get

TABLE 1 Deviation measures of five alternatives

	B_1	B_2	B_3	B_4
A_1	0.0679	0.0298	0.0543	0.0623
A_2	−0.0088	−0.0040	−0.0285	−0.0310
A_3	0.0360	0.0041	0.0132	0.0307
A_4	−0.0951	−0.0299	−0.0391	−0.0576

TABLE 2 Results obtained by two methods under MGUHFLTS environment

Methods	Evaluation values	Ranking
MGUHFLCA method[19]	$S(A_1) = 0.8020, S(A_2) = 0.5421, S(A_3) = 0.7017, S(A_4) = 0.3530$	$A_1 \succ A_3 \succ A_2 \succ A_4$
The proposed method	$S(A_1) = 0.2143, S(A_2) = -0.0722, S(A_3) = 0.0840, S(A_4) = -0.2217$	$A_1 \succ A_3 \succ A_2 \succ A_4$

Abbreviations: MGUHFLCA, multi-granular unbalanced hesitant fuzzy linguistic Choquet integral average; MGUHFLTS, multigranular unbalanced hesitant fuzzy linguistic term set.

$\mu(C_1, C_2) = 1/3$, $\mu(C_1, C_3) = 5/9$, $\mu(C_1, C_4) = 2/3$, $\mu(C_2, C_3) = 1/3$, $\mu(C_2, C_4) = 4/9$, $\mu(C_3, C_4) = 5/9$, $\mu(C_1, C_2, C_3) = 2/3$, $\mu(C_1, C_2, C_4) = 7/9$, $\mu(C_1, C_3, C_4) = 8/9$, $\mu(C_2, C_3, C_4) = 2/3$, and $\mu(C_1, C_2, C_3, C_4) = 1$.

Step 6. *MGUHFLCA* operator is used to integrate the attribute values of each alternative into a collective assessment $\overline{H}_i^B$, here $\overline{H}_i^B$ is a proportional 2-tuple fuzzy LV on S^B. For example,

$$\overline{H}_1^B = \left\{\left(0.6707s_3^3, 0.3293s_4^3\right), \left(0.6233s_3^3, 0.3767s_4^3\right), \ldots, \left(0.6026s_3^3, 0.3974s_4^3\right), \left(0.6484s_3^3, 0.3516s_4^3\right)\right\}.$$

Step 7. For each alternative, calculating the score function,

$$S(A_1) = 0.8020, S(A_2) = 0.5421, S(A_3) = 0.7017, S(A_4) = 0.3530.$$

Step 8. According to values of score function, we get $A_1 \succ A_3 \succ A_2 \succ A_4$. So the best alternative is A_1.

The results of the two methods are shown in Table 2.

The ranking results in Table 2 by means of MGUHFLCA method[19] and the proposed method demonstrate the same results, which is $A_1 \succ A_3 \succ A_2 \succ A_4$. The above ranking results prove the validity of the proposed method.

4.2.2 | Superiority analysis of the proposed method

To prove the advantages of the proposed method, the comparison with different methods should be given attention first. These methods are MGUHFLCA method,[19] hesitant linguistic

TABLE 3 The evaluation results by different methods

Methods	Evaluation values	Ranking
DAWA method[36]	Cannot be obtained	–
HLWA method[18]	$E(A_1) = 0.5200, E(A_2) = 0.5700, E(A_3) = 0.5800, E(A_4) = 0.5628$	$A_3 \succ A_2 \succ A_4 \succ A_1$
MGUHFLCA method[19]	$S(A_1) = 0.4517, S(A_2) = 0.5000, S(A_3) = 0.6234, S(A_4) = 0.5635$	$A_3 \succ A_4 \succ A_2 \succ A_1$
The proposed method	$S(A_1) = -0.0400, S(A_2) = -0.0251, S(A_3) = 0.0496, S(A_4) = 0.0154$	$A_3 \succ A_4 \succ A_2 \succ A_1$

Abbreviations: DAWA, the weighted averaging operator of linguistic distribution assessments; HLWA, hesitant linguistic weighted average; MGUHFLCA, multi-granular unbalanced hesitant fuzzy linguistic Choquet integral average.

TABLE 4 Decision information given by three DMs

	$C_1(D_1)$	$C_2(D_1)$	$C_3(D_1)$	$C_1(D_2)$	$C_2(D_2)$	$C_3(D_2)$	$C_1(D_3)$	$C_2(D_3)$	$C_3(D_3)$
A_1	$\{s_2^1\}$	$\{s_2^1\}$	$\{s_2^1\}$	$\{s_2^2\}$	$\{s_2^2\}$	$\{s_2^2\}$	$\{s_3^3,s_4^3\}$	$\{s_3^3,s_4^3\}$	$\{s_2^3\}$
A_2	$\{s_2^1\}$	$\{s_3^1\}$	$\{s_1^1,s_2^1\}$	$\{s_1^2\}$	$\{s_1^2\}$	$\{s_1^2\}$	$\{s_2^3\}$	$\{s_3^3,s_4^3\}$	$\{s_3^3,s_4^3\}$
A_3	$\{s_2^1, s_3^1\}$	$\{s_3^1\}$	$\{s_2^1\}$	$\{s_4^2,s_5^2\}$	$\{s_4^2,s_5^2\}$	$\{s_4^2,s_5^2\}$	$\{s_5^3\}$	$\{s_4^3,s_5^3\}$	$\{s_2^3\}$
A_4	$\{s_1^1\}$	$\{s_1^1,s_2^1\}$	$\{s_3^1\}$	$\{s_3^2\}$	$\{s_3^2\}$	$\{s_3^2\}$	$\{s_2^3\}$	$\{s_2^3\}$	$\{s_2^3,s_3^3\}$

weighted average (HLWA) method,[18] and the weighted averaging operator of linguistic distribution assessments (DAWA) method.[36] Due to the limitation of DAWA method, the following superiority analysis will be divided into two parts.

Part A. Superiority analysis under unbalanced environment.

Because the method of HLWA method cannot directly process the MGUHFLTS information, we adopt evaluation information under UHFLTS environment in example 5 from Liu paper.[19] The original evaluation data and the semantic of ULTSs are the same as example 5, the weight of DMs is {1/3, 1/3, 1/3}, and attribute weight is {0.3, 0.1, 0.6}. The evaluation results by different methods are shown in Table 3.

DAWA method cannot deal with unbalanced information, so the result will be shown in Part B. The results in Table 3 show that the ranking results of the three methods are slightly different. The best and worst alternative results of the three methods are the same, the former is A_3 and the latter is A_1. But HLWA method's result is slightly different from the other two methods, which is displayed on the ranking of A_2 and A_4. The main reason of the different rankings is that HLWA method is likely to lead to information loss. Thus, Example 3 is proposed to prove how the information is missed.

Example 3. Let $S = \{s_0, s_1, ..., s_6\}$ be a ULTS with $NS(s_0) = 0, NS(s_1) = 4, NS(s_2) = 7, NS(s_3) = 8, NS(s_4) = 12, NS(s_5) = 15, NS(s_6) = 16$. Let $H_S^1 = \{s_1, s_2\}$ and $H_S^2 = \{s_3, s_4\}$ be two UHTLTSs on S, $w_1 = w_2 = 0.5$.

The result of HLWA method:

$$\begin{aligned}C_{NS}^2(0.5, H_S^1, 0.5, H_S^2) &= \{round'(NS^{-1}(0.5 \times 4 + 0.5 \times 8)), round(NS^{-1}(0.5 \times 4 + 0.5 \times 12)),\\ &\quad round'(NS^{-1}(0.5 \times 7 + 0.5 \times 8)), round(NS^{-1}(0.5 \times 7 + 0.5 \times 12))\}\\ &= \{round'(NS^{-1}(6)), round(NS^{-1}(8)), round'(NS^{-1}(7.5)), round(\\ &\quad NS^{-1}(9.5))\}\\ &= \{round'(s_2, -0.33), round'(s_3), round'(s_3, -0.5), round'(s_4, 0.38)\}\\ &= \{s_2, s_3, s_4\}.\end{aligned}$$

The result of our method:

$$\begin{aligned}\oplus_{j=1}^{2} w_j \overline{h}_{S_j} &= \{NS^{-1}(0.5 \times 4 + 0.5 \times 8), NS^{-1}(0.5 \times 4 + 0.5 \times 12), NS^{-1}(0.5 \times 7\\ &\quad + 0.5 \times 8), NS^{-1}(0.5 \times 7 + 0.5 \times 12)\}\\ &= \{(s_2, -0.3333), (s_3), (s_3, -0.5000), (s_3, 0.3750)\}.\end{aligned}$$

On the basis of the comparison between Dong's method and our proposed method, it is obvious that there is information loss in Dong's method, while our method can represent information more accurately. According to Example 3, the calculation by HLWA method resulted in the loss of information in two aspects. One is the transformation between 2-tuple and HFLTS. In HLWA method, $(s_2, -0.033)$ is transformed to s_2, but the previous is more precise. On the contrary, our proposed method keeps the form of 2-tuple $(s_2, -0.033)$, which is expressed in a more precise way. The other is the combination of the LVs. In HLWA method, (s_3) and $(s_3, -0.5)$ are combined as s_3, so the 2-tuple variable $(s_3, -0.5)$ is missed. On the contrary, our proposed method keeps all the 2-tuple variables, which makes the evaluation information more accurate.

When it comes to MGUHFLCA method, it can be seen that the ranking result is the same as our proposed method. Although we obtained the same result, our proposed method still has its advantages. First, the computation of our method will not increase with the increase of attributes, while the computation of MGUHFLCA method will increase significantly by means of $2^n - 1$.[19] Second, our method is characterized with more flexibility and applicability. MGUHFLCA method is based on Wang and Hao's model, which is calculated by *CCV*, while our method is based on the 2-tuple model, which is calculated by *NS*. It is proved that Wang and Hao's models can be obtained by the *NS* model. Therefore, our method is more universal.

Part B. Superiority analysis under balanced environment.

DAWA method can only deal with multigranularity balanced linguistic information, while other three methods can deal with both balanced linguistic information and unbalanced linguistic information.

Example 4. Assume that a university assesses four MOOCs A_1, A_2, A_3, A_4, the assessment is based on three attributes, that is, teaching team (C_1), teaching activity (C_2), and teaching effectiveness (C_3). Three DMs give their evaluation from balance LTS $S^{MG} = \{S^1, S^2, S^3\}$, $S^1 = \{s_0^1, s_1^1, s_2^1, s_3^1, s_4^1\}$, and $S^2 = \{s_0^2, s_1^2, s_2^2, s_3^2, s_4^2, s_5^2, s_6^2\} = S^3$. The *NS* of S^1 is $\{0, 1/4, 2/4, 3/4, 1\}$, and the *NS* of S^2 is $\{0, 1/6, 2/6, 3/6, 4/6, 5/6, 1\}$, $NS(S^2) = NS(S^3)$. Given that the attributes weights are $w_c = \{1/3, 1/3, 1/3\}$, and the DMs weights are $w_D = \{1/3, 1/3, 1/3\}$. Assume the decision information given by three DMs is shown in Table 4.

By using DAWA, HLWA, MGUHFLCA, and our proposed methods, the ranking results are shown in Table 5.

From Table 3, there are the same ranking results both in MGUHFLCA method and in our method, which is $A_3 \succ A_1 \succ A_2 \succ A_4$. HLWA method's ranking result is slightly different with MGUHFLCA method, and our method, A_3 is still the best one. But DAWA method's ranking result is taken A_1 as the best one. The main reason why different ranking results appeared is different ways of calculation. Both MGUHFLCA method and our method offer the most accurate information, whose calculation is based on *CCV* and *NS*; HLWA method provides moderately accurate information, because the combination of the LVs leads to partly loss of information; DAWA method is based on linguistic distribution, variables with different granularities need to be transformed frequently during calculation, which is likely to extremely lose information.

To verify advantages of our proposed method, the computational characteristics of different methods are compared in Table 6.

It can be seen from Table 6 that: DAWA method's advantages are just easy to deal with decision problems with more attributes; HLWA method's advantages are displayed in two aspects, which are computation models and can deal with more attributes; MGUHFLCA method's advantages are

TABLE 5 Ranking results by different methods

Methods	Evaluation values	Ranking
DAWA method[36]	$E(A_1) = 0.4787, E(A_2) = 0.3583, E(A_3) = 0.4250, E(A_4) = 0.3519$	$A_1 \succ A_3 \succ A_2 \succ A_4$
HLWA method[18]	$E(A_1) = 0.5833, E(A_2) = 0.3750, E(A_3) = 0.6667, E(A_4) = 0.3750$	$A_3 \succ A_1 \succ A_2 \sim A_4$
MGUHFLCA method[19]	$S(A_1) = 0.5655, S(A_2) = 0.5159, S(A_3) = 0.5705, S(A_4) = 0.2821$	$A_3 \succ A_1 \succ A_2 \succ A_4$
The proposed method	$S(A_1) = -0.0725, S(A_2) = -0.0772, S(A_3) = 0.0710, S(A_4) = -0.1327$	$A_3 \succ A_1 \succ A_2 \succ A_4$

Abbreviations: DAWA, the weighted averaging operator of linguistic distribution assessments; HLWA, hesitant linguistic weighted average; MGUHFLCA, multi-granular unbalanced hesitant fuzzy linguistic Choquet integral average.

TABLE 6 Comparison of computational characteristics with different methods

Method	Processing multigranularity linguistic information directly	The computation model is universal	Less information loss during transformation	Easy to deal with decision problems with more attributes
DAWA method[36]	No	No	No	Yes
HLWA method[18]	No	Yes	No	Yes
MGUHFLCA method[19]	Yes	No	Yes	No
The proposed method	Yes	Yes	Yes	Yes

Abbreviations: DAWA, the weighted averaging operator of linguistic distribution assessments; HLWA, hesitant linguistic weighted average; MGUHFLCA, multi-granular unbalanced hesitant fuzzy linguistic Choquet integral average.

displayed in two aspects, which are processing multigranularity linguistic information directly and less information loss during transformation; our proposed method covers all above advantages.

From the above analysis, no matter under unbalanced environment or balanced environment, our proposed method has shown the validity and superiority.

5 | APPLICATION OF THE MGUHFLTS–MABAC MODEL FOR MOOCS EVALUATION

MOOCs, as a new online learning mode, have drawn the attention of teachers, learners, and scholars in recent years. It has expanded the teaching time and space, transformed the way of teaching and learning, and brought great impact on traditional higher education mode. For example, on the platform of "MOOCs University in China," by the end of April 2020, 374 institutions had provided 5520 MOOCs′ courses, involving engineering, science, economic management, literary history, and many other disciplines. Due to the rapid development of MOOCs in China, the evaluation of MOOCs is significant.

"Modern Chinese Language" is a required course for Chinese related majors in universities, and 176 such courses can be found on "MOOCs University in China" in 2020. Among them fives courses are chosen for evaluation, the reason why these five courses present representative is that the number of learners in each course can reach more than 1000.

In Section 5.1, the MOOCs′ evaluation index system is built. In Section 5.2, the weights of indicators are determined. In Section 5.3, assessment information of MOOCs is obtained. In Section 5.4, five MOOCs′ courses of each group are ranked by using the MGUHFLTS–MABAC model.

5.1 | The construction of MOOCs′ evaluation index system

To evaluate MOOCs effectively, a credible evaluation index system should be constructed. Fifteen experts are invited to show their opinions for the construction of the MOOCs′ evaluation index system, who are from the field of Chinese teaching, and MOOCs′ teaching. The system is established as follows, which contains six elements and 16 indicators.

5.1.1 | Teaching Team (C1)

Teaching team is considered as the primary element, because most learners in MOOCs are attracted by famous universities and their excellent teaching team. Meanwhile, these teaching teams can make themselves well known through online platform. The indicators of Teaching Team (C1) include:

1. *The level of university (B1)*: There is a close connection between quality of MOOCs and level of universities. Top universities with excellent teaching and scientific research level usually lead to high quality of MOOCs.
2. *Chief teacher (B2)*: The chief teacher in MOOCs plays the same role as CEO in enterprise, whose teaching level, scientific research ability, and organizational management ability will affect the teaching quality of MOOCs.

3. *Team members (B3)*: MOOCs' teaching contains multiple tasks with many parts, chief teacher could not complete the whole process alone. Thus, more than three team members are needed to be responsible for the course preparation, video recorded, and maintenance of the MOOCs course.

5.1.2 | Teaching Objectives (C2)

MOOCs' teaching activities should strictly follow specific teaching objectives, so teaching objectives are of great importance for quality of MOOCs' evaluation. Whether teaching objectives are scientific and reasonable will determine the organization and the guidance of teaching evaluation. The indicators of Teaching Objectives (C2) include:

1. *Explicit and visual (B4)*: It is not only in the teacher's teaching plan, but also at the beginning of courses that the teaching objectives should be expressed clearly. At the beginning of the MOOCs, teaching objectives should be clearly communicated to the learners, using verbs, such as "know, understand, use, analyze, synthesize and evaluate." In this way, learners can foresee how much they should master and distinguish the prioritization of learning objectives, to allocate time and energy.
2. *Scientific and reasonable (B5)*: Both general teaching objectives and each chapter objectives should be scientific and reasonable, demonstrating moderate difficulty. The teaching objectives depend on MOOCs learners' educational backgrounds and different ages.
3. *Diversity (B6)*: Teaching objectives should follow the principle of diversity. Single teaching objective cannot satisfy the demand of diverse MOOCs learners, so that various teaching objectives should cover knowledge objectives, skill objectives, and emotional objectives. Emotional objectives are indispensable, which can transfer the advantages of traditional classroom to MOOCs.

5.1.3 | Teaching Methods and Means (C3)

Teaching methods and means are of great significance in MOOCs teaching, not only because appropriate teaching methods can complete the corresponding teaching tasks, but also because teaching methods can relate to the whole process of teaching activities. As multimedia technology and "internet plus" have been applied wildly, a new trend is how to meet the needs of MOOCs learners. Thus, teaching methods and means face the challenges of fragmentation learning and mobile learning. The indicators of Teaching Methods and Means (C3) include:

1. *Teaching media (B7)*: MOOCs are mostly displayed on network platform, teaching media need take the source advantage of internet technology. To make full use of the advantages, MOOCs should be presented with simple course interface, clear navigation, vivid course video, neat electronic blackboard, and proper color of pictures.
2. *Teaching methods (B8)*: On the one hand, MOOCs' teaching methods should conform to the characteristics of online learning. On the other hand, they should also pay attention to the comprehensive application of teaching methods. Teachers should combine the above characteristics flexibly and apply various effective teaching methods.

3. *Teaching means (B9)*: To complete the teaching tasks, proper teaching means should be chosen. Those means refer to the tools, materials, and facilities according to a certain teaching method. Teaching means should serve the teaching objectives, which is a key part among scientific selection of reasonable teaching means.

5.1.4 | Content of the Course (C4)

The content of course is the main information transmitted in the process of interaction between teaching and learning. In the evaluation of MOOCs teaching quality, Content of the Course (C4) mainly includes:

1. *Syllabus (B10)*: The syllabus should provide the introduction of course content, clear explanation of the assessment method, credit and certification requirements of the course. In consideration of the different knowledge backgrounds and ages of learners, a questionnaire about learners' age, knowledge structure, and needs should be completed with meet the demand of MOOCs learners and the syllabus should be revised correspondingly.
2. *Teaching design (B11)*: According to the questionnaire, curriculum framework, difficult points, course time, and tests are set in the teaching design. On the basis of this, teachers should properly adjust the teaching steps and contents. Curriculum framework and difficult points should be clearly informed at the beginning of each chapter, the course time and how to test should be given.
3. *Teaching resources (B12)*: The most important teaching resource of MOOCs teaching is video. The video should display knowledge points, logical content arrangement, and moderate difficulty. Teaching resources matching with video should have PPT, texts, extended reading materials, and relative books. Teaching resources also cover exercises and tests, which maintain moderate difficulties and tests of chapter, midterm, and final should be well designed.

5.1.5 | Teaching Activities (C5)

Teaching is a kind of bilateral activity which consists of teacher activities and learner activities under the standard of certain educational objective. In this activity, teachers play the role of teaching guider and organizer, and learners are the followers of teachers. The indicators of Teaching Activities (C5) include:

1. *Teacher activities (B13)*: Teacher activities should be carried out according to the characteristics of MOOCs' teaching, which requires teachers to introduce the course clearly. In the teaching process of MOOCs, the manners are natural and generous, the speed is moderate, and the tone is inspiring. In addition, in the online discussion area, teachers should actively participate in the discussion, respond to learners' questions in time.
2. *Learners activities (B14)*: Learner activities are mainly reflected by the online interaction. The participation of the learners can be reflected by the statistics of learners who sign up for the MOOCs, courses visited, teaching videos watched, and posts the discussion area.

TABLE 7 MOOCs evaluation criteria

Elements	Indicators
C1. Teaching team	B1. The level of university
	B2. Chief teacher
	B3. Team members
C2. Teaching objectives	B4. Explicit and visual
	B5. Scientific and reasonable
	B6. Diversity
C3. Teaching methods and means	B7. Teaching media
	B8. Teaching methods
	B9. Teaching means
C4. Content of the course	B10. Syllabus
	B11. Teaching design
	B12. Teaching resources
C5. Teaching activities	B13. Teacher activities
	B14. Learners activities
C6. Teaching evaluation and feedback	B15. Task design
	B16. Learners' performance evaluation

Abbreviation: MOOC, massive open online course.

5.1.6 | Teaching Evaluation and Feedback (C6)

The Teaching Evaluation and Feedback of MOOCs can be divided into two steps: the first is the task design after each class and the second is the course evaluation (Table 7).

1. *Task design (B15):* The teaching team should pay attention to three aspects of task design, which are difficulty, types, and feedback. The difficulty of task is moderate to most learners, to make the majority pass. The types of tasks are various, including multiple-choice questions, calculation questions, discussion questions, and so on. The feedback of task should be timely, which can help learners improving.
2. *Learners' performance evaluation (B16)*: In the teaching evaluation, the teaching team should not only focus on task but also learners' performance. Learners' performance refers to the numbers of video watching, the times of texts, and the frequency of discussion. Meanwhile, the feedback from the learners can show their attitudes about the MOOCs.

5.2 | Obtain the assessment information of MOOCs

Five courses $A = \{A_1, A_2, A_3, A_4, A_5\}$ of "Modern Chinese Language" in "MOOCs University in China" are evaluated, constructed by Zhejiang University (A_1), Henan Normal University (A_2), Zhengzhou Normal University (A_3), Yancheng Normal University (A_4), and Huazhong Agricultural

TABLE 8 Conversion relationship between NS and LTs S^1

NS	0	4	6	7	8
Linguistic phrases	Very bad	Bad	Medium	Good	Very good
Representation	s_0^1	s_1^1	s_2^1	s_3^1	s_4^1

Abbreviations: LT, linguistic term; NS, numerical scale.

University (A_5). Nine experts (E) are invited to provide their assessment information with MGUHFLEs. All experts are divided into three groups according to their specialties, Chinese language experts' group (G_1), online education experts' group (G_2), and experts who have taught on MOOCs (G_3). Experts E_1, E_2, and E_3 are in G_1; Experts E_4, E_5, and E_6 are in G_2; Experts E_7, E_8, and E_9 are in G_3. The groups of DMs are independent of each other, and the weight vector of group is as follows: $W_G = \{0.3, 0.3, 0.4\}$. Three groups of DMs use ULTSs, whose corresponding NSs are given in Tables 8–10.

Experts in three groups use different ULTSs, experts in G_1 express their assessment information in S^1 and S^2, experts in G_2 express their assessment information in S^2 and S^3, and experts in G_3 express their assessment information in S^1, S^2, and S^3. The assessment values with MGUHFLEs are shown in Tables 11–13.

5.3 | The weight determination of the indicators

In this paper, the weights of MOOCs evaluation index are comprehensive weights, which are composed of subjective weights and objective weights. The subjective weights adopt the analytic hierarchy process (AHP) method and the objective weights adopt the entropy weight method.

5.3.1 | The subjective weight determination of the indicators

The subjective weights of MOOCs evaluation index are determined by 11 experts using AHP method. The relative importance scale is used in the expert evaluation, and the relative importance with the numbers is as follows (Table 14):

The comparison matrix between different indexes is constructed as shown in Table 15. Take the comparison matrix of the indicators in C_1 as an example:

Thus, the weight is obtained: $\varsigma_{C_1-B} = (0.31, 0.41, 0.28)$. The weights have passed the consistency test. According to the same algorithm, get the following weights:

TABLE 9 Conversion relationship between NS and LTs S^2

NS	0	5	6	7	8	10	16
Linguistic phrases	Extremely bad	Very bad	Bad	Medium	Good	Very good	Extremely good
Representation	s_0^2	s_1^2	s_2^2	s_3^2	s_4^2	s_5^2	s_6^2

Abbreviations: LT, linguistic term; NS, numerical scale.

TABLE 10 Conversion relationship between NS and LTs S^3

NS	0	4	5	6	7	8	10	16	20
Linguistic phrases	Extremely bad	Very bad	A little bad	Bad	Medium	Good	A little good	Very good	Extremely good
Representation	s_0^3	s_1^3	s_2^3	s_3^3	s_4^3	s_5^3	s_6^3	s_7^3	s_8^3

Abbreviations: LT, linguistic term; NS, numerical scale.

TABLE 11 Assessment values of different attributes of five MOOCs given by G_1

G_1	A_1	A_2	A_3	A_4	A_5
B1	$\{s_4^1, s_4^1, s_6^2\}$	$\{s_3^1, s_3^1, s_4^2\}$	$\{s_2^1, s_3^1, s_2^2\}$	$\{s_2^1, s_3^1, s_3^2\}$	$\{s_4^1, s_4^1, s_5^2\}$
B2	$\{s_4^1, s_4^1, s_6^2\}$	$\{s_3^1, s_3^1, s_5^2\}$	$\{s_2^1, s_3^1, s_4^2\}$	$\{s_4^1, s_4^1, s_5^2\}$	$\{s_3^1, s_3^1, s_5^2\}$
B3	$\{s_3^1, s_4^1, s_6^2\}$	$\{s_2^1, s_3^1, s_3^2\}$	$\{s_2^1, s_2^1, s_2^2\}$	$\{s_2^1, s_2^1, s_3^2\}$	$\{s_3^1, s_3^1, s_4^2\}$
B4	$\{s_3^1, s_3^1, s_5^2\}$	$\{s_2^1, s_3^1, s_2^2\}$	$\{s_2^1, s_2^1, s_2^2\}$	$\{s_4^1, s_4^1, s_6^2\}$	$\{s_2^1, s_3^1, s_3^2\}$
B5	$\{s_3^1, s_3^1, s_5^2\}$	$\{s_3^1, s_3^1, s_5^2\}$	$\{s_2^1, s_2^1, s_3^2\}$	$\{s_3^1, s_4^1, s_6^2\}$	$\{s_3^1, s_4^1, s_5^2\}$
B6	$\{s_3^1, s_4^1, s_5^2\}$	$\{s_4^1, s_4^1, s_6^2\}$	$\{s_2^1, s_2^1, s_2^2\}$	$\{s_4^1, s_4^1, s_5^2\}$	$\{s_3^1, s_3^1, s_5^2\}$
B7	$\{s_3^1, s_3^1, s_5^2\}$	$\{s_4^1, s_4^1, s_6^2\}$	$\{s_3^1, s_3^1, s_5^2\}$	$\{s_3^1, s_3^1, s_5^2\}$	$\{s_1^1, s_2^1, s_2^2\}$
B8	$\{s_3^1, s_4^1, s_5^2\}$	$\{s_4^1, s_4^1, s_6^2\}$	$\{s_2^1, s_3^1, s_3^2\}$	$\{s_3^1, s_4^1, s_5^2\}$	$\{s_2^1, s_3^1, s_3^2\}$
B9	$\{s_3^1, s_3^1, s_4^2\}$	$\{s_3^1, s_4^1, s_5^2\}$	$\{s_2^1, s_3^1, s_3^2\}$	$\{s_3^1, s_4^1, s_5^2\}$	$\{s_2^1, s_3^1, s_3^2\}$
B10	$\{s_3^1, s_3^1, s_5^2\}$	$\{s_2^1, s_2^1, s_3^2\}$	$\{s_2^1, s_2^1, s_3^2\}$	$\{s_4^1, s_4^1, s_6^2\}$	$\{s_2^1, s_3^1, s_3^2\}$
B11	$\{s_3^1, s_3^1, s_5^2\}$	$\{s_4^1, s_4^1, s_6^2\}$	$\{s_2^1, s_2^1, s_2^2\}$	$\{s_3^1, s_4^1, s_5^2\}$	$\{s_2^1, s_3^1, s_3^2\}$
B12	$\{s_3^1, s_4^1, s_5^2\}$	$\{s_3^1, s_4^1, s_5^2\}$	$\{s_2^1, s_2^1, s_3^2\}$	$\{s_3^1, s_4^1, s_5^2\}$	$\{s_2^1, s_3^1, s_3^2\}$
B13	$\{s_3^1, s_4^1, s_5^2\}$	$\{s_4^1, s_4^1, s_6^2\}$	$\{s_3^1, s_4^1, s_5^2\}$	$\{s_3^1, s_4^1, s_6^2\}$	$\{s_1^1, s_2^1, s_2^2\}$
B14	$\{s_4^1, s_4^1, s_5^2\}$	$\{s_3^1, s_4^1, s_5^2\}$	$\{s_2^1, s_3^1, s_3^2\}$	$\{s_3^1, s_4^1, s_5^2\}$	$\{s_1^1, s_1^1, s_2^2\}$
B15	$\{s_3^1, s_4^1, s_5^2\}$	$\{s_3^1, s_4^1, s_5^2\}$	$\{s_2^1, s_3^1, s_3^2\}$	$\{s_4^1, s_4^1, s_6^2\}$	$\{s_3^1, s_4^1, s_5^2\}$
B16	$\{s_2^1, s_3^1, s_3^2\}$	$\{s_3^1, s_4^1, s_5^2\}$	$\{s_2^1, s_2^1, s_3^2\}$	$\{s_4^1, s_4^1, s_6^2\}$	$\{s_1^1, s_1^1, s_1^2\}$

Abbreviation: MOOC, massive open online course.

$\varsigma_C = (0.17, 0.19, 0.17, 0.19, 0.14, 0.14)$, $\varsigma_{C_2-B} = (0.39, 0.31, 0.30)$, $\varsigma_{C_3-B} = (0.29, 0.43, 0.28)$, $\varsigma_{C_4-B} = (0.29, 0.28, 0.43)$, $\varsigma_{C_5-B} = (0.61, 0.39)$, and $\varsigma_{C_6-B} = (0.49, 0.51)$. All the weights have passed the consistency test.

On the basis of the results of ς_C, ς_{C_1-B}, ς_{C_2-B}, ς_{C_3-B}, ς_{C_4-B}, ς_{C_5-B}, and ς_{C_6-B}, the subjective weights of all the 16 indicators are

$$\omega = (0.0527, 0.0697, 0.0476, 0.0741, 0.0589, 0.0570, 0.0493, 0.0731, 0.0476, 0.0551, 0.0532, 0.0817, 0.0854, 0.0546, 0.0686, 0.0714).$$

5.3.2 | The objective weight determination of the indicators

The above is the subjective weight, and the objective weight is calculated by entropy weight method.

First, according to formulation (23) the deviation D_j^i between alternative A_i and other schemes is calculated.

$$D_j^i = \sum_{p=1}^{m} d\left(\bar{h}_{ij}^k, \bar{h}_{pj}^k\right) \quad (i = 1, 2, ..., m; \quad j = 1, 2, ..., n; \quad k = 1, 2, ..., q), \tag{23}$$

TABLE 12 Assessment values of different attributes of five MOOCs given by G_2

G_2	A_1	A_2	A_3	A_4	A_5
B1	$\{s_6^2, s_8^3, s_8^3\}$	$\{s_4^2, s_4^3, s_5^3\}$	$\{s_2^2, s_2^3, s_3^3\}$	$\{s_2^2, s_2^3, s_3^3\}$	$\{s_5^2, s_6^3, s_7^3\}$
B2	$\{s_6^2, s_7^3, s_8^3\}$	$\{s_3^2, s_4^3, s_4^3\}$	$\{s_4^2, s_5^3, s_6^3\}$	$\{s_3^2, s_4^3, s_5^3\}$	$\{s_5^2, s_7^3, s_7^3\}$
B3	$\{s_6^2, s_8^3, s_8^3\}$	$\{s_3^2, s_4^3, s_5^3\}$	$\{s_2^2, s_3^3, s_4^3\}$	$\{s_3^2, s_4^3, s_4^3\}$	$\{s_3^2, s_4^3, s_5^3\}$
B4	$\{s_4^2, s_5^3, s_6^3\}$	$\{s_2^2, s_2^3, s_3^3\}$	$\{s_2^2, s_3^3, s_5^3\}$	$\{s_6^2, s_7^3, s_8^3\}$	$\{s_2^2, s_3^3, s_3^3\}$
B5	$\{s_5^2, s_6^3, s_7^3\}$	$\{s_5^2, s_6^3, s_7^3\}$	$\{s_3^2, s_4^3, s_5^3\}$	$\{s_6^2, s_7^3, s_7^3\}$	$\{s_2^2, s_3^3, s_3^3\}$
B6	$\{s_4^2, s_5^3, s_6^3\}$	$\{s_5^2, s_6^3, s_7^3\}$	$\{s_2^2, s_3^3, s_3^3\}$	$\{s_5^2, s_7^3, s_7^3\}$	$\{s_2^2, s_3^3, s_3^3\}$
B7	$\{s_5^2, s_6^3, s_7^3\}$	$\{s_6^2, s_8^3, s_8^3\}$	$\{s_3^2, s_4^3, s_5^3\}$	$\{s_4^2, s_5^3, s_5^3\}$	$\{s_2^2, s_3^3, s_4^3\}$
B8	$\{s_5^2, s_7^3, s_7^3\}$	$\{s_6^2, s_8^3, s_8^3\}$	$\{s_3^2, s_4^3, s_4^3\}$	$\{s_4^2, s_5^3, s_5^3\}$	$\{s_2^2, s_2^3, s_3^3\}$
B9	$\{s_4^2, s_5^3, s_5^3\}$	$\{s_5^2, s_6^3, s_7^3\}$	$\{s_2^2, s_3^3, s_4^3\}$	$\{s_5^2, s_6^3, s_7^3\}$	$\{s_3^2, s_3^3, s_4^3\}$
B10	$\{s_3^2, s_5^3, s_5^3\}$	$\{s_3^2, s_3^3, s_4^3\}$	$\{s_3^2, s_3^3, s_4^3\}$	$\{s_5^2, s_7^3, s_7^3\}$	$\{s_3^2, s_4^3, s_4^3\}$
B11	$\{s_3^2, s_5^3, s_6^3\}$	$\{s_6^2, s_8^3, s_8^3\}$	$\{s_3^2, s_3^3, s_3^3\}$	$\{s_5^2, s_6^3, s_7^3\}$	$\{s_3^2, s_3^3, s_4^3\}$
B12	$\{s_4^2, s_5^3, s_6^3\}$	$\{s_5^2, s_6^3, s_7^3\}$	$\{s_3^2, s_3^3, s_4^3\}$	$\{s_5^2, s_7^3, s_8^3\}$	$\{s_3^2, s_4^3, s_4^3\}$
B13	$\{s_5^2, s_6^3, s_7^3\}$	$\{s_5^2, s_7^3, s_7^3\}$	$\{s_3^2, s_3^3, s_4^3\}$	$\{s_6^2, s_8^3, s_8^3\}$	$\{s_1^2, s_2^3, s_2^3\}$
B14	$\{s_5^2, s_7^3, s_8^3\}$	$\{s_5^2, s_7^3, s_7^3\}$	$\{s_2^2, s_3^2, s_4^3\}$	$\{s_5^2, s_6^3, s_7^3\}$	$\{s_1^2, s_2^3, s_2^3\}$
B15	$\{s_4^2, s_5^3, s_5^3\}$	$\{s_5^2, s_6^3, s_7^3\}$	$\{s_2^2, s_3^2, s_4^3\}$	$\{s_6^2, s_7^3, s_8^3\}$	$\{s_5^2, s_6^3, s_7^3\}$
B16	$\{s_3^2, s_4^3, s_5^3\}$	$\{s_4^2, s_6^3, s_6^3\}$	$\{s_3^2, s_3^3, s_4^3\}$	$\{s_6^2, s_8^3, s_8^3\}$	$\{s_1^2, s_2^3, s_2^3\}$

Abbreviation: MOOC, massive open online course.

where $d\left(\bar{h}_{ij}^k, \bar{h}_{pj}^k\right)$ is the distance between $\bar{h}_{ij}^k$ and $\bar{h}_{pj}^k$. We get

$$\left(\mathrm{D}_j^{\mathrm{i}}\right)^T = \begin{bmatrix} 26.3333 & 11.2333 & 16.3333 & 12.4333 & 12.7333 \\ 23.8000 & 11.3667 & 9.5000 & 10.4667 & 11.0000 \\ 29.5667 & 10.1000 & 10.9333 & 10.4333 & 11.7667 \\ 12.8667 & 10.4000 & 10.2000 & 25.2667 & 10.0667 \\ 8.6667 & 8.6667 & 12.7667 & 15.0667 & 11.7667 \\ 11.2000 & 16.4333 & 15.2333 & 13.4333 & 13.8333 \\ 11.3667 & 27.1667 & 12.5667 & 10.9000 & 16.6667 \\ 12.3000 & 26.6000 & 13.4333 & 11.4333 & 16.2333 \\ 6.3000 & 8.8000 & 7.2000 & 8.8000 & 6.9000 \\ 6.2333 & 5.5667 & 6.3667 & 15.1333 & 5.3667 \\ 10.2000 & 26.7000 & 11.4000 & 11.2000 & 13.3000 \\ 8.8000 & 11.7333 & 10.6667 & 12.3333 & 10.0667 \\ 14.2333 & 17.0667 & 15.9000 & 22.1667 & 26.5000 \\ 12.5333 & 16.8333 & 15.5667 & 11.8333 & 20.1667 \\ 10.8333 & 9.3000 & 17.4333 & 21.4000 & 9.3000 \\ 12.7333 & 14.5000 & 13.5667 & 31.0000 & 19.6667 \end{bmatrix}$$

Take D_1^1 as an example. $d_1^1 = 0$, $d_2^1 = 6.0333$, $d_3^1 = 8.5333$, $d_4^1 = 7.2333$, $d_5^1 = 4.5333$. Then we get $D_1^1 = 26.3333$.

Calculate the deviation D_j between each alternative and all the other alternatives. For C_j,

TABLE 13 Assessment values of different attributes of five MOOCs given by G_3

G_3	A_1	A_2	A_3	A_4	A_5
B1	$\{s_4^1, s_6^2, s_8^3\}$	$\{s_3^1, s_5^2, s_7^3\}$	$\{s_2^1, s_3^2, s_3^3\}$	$\{s_3^1, s_3^2, s_7^3\}$	$\{s_3^1, s_5^2, s_7^3\}$
B2	$\{s_4^1, s_6^2, s_8^3\}$	$\{s_2^1, s_3^2, s_3^3\}$	$\{s_3^1, s_5^2, s_6^3\}$	$\{s_2^1, s_3^2, s_3^3\}$	$\{s_3^1, s_5^2, s_6^3\}$
B3	$\{s_4^1, s_6^2, s_8^3\}$	$\{s_2^1, s_3^2, s_4^3\}$	$\{s_2^1, s_3^2, s_4^3\}$	$\{s_2^1, s_3^2, s_3^3\}$	$\{s_3^1, s_5^2, s_7^3\}$
B4	$\{s_3^1, s_5^2, s_7^3\}$	$\{s_2^1, s_3^2, s_3^3\}$	$\{s_2^1, s_2^2, s_3^3\}$	$\{s_4^1, s_5^2, s_8^3\}$	$\{s_2^1, s_3^2, s_3^3\}$
B5	$\{s_3^1, s_5^2, s_7^3\}$	$\{s_3^1, s_5^2, s_7^3\}$	$\{s_2^1, s_2^2, s_3^3\}$	$\{s_4^1, s_6^2, s_7^3\}$	$\{s_2^1, s_3^2, s_3^3\}$
B6	$\{s_3^1, s_5^2, s_7^3\}$	$\{s_4^1, s_6^2, s_8^3\}$	$\{s_2^1, s_3^2, s_3^3\}$	$\{s_4^1, s_5^2, s_8^3\}$	$\{s_2^1, s_2^2, s_3^3\}$
B7	$\{s_3^1, s_5^2, s_6^3\}$	$\{s_4^1, s_6^2, s_8^3\}$	$\{s_2^1, s_3^2, s_4^3\}$	$\{s_3^1, s_5^2, s_7^3\}$	$\{s_2^1, s_2^2, s_3^3\}$
B8	$\{s_3^1, s_5^2, s_6^3\}$	$\{s_4^1, s_6^2, s_8^3\}$	$\{s_3^1, s_3^2, s_5^3\}$	$\{s_3^1, s_5^2, s_7^3\}$	$\{s_2^1, s_2^2, s_3^3\}$
B9	$\{s_2^1, s_4^2, s_5^3\}$	$\{s_3^1, s_5^2, s_7^3\}$	$\{s_2^1, s_3^2, s_4^3\}$	$\{s_3^1, s_5^2, s_7^3\}$	$\{s_3^1, s_3^2, s_5^3\}$
B10	$\{s_3^1, s_3^2, s_5^3\}$	$\{s_2^1, s_3^2, s_4^3\}$	$\{s_2^1, s_2^2, s_3^3\}$	$\{s_3^1, s_5^2, s_6^3\}$	$\{s_2^1, s_3^2, s_4^3\}$
B11	$\{s_3^1, s_5^2, s_6^3\}$	$\{s_4^1, s_6^2, s_8^3\}$	$\{s_3^1, s_5^2, s_6^3\}$	$\{s_3^1, s_5^2, s_6^3\}$	$\{s_2^1, s_3^2, s_4^3\}$
B12	$\{s_3^1, s_3^2, s_5^3\}$	$\{s_4^1, s_6^2, s_7^3\}$	$\{s_2^1, s_3^2, s_4^3\}$	$\{s_4^1, s_5^2, s_7^3\}$	$\{s_2^1, s_3^2, s_4^3\}$
B13	$\{s_3^1, s_5^2, s_7^3\}$	$\{s_4^1, s_6^2, s_8^3\}$	$\{s_3^1, s_4^2, s_7^3\}$	$\{s_4^1, s_6^2, s_8^3\}$	$\{s_1^1, s_1^2, s_1^3\}$
B14	$\{s_4^1, s_5^2, s_6^3\}$	$\{s_4^1, s_6^2, s_8^3\}$	$\{s_2^1, s_2^2, s_3^3\}$	$\{s_3^1, s_5^2, s_7^3\}$	$\{s_1^1, s_1^2, s_2^3\}$
B15	$\{s_3^1, s_5^2, s_6^3\}$	$\{s_3^1, s_5^2, s_7^3\}$	$\{s_2^1, s_2^2, s_3^3\}$	$\{s_4^1, s_6^2, s_8^3\}$	$\{s_3^1, s_5^2, s_7^3\}$
B16	$\{s_3^1, s_3^2, s_6^3\}$	$\{s_3^1, s_4^2, s_7^3\}$	$\{s_2^1, s_3^2, s_4^3\}$	$\{s_4^1, s_6^2, s_8^3\}$	$\{s_1^1, s_1^2, s_1^3\}$

Abbreviation: MOOC, massive open online course.

TABLE 14 Relative importance levels

Relative importance degree	Grades	Relative importance degree	Grades
Equal	1	Equal	1
Slightly important	3	Slightly unimportant	1/3
Important	5	Unimportant	1/5
Very important	7	Very unimportant	1/7
Extremely important	9	Extremely unimportant	1/9
Intermediate value of two adjacent degrees	2, 4, 6, 8	Intermediate value of two adjacent degrees	1/2, 1/4, 1/6, 1/8

TABLE 15 The comparison matrix $C_1 - B$

C_1	B_1	B_2	B_3
B_1	1	1/3	1
B_2	3	1	3
B_3	1	1/3	1

TABLE 16 The weights of MOOCs evaluation index

Serial number	Specific indicators	Subjective weights	Objective weights	Comprehensive weights
B1	The level of university	0.0527	0.0666	0.0596
B2	Chief teacher	0.0697	0.0845	0.0771
B3	Team members	0.0476	0.1346	0.0911
B4	Explicit and visual	0.0741	0.0942	0.0842
B5	Scientific and reasonable	0.0589	0.0282	0.0436
B6	Diversity	0.0570	0.0097	0.0334
B7	Teaching media	0.0493	0.0809	0.0651
B8	Teaching methods	0.0731	0.0652	0.0692
B9	Teaching means	0.0476	0.0109	0.0292
B10	Syllabus	0.0551	0.1108	0.0866
B11	Teaching design	0.0532	0.0932	0.0732
B12	Teaching resources	0.0817	0.0082	0.0450
B13	Teacher activities	0.0854	0.0325	0.0590
B14	Learners activities	0.0546	0.0230	0.0388
B15	Task design	0.0686	0.0747	0.0716
B16	Learners' performance evaluation	0.0714	0.0756	0.0735

Abbreviation: MOOC, massive open online course.

$$D_j = \sum_{i=1}^{m} D_j^i = \sum_{i=1}^{m}\sum_{p=1}^{m} d\left(\bar{h}_{ij}^k, \bar{h}_{pj}^k\right) \quad (j = 1, 2, ..., n; \quad k = 1, 2, ..., q), \tag{24}$$

$D_1 = 79.0667, D_2 = 66.1333, D_3 = 72.8000, D_4 = 68.8000, D_5 = 56.9333, D_6 = 70.1333,$
$D_7 = 78.6667,$
$D_8 = 80.0000, D_9 = 38.0000, D_{10} = 38.6667, D_{11} = 72.8000, D_{12} = 53.6000, D_{13} = 95.8667,$
$D_{14} = 76.9333, D_{15} = 68.2667, D_{16} = 91.4667.$

Calculate the information entropy value E_j for each attribute,

$$E_j = -K \sum_{i=1}^{m} \frac{D_j^i}{D_j} \ln \frac{D_j^i}{D_j} \quad (1 \le j \le n), \tag{25}$$

where m is the number of alternatives and $K = \frac{1}{\ln m}$.

$E_1 = -\frac{1}{\ln m}\left(\frac{D_1^1}{D_1} \ln \frac{D_1^1}{D_1} + \frac{D_2^1}{D_1} \ln \frac{D_2^1}{D_1} + \cdots + \frac{D_{16}^1}{D_1} \ln \frac{D_{16}^1}{D_1}\right) = 0.9657$. Similarly,

$E_2 = 0.9564, E_3 = 0.9306, E_4 = 0.9514, E_5 = 0.9854, E_6 = 0.9905, E_7 = 0.9583,$
$E_8 = 0.9664, E_9 = 0.9944,$
$E_{10} = 0.9391, E_{11} = 0.9520, E_{12} = 0.9958, E_{13} = 0.9832, E_{14} = 0.9881, E_{15} = 0.9615,$
$E_{16} = 0.9610.$

Calculate the difference degree G_j of C_j:

$$G_j = 1 - E_j \quad (1 \le j \le n), \tag{26}$$

$G_1 = 0.0343, G_2 = 0.0436, G_3 = 0.0694, G_4 = 0.0486, G_5 = 0.0146, G_6 = 0.0050,$
$G_7 = 0.0417, G_8 = 0.0336,$
$G_9 = 0.0056, G_{10} = 0.0609, G_{11} = 0.0480, G_{12} = 0.0042, G_{13} = 0.0168, G_{14} = 0.0119,$
$G_{15} = 0.0385, G_{16} = 0.0390.$

Calculate the entropy weight w_j:

$$\mathrm{w}_j = G_j \bigg/ \sum_{j=1}^{n} G_j \quad (1 \le j \le n), \tag{27}$$

$w_1 = 0.0666, w_2 = 0.0845, w_3 = 0.1364, w_4 = 0.0942, w_5 = 0.0282, w_6 = 0.0097,$
$w_7 = 0.0809, w_8 = 0.0652,$
$w_9 = 0.0109, w_{10} = 0.1180, w_{11} = 0.0932, w_{12} = 0.0082, w_{13} = 0.0325, w_{14} = 0.0230,$
$w_{15} = 0.0747, w_{16} = 0.0756.$

5.3.3 | The comprehensive weight determination of the indicators

After getting the subjective weights and objective weights, the following formula is used to get the comprehensive weights:

$$W_j = \alpha\omega_j + (1 - \alpha)w_j, \tag{28}$$

where $\alpha \in [0, 1]$. Considering the same importance of subjective weights and objective weights, we set $\alpha = 0.5$. After calculation, the comprehensive weights are as follows, and the weights of the 16 indicators are shown in Table 16:

$W_1 = 0.0596, W_2 = 0.0771, W_3 = 0.0911, W_4 = 0.0842, W_5 = 0.0436, W_6 = 0.0334,$
$W_7 = 0.0651, W_8 = 0.0692,$
$W_9 = 0.0292, W_{10} = 0.0866, W_{11} = 0.0732, W_{12} = 0.0450, W_{13} = 0.0590, W_{14} = 0.0388,$
$W_{15} = 0.0716, W_{16} = 0.0735.$

5.4 | Rank the alternatives of each group using the MABAC method

Step 1. Set a basic ULTS S^B. In this paper, S^2 is selected as S^B.

Step 2. Transform the assessment information MGHFLTEs to the linguistic 2-tuple elements and then get the aggregated decision matrix X of different DMs.

The decision matrices in the form of linguistic 2-tuple sets are shown as

$$\overline{H}_{s_1}^T = \begin{bmatrix}
\{(s_4^1,0),(s_4^1,0),(s_6^2,0)\} & \{(s_3^1,0),(s_3^1,0),(s_4^2,0)\} & \{(s_2^1,0),(s_3^1,0),(s_2^2,0)\} & \{(s_2^1,0),(s_3^1,0),(s_3^2,0)\} & \{(s_4^1,0),(s_4^1,0),(s_5^2,0)\} \\
\{(s_4^1,0),(s_4^1,0),(s_6^2,0)\} & \{(s_3^1,0),(s_3^1,0),(s_5^2,0)\} & \{(s_2^1,0),(s_3^1,0),(s_4^2,0)\} & \{(s_4^1,0),(s_4^1,0),(s_5^2,0)\} & \{(s_3^1,0),(s_3^1,0),(s_5^2,0)\} \\
\{(s_3^1,0),(s_4^1,0),(s_6^2,0)\} & \{(s_2^1,0),(s_3^1,0),(s_3^2,0)\} & \{(s_2^1,0),(s_2^1,0),(s_2^2,0)\} & \{(s_2^1,0),(s_2^1,0),(s_3^2,0)\} & \{(s_3^1,0),(s_3^1,0),(s_4^2,0)\} \\
\{(s_3^1,0),(s_3^1,0),(s_5^2,0)\} & \{(s_2^1,0),(s_3^1,0),(s_2^2,0)\} & \{(s_2^1,0),(s_2^1,0),(s_2^2,0)\} & \{(s_4^1,0),(s_4^1,0),(s_6^2,0)\} & \{(s_2^1,0),(s_3^1,0),(s_3^2,0)\} \\
\{(s_3^1,0),(s_3^1,0),(s_5^2,0)\} & \{(s_3^1,0),(s_3^1,0),(s_5^2,0)\} & \{(s_2^1,0),(s_2^1,0),(s_3^2,0)\} & \{(s_3^1,0),(s_4^1,0),(s_6^2,0)\} & \{(s_3^1,0),(s_4^1,0),(s_5^2,0)\} \\
\{(s_3^1,0),(s_4^1,0),(s_5^2,0)\} & \{(s_4^1,0),(s_4^1,0),(s_6^2,0)\} & \{(s_2^1,0),(s_2^1,0),(s_2^2,0)\} & \{(s_4^1,0),(s_4^1,0),(s_5^2,0)\} & \{(s_3^1,0),(s_3^1,0),(s_5^2,0)\} \\
\{(s_3^1,0),(s_3^1,0),(s_5^2,0)\} & \{(s_4^1,0),(s_4^1,0),(s_6^2,0)\} & \{(s_3^1,0),(s_3^1,0),(s_5^2,0)\} & \{(s_3^1,0),(s_3^1,0),(s_5^2,0)\} & \{(s_1^1,0),(s_2^1,0),(s_2^2,0)\} \\
\{(s_3^1,0),(s_4^1,0),(s_5^2,0)\} & \{(s_4^1,0),(s_4^1,0),(s_6^2,0)\} & \{(s_2^1,0),(s_3^1,0),(s_3^2,0)\} & \{(s_3^1,0),(s_4^1,0),(s_5^2,0)\} & \{(s_2^1,0),(s_3^1,0),(s_3^2,0)\} \\
\{(s_3^1,0),(s_3^1,0),(s_4^2,0)\} & \{(s_3^1,0),(s_4^1,0),(s_5^2,0)\} & \{(s_2^1,0),(s_3^1,0),(s_3^2,0)\} & \{(s_3^1,0),(s_4^1,0),(s_5^2,0)\} & \{(s_2^1,0),(s_3^1,0),(s_3^2,0)\} \\
\{(s_3^1,0),(s_3^1,0),(s_5^2,0)\} & \{(s_2^1,0),(s_2^1,0),(s_3^2,0)\} & \{(s_2^1,0),(s_2^1,0),(s_3^2,0)\} & \{(s_4^1,0),(s_4^1,0),(s_6^2,0)\} & \{(s_2^1,0),(s_3^1,0),(s_3^2,0)\} \\
\{(s_3^1,0),(s_3^1,0),(s_5^2,0)\} & \{(s_4^1,0),(s_4^1,0),(s_6^2,0)\} & \{(s_2^1,0),(s_2^1,0),(s_2^2,0)\} & \{(s_3^1,0),(s_4^1,0),(s_5^2,0)\} & \{(s_2^1,0),(s_3^1,0),(s_3^2,0)\} \\
\{(s_3^1,0),(s_4^1,0),(s_5^2,0)\} & \{(s_3^1,0),(s_4^1,0),(s_5^2,0)\} & \{(s_2^1,0),(s_2^1,0),(s_3^2,0)\} & \{(s_3^1,0),(s_4^1,0),(s_5^2,0)\} & \{(s_2^1,0),(s_3^1,0),(s_3^2,0)\} \\
\{(s_3^1,0),(s_4^1,0),(s_5^2,0)\} & \{(s_4^1,0),(s_4^1,0),(s_6^2,0)\} & \{(s_3^1,0),(s_4^1,0),(s_5^2,0)\} & \{(s_3^1,0),(s_4^1,0),(s_6^2,0)\} & \{(s_1^1,0),(s_2^1,0),(s_2^2,0)\} \\
\{(s_4^1,0),(s_4^1,0),(s_5^2,0)\} & \{(s_3^1,0),(s_4^1,0),(s_5^2,0)\} & \{(s_2^1,0),(s_3^1,0),(s_3^2,0)\} & \{(s_3^1,0),(s_4^1,0),(s_5^2,0)\} & \{(s_1^1,0),(s_1^1,0),(s_2^2,0)\} \\
\{(s_3^1,0),(s_4^1,0),(s_5^2,0)\} & \{(s_3^1,0),(s_4^1,0),(s_5^2,0)\} & \{(s_2^1,0),(s_3^1,0),(s_3^2,0)\} & \{(s_4^1,0),(s_4^1,0),(s_6^2,0)\} & \{(s_3^1,0),(s_4^1,0),(s_5^2,0)\} \\
\{(s_2^1,0),(s_3^1,0),(s_3^2,0)\} & \{(s_3^1,0),(s_4^1,0),(s_5^2,0)\} & \{(s_2^1,0),(s_2^1,0),(s_3^2,0)\} & \{(s_4^1,0),(s_4^1,0),(s_6^2,0)\} & \{(s_1^1,0),(s_1^1,0),(s_1^2,0)\}
\end{bmatrix},$$

$$\overline{H}_{s_2}^T = \begin{bmatrix}
\{(s_6^2,0),(s_8^3,0),(s_8^3,0)\} & \{(s_4^2,0),(s_4^3,0),(s_5^3,0)\} & \{(s_2^2,0),(s_2^3,0),(s_3^3,0)\} & \{(s_2^2,0),(s_2^3,0),(s_3^3,0)\} & \{(s_5^2,0),(s_6^3,0),(s_7^3,0)\} \\
\{(s_6^2,0),(s_7^3,0),(s_8^3,0)\} & \{(s_3^2,0),(s_4^3,0),(s_4^3,0)\} & \{(s_4^2,0),(s_5^3,0),(s_6^3,0)\} & \{(s_3^2,0),(s_4^3,0),(s_5^3,0)\} & \{(s_5^2,0),(s_7^3,0),(s_7^3,0)\} \\
\{(s_6^2,0),(s_8^3,0),(s_8^3,0)\} & \{(s_3^2,0),(s_4^3,0),(s_5^3,0)\} & \{(s_2^2,0),(s_3^3,0),(s_4^3,0)\} & \{(s_3^2,0),(s_4^3,0),(s_4^3,0)\} & \{(s_3^2,0),(s_4^3,0),(s_5^3,0)\} \\
\{(s_4^2,0),(s_5^3,0),(s_6^3,0)\} & \{(s_2^2,0),(s_2^3,0),(s_3^3,0)\} & \{(s_2^2,0),(s_3^3,0),(s_5^3,0)\} & \{(s_6^2,0),(s_7^3,0),(s_8^3,0)\} & \{(s_2^2,0),(s_3^3,0),(s_3^3,0)\} \\
\{(s_5^2,0),(s_6^3,0),(s_7^3,0)\} & \{(s_5^2,0),(s_6^3,0),(s_7^3,0)\} & \{(s_3^2,0),(s_4^3,0),(s_5^3,0)\} & \{(s_6^2,0),(s_7^3,0),(s_7^3,0)\} & \{(s_2^2,0),(s_3^3,0),(s_3^3,0)\} \\
\{(s_4^2,0),(s_5^3,0),(s_6^3,0)\} & \{(s_5^2,0),(s_6^3,0),(s_7^3,0)\} & \{(s_2^2,0),(s_3^3,0),(s_3^3,0)\} & \{(s_5^2,0),(s_7^3,0),(s_7^3,0)\} & \{(s_2^2,0),(s_3^3,0),(s_3^3,0)\} \\
\{(s_5^2,0),(s_6^3,0),(s_7^3,0)\} & \{(s_6^2,0),(s_8^3,0),(s_8^3,0)\} & \{(s_3^2,0),(s_4^3,0),(s_5^3,0)\} & \{(s_4^2,0),(s_5^3,0),(s_5^3,0)\} & \{(s_2^2,0),(s_3^3,0),(s_4^3,0)\} \\
\{(s_5^2,0),(s_7^3,0),(s_7^3,0)\} & \{(s_6^2,0),(s_8^3,0),(s_8^3,0)\} & \{(s_3^2,0),(s_4^3,0),(s_4^3,0)\} & \{(s_4^2,0),(s_5^3,0),(s_5^3,0)\} & \{(s_2^2,0),(s_2^3,0),(s_3^3,0)\} \\
\{(s_4^2,0),(s_5^3,0),(s_5^3,0)\} & \{(s_5^2,0),(s_6^3,0),(s_7^3,0)\} & \{(s_2^2,0),(s_3^3,0),(s_4^3,0)\} & \{(s_5^2,0),(s_6^3,0),(s_7^3,0)\} & \{(s_3^2,0),(s_3^3,0),(s_4^3,0)\} \\
\{(s_3^2,0),(s_5^3,0),(s_5^3,0)\} & \{(s_3^2,0),(s_3^3,0),(s_4^3,0)\} & \{(s_3^2,0),(s_3^3,0),(s_4^3,0)\} & \{(s_5^2,0),(s_7^3,0),(s_7^3,0)\} & \{(s_3^2,0),(s_4^3,0),(s_4^3,0)\} \\
\{(s_3^2,0),(s_5^3,0),(s_6^3,0)\} & \{(s_6^2,0),(s_8^3,0),(s_8^3,0)\} & \{(s_3^2,0),(s_3^3,0),(s_3^3,0)\} & \{(s_5^2,0),(s_6^3,0),(s_7^3,0)\} & \{(s_3^2,0),(s_3^3,0),(s_4^3,0)\} \\
\{(s_4^2,0),(s_5^3,0),(s_6^3,0)\} & \{(s_5^2,0),(s_6^3,0),(s_7^3,0)\} & \{(s_3^2,0),(s_3^3,0),(s_4^3,0)\} & \{(s_5^2,0),(s_7^3,0),(s_8^3,0)\} & \{(s_3^2,0),(s_4^3,0),(s_4^3,0)\} \\
\{(s_5^2,0),(s_6^3,0),(s_7^3,0)\} & \{(s_5^2,0),(s_7^3,0),(s_7^3,0)\} & \{(s_3^2,0),(s_3^3,0),(s_4^3,0)\} & \{(s_6^2,0),(s_8^3,0),(s_8^3,0)\} & \{(s_1^2,0),(s_2^3,0),(s_2^3,0)\} \\
\{(s_5^2,0),(s_7^3,0),(s_8^3,0)\} & \{(s_5^2,0),(s_7^3,0),(s_7^3,0)\} & \{(s_2^2,0),(s_3^3,0),(s_4^3,0)\} & \{(s_5^2,0),(s_6^3,0),(s_7^3,0)\} & \{(s_1^2,0),(s_2^3,0),(s_2^3,0)\} \\
\{(s_4^2,0),(s_5^3,0),(s_5^3,0)\} & \{(s_5^2,0),(s_6^3,0),(s_7^3,0)\} & \{(s_2^2,0),(s_3^3,0),(s_4^3,0)\} & \{(s_6^2,0),(s_7^3,0),(s_8^3,0)\} & \{(s_5^2,0),(s_6^3,0),(s_7^3,0)\} \\
\{(s_3^2,0),(s_4^3,0),(s_5^3,0)\} & \{(s_4^2,0),(s_6^3,0),(s_6^3,0)\} & \{(s_3^2,0),(s_3^3,0),(s_4^3,0)\} & \{(s_6^2,0),(s_8^3,0),(s_8^3,0)\} & \{(s_1^2,0),(s_2^3,0),(s_2^3,0)\}
\end{bmatrix},$$

$$\overline{H}_{s_3}^T = \begin{bmatrix}
\{(s_4^1,0),(s_6^2,0),(s_8^3,0)\} & \{(s_3^1,0),(s_5^2,0),(s_7^3,0)\} & \{(s_2^1,0),(s_3^2,0),(s_3^3,0)\} & \{(s_3^1,0),(s_3^2,0),(s_7^3,0)\} & \{(s_3^1,0),(s_5^2,0),(s_7^3,0)\} \\
\{(s_4^1,0),(s_6^2,0),(s_8^3,0)\} & \{(s_2^1,0),(s_3^2,0),(s_3^3,0)\} & \{(s_3^1,0),(s_5^2,0),(s_6^3,0)\} & \{(s_2^1,0),(s_3^2,0),(s_3^3,0)\} & \{(s_3^1,0),(s_5^2,0),(s_6^3,0)\} \\
\{(s_4^1,0),(s_6^2,0),(s_8^3,0)\} & \{(s_2^1,0),(s_3^2,0),(s_4^3,0)\} & \{(s_2^1,0),(s_3^2,0),(s_4^3,0)\} & \{(s_2^1,0),(s_3^2,0),(s_3^3,0)\} & \{(s_3^1,0),(s_5^2,0),(s_7^3,0)\} \\
\{(s_3^1,0),(s_5^2,0),(s_7^3,0)\} & \{(s_2^1,0),(s_3^2,0),(s_3^3,0)\} & \{(s_2^1,0),(s_2^2,0),(s_3^3,0)\} & \{(s_4^1,0),(s_5^2,0),(s_8^3,0)\} & \{(s_2^1,0),(s_3^2,0),(s_3^3,0)\} \\
\{(s_3^1,0),(s_5^2,0),(s_7^3,0)\} & \{(s_3^1,0),(s_5^2,0),(s_7^3,0)\} & \{(s_2^1,0),(s_2^2,0),(s_3^3,0)\} & \{(s_4^1,0),(s_6^2,0),(s_7^3,0)\} & \{(s_2^1,0),(s_3^2,0),(s_3^3,0)\} \\
\{(s_3^1,0),(s_5^2,0),(s_7^3,0)\} & \{(s_4^1,0),(s_6^2,0),(s_8^3,0)\} & \{(s_2^1,0),(s_3^2,0),(s_3^3,0)\} & \{(s_4^1,0),(s_5^2,0),(s_8^3,0)\} & \{(s_2^1,0),(s_2^2,0),(s_3^3,0)\} \\
\{(s_3^1,0),(s_5^2,0),(s_6^3,0)\} & \{(s_4^1,0),(s_6^2,0),(s_8^3,0)\} & \{(s_2^1,0),(s_3^2,0),(s_4^3,0)\} & \{(s_3^1,0),(s_5^2,0),(s_7^3,0)\} & \{(s_2^1,0),(s_2^2,0),(s_3^3,0)\} \\
\{(s_3^1,0),(s_5^2,0),(s_6^3,0)\} & \{(s_4^1,0),(s_6^2,0),(s_8^3,0)\} & \{(s_3^1,0),(s_3^2,0),(s_5^3,0)\} & \{(s_3^1,0),(s_5^2,0),(s_7^3,0)\} & \{(s_2^1,0),(s_2^2,0),(s_3^3,0)\} \\
\{(s_2^1,0),(s_4^2,0),(s_5^3,0)\} & \{(s_3^1,0),(s_5^2,0),(s_7^3,0)\} & \{(s_2^1,0),(s_3^2,0),(s_4^3,0)\} & \{(s_3^1,0),(s_5^2,0),(s_7^3,0)\} & \{(s_3^1,0),(s_3^2,0),(s_5^3,0)\} \\
\{(s_3^1,0),(s_3^2,0),(s_5^3,0)\} & \{(s_2^1,0),(s_3^2,0),(s_4^3,0)\} & \{(s_2^1,0),(s_2^2,0),(s_3^3,0)\} & \{(s_3^1,0),(s_5^2,0),(s_6^3,0)\} & \{(s_2^1,0),(s_3^2,0),(s_4^3,0)\} \\
\{(s_3^1,0),(s_5^2,0),(s_6^3,0)\} & \{(s_4^1,0),(s_6^2,0),(s_8^3,0)\} & \{(s_3^1,0),(s_5^2,0),(s_6^3,0)\} & \{(s_3^1,0),(s_5^2,0),(s_6^3,0)\} & \{(s_2^1,0),(s_3^2,0),(s_4^3,0)\} \\
\{(s_3^1,0),(s_3^2,0),(s_5^3,0)\} & \{(s_4^1,0),(s_6^2,0),(s_7^3,0)\} & \{(s_2^1,0),(s_3^2,0),(s_4^3,0)\} & \{(s_4^1,0),(s_5^2,0),(s_7^3,0)\} & \{(s_2^1,0),(s_3^2,0),(s_4^3,0)\} \\
\{(s_3^1,0),(s_5^2,0),(s_7^3,0)\} & \{(s_4^1,0),(s_6^2,0),(s_8^3,0)\} & \{(s_3^1,0),(s_4^2,0),(s_7^3,0)\} & \{(s_4^1,0),(s_6^2,0),(s_8^3,0)\} & \{(s_1^1,0),(s_1^2,0),(s_1^3,0)\} \\
\{(s_4^1,0),(s_5^2,0),(s_6^3,0)\} & \{(s_4^1,0),(s_6^2,0),(s_8^3,0)\} & \{(s_2^1,0),(s_2^2,0),(s_3^3,0)\} & \{(s_3^1,0),(s_5^2,0),(s_7^3,0)\} & \{(s_1^1,0),(s_1^2,0),(s_2^3,0)\} \\
\{(s_3^1,0),(s_5^2,0),(s_6^3,0)\} & \{(s_3^1,0),(s_5^2,0),(s_7^3,0)\} & \{(s_2^1,0),(s_2^2,0),(s_3^3,0)\} & \{(s_4^1,0),(s_6^2,0),(s_8^3,0)\} & \{(s_3^1,0),(s_5^2,0),(s_7^3,0)\} \\
\{(s_3^1,0),(s_3^2,0),(s_6^3,0)\} & \{(s_3^1,0),(s_4^2,0),(s_7^3,0)\} & \{(s_2^1,0),(s_3^2,0),(s_4^3,0)\} & \{(s_4^1,0),(s_6^2,0),(s_8^3,0)\} & \{(s_1^1,0),(s_1^2,0),(s_1^3,0)\}
\end{bmatrix}.$$

Formula (10) is used to calculate the data of the three DMs groups, and get the aggregated decision matrix X.

$$X^T = \begin{bmatrix}
\{(s_6^2, -0.222)\} & \{(s_4^2, 0.0633)\} & \{(s_2^2, 0.0190)\} & \{(s_3^2, 0.0542)\} & \{(s_5^2, 0.0083)\} \\
\{(s_6^2, -0.3222)\} & \{(s_3^2, 0.0042)\} & \{(s_4^2, 0.0300)\} & \{(s_3^2, 0.0417)\} & \{(s_5^2, -0.1000)\} \\
\{(s_6^2, -02556)\} & \{(s_3^2, -0.1333)\} & \{(s_2^2, 0.0524)\} & \{(s_3^2, -0.4667)\} & \{(s_4^2, 0.0533)\} \\
\{(s_5^2, -0.4333)\} & \{(s_2^2, 0.0190)\} & \{(s_2^2, 0.0286)\} & \{(s_6^2, -0.4556)\} & \{(s_2^2, 0.0476)\} \\
\{(s_5^2, -0.0333)\} & \{(s_5^2, -0.0333)\} & \{(s_3^2, -0.5000)\} & \{(s_5^2, 0.1292)\} & \{(s_3^2, -0.1667)\} \\
\{(s_5^2, -0.3833)\} & \{(s_5^2, 0.1542)\} & \{(s_2^2, 0.0190)\} & \{(s_5^2, 0.0917)\} & \{(s_3^2, -0.4000)\} \\
\{(s_5^2, -0.3000)\} & \{(s_6^2, -0.2222)\} & \{(s_4^2, -0.0733)\} & \{(s_4^2, 0.0933)\} & \{(s_2^2, -0.1000)\} \\
\{(s_5^2, -0.0500)\} & \{(s_6^2, -0.2222)\} & \{(s_3^2, 0.0042)\} & \{(s_5^2, -0.4833)\} & \{(s_2^2, 0.0143)\} \\
\{(s_4^2, -0.0467)\} & \{(s_5^2, 0.0021)\} & \{(s_3^2, -0.1667)\} & \{(s_5^2, 0.0021)\} & \{(s_3^2, -0.0667)\} \\
\{(s_4^2, -0.0367)\} & \{(s_3^2, -0.4333)\} & \{(s_2^2, 0.0429)\} & \{(s_5^2, 0.0375)\} & \{(s_3^2, -0.2333)\} \\
\{(s_4^2, 0.0500)\} & \{(s_6^2, -0.2222)\} & \{(s_3^2, 0.0375)\} & \{(s_5^2, -0.2500)\} & \{(s_3^2, -0.3333)\} \\
\{(s_4^2, 0.0033)\} & \{(s_5^2, 0.0604)\} & \{(s_3^2, -0.4333)\} & \{(s_5^2, 0.0729)\} & \{(s_5^2, -0.2333)\} \\
\{(s_5^2, 0.0021)\} & \{(s_5^2, 0.1792)\} & \{(s_4^2, 0.0367)\} & \{(s_6^2, -0.2389)\} & \{(s_1^2, -0.0333)\} \\
\{(s_5^2, 0.0458)\} & \{(s_5^2, 0.1354)\} & \{(s_2^2, 0.0429)\} & \{(s_5^2, 0.0021)\} & \{(s_1^2, -0.0467)\} \\
\{(s_4^2, 0.0500)\} & \{(s_5^2, 0.0021)\} & \{(s_2^2, 0.0429)\} & \{(s_6^2, -0.3222)\} & \{(s_5^2, 0.0021)\} \\
\{(s_3^2, 0.0500)\} & \{(s_5^2, -0.4167)\} & \{(s_3^2, -0.4333)\} & \{(s_6^2, -0.2222)\} & \{(s_1^2, -0.0933)\}
\end{bmatrix}.$$

Here we take aggregation of $\{\overline{H}^{11}_{S_1}, \overline{H}^{11}_{S_2}, \overline{H}^{11}_{S_3}\}$ as an example to demonstrate the process. By formula (10) the linguistic 2-tuple elements are initially aggregated as

$$\oplus^3_{z=1}\lambda_z\overline{H}^1_{S_z} = \cup_{\overline{h}_{Sz}\in\overline{H}^1_{S_z}, j=1,2,3}\{\oplus^3_{z=1}\lambda_z\overline{h}_{S_z}\}$$

$$= \Big\{NS_B^{-1}(0.3\times 8+0.3\times 16+0.4\times 8), NS_B^{-1}(0.3\times 8+0.3\times 16+0.4\times 16), NS_B^{-1}(0.3\times 8+0.3\times 16+0.4\times 20),$$
$$NS_B^{-1}(0.3\times 8+0.3\times 20+0.4\times 8), NS_B^{-1}(0.3\times 8+0.3\times 20+0.4\times 16), NS_B^{-1}(0.3\times 8+0.3\times 20+0.4\times 20),$$
$$NS_B^{-1}(0.3\times 8+0.3\times 20+0.4\times 8), NS_B^{-1}(0.3\times 8+0.3\times 20+0.4\times 16), NS_B^{-1}(0.3\times 8+0.3\times 20+0.4\times 20),$$
$$NS_B^{-1}(0.3\times 8+0.3\times 16+0.4\times 8), NS_B^{-1}(0.3\times 8+0.3\times 16+0.4\times 16), NS_B^{-1}(0.3\times 8+0.3\times 16+0.4\times 20),$$
$$NS_B^{-1}(0.3\times 8+0.3\times 20+0.4\times 8), NS_B^{-1}(0.3\times 8+0.3\times 20+0.4\times 16), NS_B^{-1}(0.3\times 8+0.3\times 20+0.4\times 20),$$
$$NS_B^{-1}(0.3\times 8+0.3\times 20+0.4\times 8), NS_B^{-1}(0.3\times 8+0.3\times 20+0.4\times 16), NS_B^{-1}(0.3\times 8+0.3\times 20+0.4\times 20),$$
$$NS_B^{-1}(0.3\times 16+0.3\times 16+0.4\times 8), NS_B^{-1}(0.3\times 16+0.3\times 16+0.4\times 16), NS_B^{-1}(0.3\times 16+0.3\times 16+0.4\times 20),$$
$$NS_B^{-1}(0.3\times 16+0.3\times 20+0.4\times 8), NS_B^{-1}(0.3\times 16+0.3\times 20+0.4\times 16), NS_B^{-1}(0.3\times 16+0.3\times 20+0.4\times 20),$$
$$NS_B^{-1}(0.3\times 16+0.3\times 20+0.4\times 8), NS_B^{-1}(0.3\times 16+0.3\times 20+0.4\times 16), NS_B^{-1}(0.3\times 16+0.3\times 20+0.4\times 20)\Big\}$$

$$= \Big\{NS_B^{-1}(10.4), NS_B^{-1}(13.6), NS_B^{-1}(15.2), NS_B^{-1}(11.6), NS_B^{-1}(14.8), NS_B^{-1}(16.4), NS_B^{-1}(11.6),$$
$$NS_B^{-1}(14.8), NS_B^{-1}(16.4), NS_B^{-1}(10.4), NS_B^{-1}(13.6), NS_B^{-1}(15.2), NS_B^{-1}(11.6), NS_B^{-1}(14.8),$$
$$NS_B^{-1}(16.4), NS_B^{-1}(11.6), NS_B^{-1}(14.8), NS_B^{-1}(16.4), NS_B^{-1}(12.8), NS_B^{-1}(16), NS_B^{-1}(17.6),$$
$$NS_B^{-1}(14), NS_B^{-1}(17.2), NS_B^{-1}(18.8), NS_B^{-1}(14), NS_B^{-1}(17.2), NS_B^{-1}(18.8)\Big\}.$$

The 27 elements of $\oplus^3_{z=1}\lambda_z\overline{H}^1_{S_z}$ are aggregated by MGUHFLWA operator, and get $x_{11} = \{(s^2_6, -0.222)\}$.

Step 3. Normalize the aggregated decision matrix N.

All the indicators are benefit criteria, so $\overline{h}_s(n^B_{ij}) = \overline{h}_s(x^B_{ij})$, the normalized matrix N is the same as the aggregated decision matrix X.

Step 4. Calculate the weighted matrix V.

The weight of the attribute is shown as follows, according to formula (10), we get the weighted matrix V.

$$W = (0.0596, 0.0771, 0.0911, 0.0842, 0.0436, 0.0334, 0.0651, 0.0692, 0.0292, 0.0866, 0.0732, 0.0450, 0.0590, 0.0388, 0.0716, 0.0735),$$

$$V^T = \begin{bmatrix} \{(s_0^2, 0.1749)\} & \{(s_0^2, 0.1030)\} & \{(s_0^2, 0.0732)\} & \{(s_0^2, 0.0887)\} & \{(s_0^2, 0.1209)\} \\ \{(s_0^2, 0.2169)\} & \{(s_0^2, 0.1084)\} & \{(s_0^2, 0.1280)\} & \{(s_0^2, 0.1131)\} & \{(s_0^2, 0.1511)\} \\ \{(s_0^2, 0.2636)\} & \{(s_0^2, 0.1251)\} & \{(s_0^2, 0.1106)\} & \{(s_0^2, 0.1191)\} & \{(s_0^2, 0.0155)\} \\ \{(s_0^2, 0.1537)\} & \{(s_0^2, 0.1032)\} & \{(s_0^2, 0.1044)\} & \{(s_0^2, 0.2233)\} & \{(s_0^2, 0.1066)\} \\ \{(s_0^2, 0.0866)\} & \{(s_0^2, 0.0866)\} & \{(s_0^2, 0.0566)\} & \{(s_0^2, 0.1052)\} & \{(s_0^2, 0.0596)\} \\ \{(s_0^2, 0.0616)\} & \{(s_0^2, 0.0832)\} & \{(s_0^2, 0.0409)\} & \{(s_0^2, 0.0765)\} & \{(s_0^2, 0.0440)\} \\ \{(s_0^2, 0.1223)\} & \{(s_0^2, 0.1909)\} & \{(s_0^2, 0.0946)\} & \{(s_0^2, 0.1163)\} & \{(s_0^2, 0.0768)\} \\ \{(s_0^2, 0.1369)\} & \{(s_0^2, 0.2029)\} & \{(s_0^2, 0.0973)\} & \{(s_0^2, 0.1250)\} & \{(s_0^2, 0.0844)\} \\ \{(s_0^2, 0.0440)\} & \{(s_0^2, 0.0586)\} & \{(s_0^2, 0.0399)\} & \{(s_0^2, 0.0586)\} & \{(s_0^2, 0.0405)\} \\ \{(s_0^2, 0.1321)\} & \{(s_0^2, 0.1137)\} & \{(s_0^2, 0.1091)\} & \{(s_0^2, 0.1835)\} & \{(s_0^2, 0.1171)\} \\ \{(s_0^2, 0.1244)\} & \{(s_0^2, 0.2147)\} & \{(s_0^2, 0.1068)\} & \{(s_0^2, 0.1390)\} & \{(s_0^2, 0.0976)\} \\ \{(s_0^2, 0.0722)\} & \{(s_0^2, 0.0986)\} & \{(s_0^2, 0.0591)\} & \{(s_0^2, 0.1004)\} & \{(s_0^2, 0.0608)\} \\ \{(s_0^2, 0.1183)\} & \{(s_0^2, 0.1517)\} & \{(s_0^2, 0.0987)\} & \{(s_0^2, 0.1718)\} & \{(s_0^2, 0.0570)\} \\ \{(s_0^2, 0.0833)\} & \{(s_0^2, 0.0945)\} & \{(s_0^2, 0.0489)\} & \{(s_0^2, 0.0779)\} & \{(s_0^2, 0.0370)\} \\ \{(s_0^2, 0.1218)\} & \{(s_0^2, 0.1437)\} & \{(s_0^2, 0.0903)\} & \{(s_0^2, 0.2015)\} & \{(s_0^2, 0.1437)\} \\ \{(s_0^2, 0.1088)\} & \{(s_0^2, 0.1347)\} & \{(s_0^2, 0.0965)\} & \{(s_0^2, 0.2155)\} & \{(s_0^2, 0.0666)\} \end{bmatrix}.$$

Step 5. Determine the BAA matrix G.

The BAA for each criterion is determined by using formula (18).

$$\begin{aligned} G = \Big(&\{(s_0^2, 0.1121)\}, \{(s_0^2, 0.1435)\}, \{(s_0^2, 0.1559)\}, \{(s_0^2, 0.1382)\}, \\ &\{(s_0^2, 0.0789)\}, \{(s_0^2, 0.0613)\}, \{(s_0^2, 0.1202)\}, \{(s_0^2, 0.1293)\}, \\ &\{(s_0^2, 0.0484)\}, \{(s_0^2, 0.1311)\}, \{(s_0^2, 0.1365)\}, \{(s_0^2, 0.0782)\}, \\ &\{(s_0^2, 0.1195)\}, \{(s_0^2, 0.0683)\}, \{(s_0^2, 0.1402)\}, \{(s_0^2, 0.1244)\}\Big). \end{aligned}$$

Step 6. Compute the distance matrix Q.

Elements of the distance matrix Q can be calculated by formula (20) and shown in Table 17.

Step 7. Rank the alternatives.

The final values of the alternatives are calculated by formula (22) and shown in Table 18.

Since $S(A_4) > S(A_1) > S(A_2) > S(A_5) > S(A_3)$, then $A_4 \succ A_1 \succ A_2 \succ A_5 \succ A_3$, and the best alternative is A_4.

TABLE 17 The deviation measures of five alternatives

	A_1	A_2	A_3	A_4	A_5
B_1	0.3141	−0.0457	−0.1948	−0.1173	0.0437
B_2	0.3670	−0.1753	−0.0776	−0.1521	0.0380
B_3	0.5388	−0.1537	−0.1992	−0.1841	−0.0018
B_4	0.0774	−0.1751	−0.1694	0.4253	−0.1582
B_5	0.0383	0.0383	−0.1113	0.1313	−0.0967
B_6	0.0018	0.1097	−0.1016	0.0763	−0.0861
B_7	0.0108	0.3536	−0.1280	−0.0195	−0.2169
B_8	0.0383	0.3679	−0.1600	−0.0217	−0.2245
B_9	−0.0216	0.0514	−0.0421	0.0514	−0.0392
B_{10}	0.0052	−0.0871	−0.1102	0.2620	−0.0698
B_{11}	−0.0605	0.3908	−0.1483	0.0127	−0.1947
B_{12}	−0.0300	0.1019	−0.0959	0.1109	−0.0869
B_{13}	−0.0059	0.1612	−0.1042	0.2614	−0.3125
B_{14}	0.0751	0.1307	−0.0971	0.0479	−0.1566
B_{15}	−0.0922	0.0177	−0.2479	0.3066	0.0177
B_{16}	−0.0784	0.0514	−0.1396	0.4556	−0.2890

TABLE 18 Rank five alternatives using MGUHFLTS–MABAC method

	Final values	Rank
A_1	1.1782	2
A_2	1.1378	3
A_3	−2.1291	5
A_4	1.6467	1
A_5	−1.8336	4

Abbreviations: MABAC, multi-attributive border approximation area comparison; MGUHFLTS, multigranular unbalanced hesitant fuzzy linguistic term set.

Therefore, the DMs considered A_4 (Yancheng Normal University) as an ideal modern Chinese language MOOCs.

5.5 | The comparison of MOOCs' evaluation studies

Many scholars focused on MOOCs evaluation from different perspectives. In this subsection, our study is compared with other five MOOCs' evaluation studies, which shows the difference among the six studies. The details are shown in Table 19.

TABLE 19 The comparison of MOOCs' evaluation studies from different perspectives

Study	Fuzzy decision	Evaluation index	Group decision	Suggestions	Method
Nie et al.[37]	✓	✓	✓	✗	AHP, DME
Liu et al.[38]	✗	✗	✗	✓	SPSS
Meinert et al.[39]	✓	✗	✗	✗	RE-AIM, Kirkatrick
Margaryan et al.[5]	✗	✗	✗	✓	SPSS
Gil-Jaurena et al.[2]	✗	✗	✗	✓	SPSS
Our study	✓	✓	✓	✓	AHP, MABAC

Abbreviations: AHP, analytic hierarchy process; MABAC, multi-attributive border approximation area comparison; RE-AIM, Reach, Effectiveness, Adoption, Implementation, and Maintenance.

When it comes to the evaluation type, three of these studies are considered as fuzzy decisions. Among these three studies, Nie et al.[37] selected words and phrases from positive emotion signifiers and negative emotion signifiers to describe evaluation information. Meinert et al.[39] applied triangular fuzzy number to show study participants' attitudes in the interviews. Furthermore, our study adopts MGUHFLTSs to evaluate MOOCs, which can better present the preference values of DMs in a qualitative environment. MGUHFLTSs not only allow the DMs to give linguistic evaluation with different ULTSs, but also represent hesitation of DMs.

As for the evaluation system, two of these studies constructed an evaluation index. In Nie et al.'s study,[37] evaluation index contained four elements, which were course planning, course content, instructional process, and learning outcomes. On the contrary, in our study, evaluation index contains six elements, which are teaching team, teaching goals, teaching methods and means, content of the course, teaching activities, and teaching evaluation and feedback. In the above six elements, our study takes teaching team and teaching feedback into account, which can better describe Chinese MOOCs.

From the number of DMs aspects, two of these studies are group decisions. In Nie et al.'s study,[37] five experts were invited to give their group decision for relative importance of the criteria. In our study, 11 experts are as a group to give their relative importance of the criteria, then nine experts are divided into three groups to give their linguistic evaluation. Group decision can avoid the limitation of an individual's knowledge and experience, and enhance the accurate and scientific evaluation.

As far as improvement is considered, four of these studies proposed their suggestions. Among these four studies, Liu et al.[38] gave six pieces of suggestions, such as the position of universities' link, the classification of courses, and so forth. Margaryan et al.[5] advised to give more attention to instructional designs. Gil-Jaurena et al.[2] suggested to keep the interests of MOOCs learners, to improve the completion rates. In our study, advantage and disadvantage's elements are mentioned at the end of Section 6.

The above six studies applied different methods. Among them, Nie et al.,[37] Margaryan et al.,[5] and Gil-Jaurena et al.[2] used SPSS to analyze the data. Meinert et al.[39] used Reach, Effectiveness, Adoption, Implementation, and Maintenance (RE-AIM) and Kirkatrick to draw data. Nie et al.[37] and our study both use AHP to determine the weights of evaluation index. In the process of alternatives ranking Nie et al.[37] applied score function, while our study uses MGUHFLTS–MABAC to make sure results' stability and steps' simplification.

Compared with the other five studies, our study has the advantages in fuzzy decision, evaluation index, group decision, suggestions, and method to make the evaluation more accurate and scientific.

6 | ANALYSIS AND SUGGESTIONS

To further analyzing the evaluation index system, MOOCs' evaluation index was used to analyze the trend of each course. To set the BAA of A1 to 1, because of its ranking in the middle position among the five MOOCs, data of the other four MOOCs are relative values. In the following paragraphs, each indicator will be analyzed to show how they influenced each element.

Figure 2 reveals that A1 performs best among the five teaching teams, which is set to 1.0. A5 is in the second place, whose value is between 0.6 and 0.8. A2–A4 perform relatively poor, which are all less than 0.6. A1 is the top 10 universities in China. Its chief teacher is a professor and the team members are more than the others, who are all associate professors. The chief teacher of A5 is an associate professor, and all team members are lectures. The reasons why relative values of A2–A4 are less than 0.6 are different. Team members of A2 are just two lectures. A3 and A4 are just common colleges in their province. In Figure 2, all indicators of A1 indicate the maximum, which means A1 MOOC teaching team is the best among the five.

Figure 3 demonstrates the teaching goals and its three specific indicators. The relative value of A4 is above 1.2. That is because MOOC teachers summarized the feedback according to learners' learning situation every week, and weekly teaching objectives will be delivered to learners on the MOOC bulletin boards or in the corresponding course videos, so that MOOC learners can get them clearly and easily. The advantages of A2 can be seen that the teaching objectives follow the principle of diversity, covering the three dimensionalities of knowledge objectives, skills objectives, and emotional objectives. Besides, the arrangement in A2 is scientific and reasonable. The disadvantages of A3 and A5 are because of no clear learning objectives on the MOOC bulletin board each week.

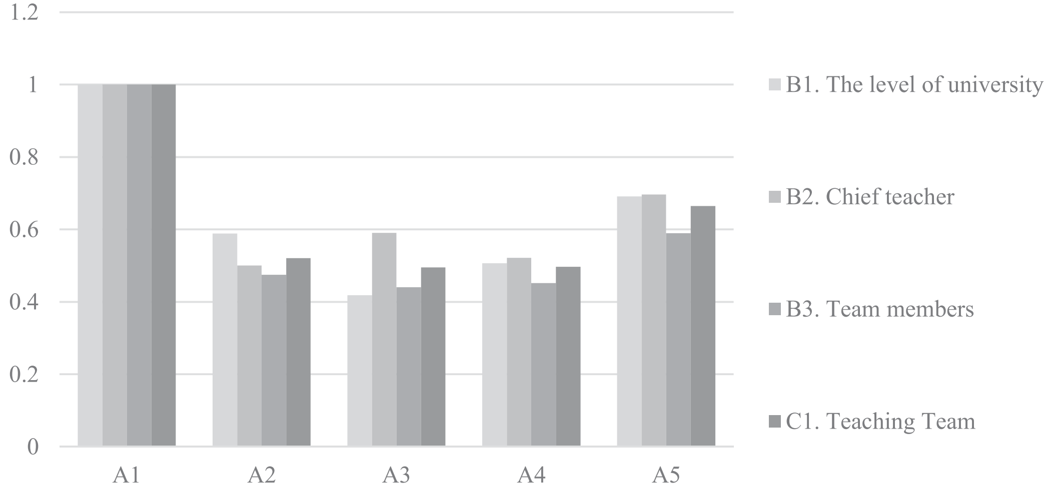

FIGURE 2 Bar chart of Teaching Team (C1) and its specific indicators (B1–B3)

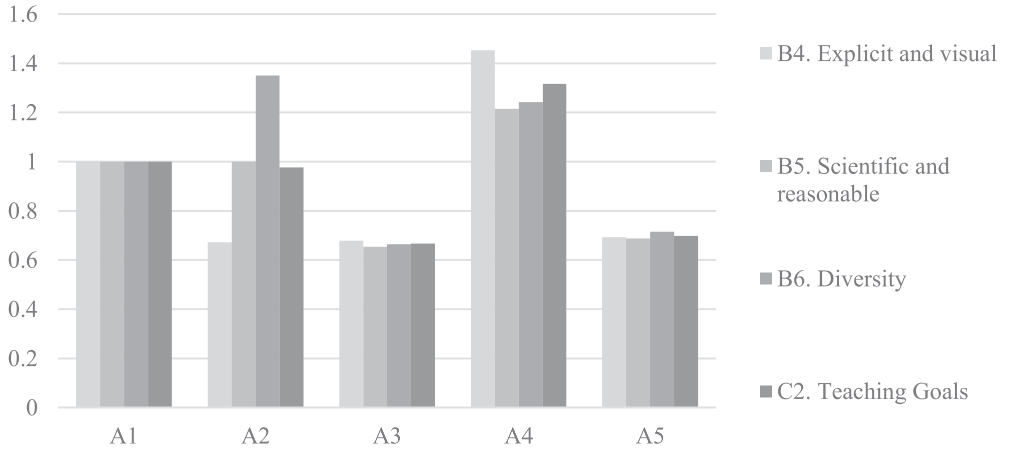

FIGURE 3 Bar chart of Teaching Goals (C2) and its specific indicators (B4–B6)

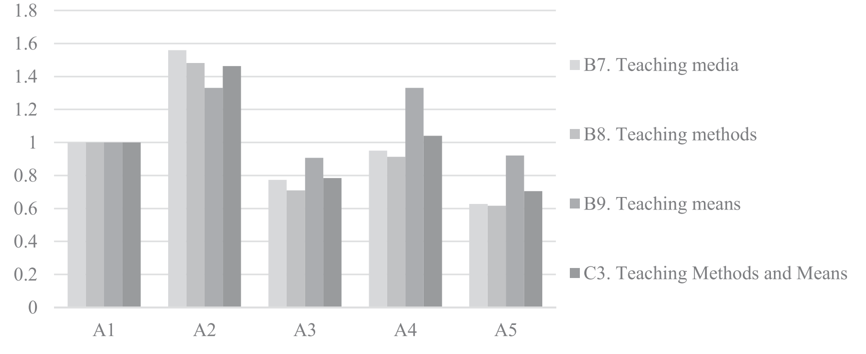

FIGURE 4 Bar chart of Teaching Methods and Means (C3) and its specific indicators (B7–B9)

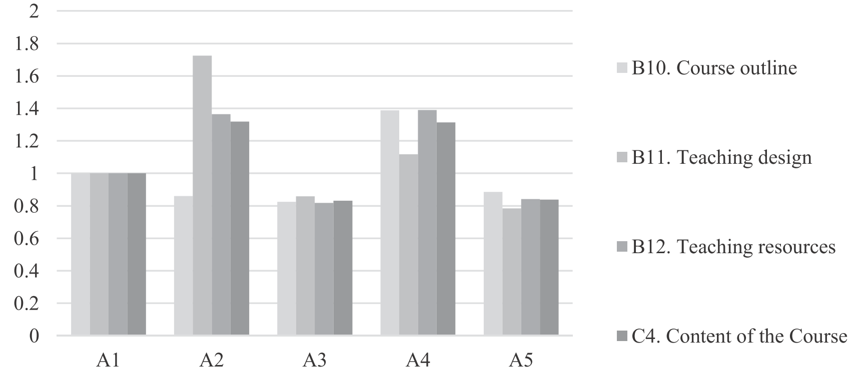

FIGURE 5 Bar chart of Content of the Course (C4) and its specific indicators (B10–B12)

Figure 4 compares the teaching methods and means. A2 performs best because its propaganda film is always student-centered, with lively music and fresh colors. In the course video, the teacher's position is changeable, and cartoon demonstration is used in time. A4's values are all above 1.0, its teachers showed strong affinity. All the examples in the MOOC are close to

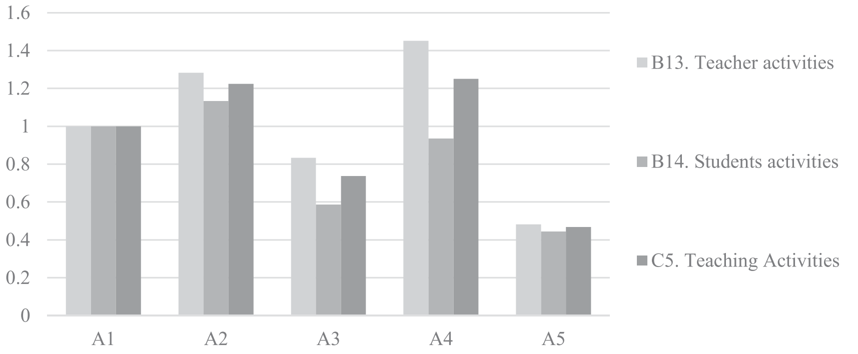

FIGURE 6 Bar chart of Teaching Activities (C5) and its specific indicators (B13–B14)

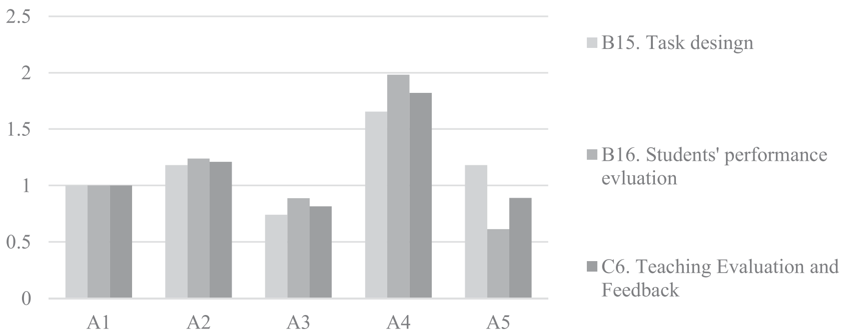

FIGURE 7 Bar chart of Teaching Evaluation and Feedback (C6) and its specific indicators (B15–B16)

lives. A1's performance is moderate with complete content and professional process. The disadvantage of A3 is that all teachers speak statically in the video, and that of A5 is that the pace of the course is very slow, and the number of words described in the lecture notes is too many for learners to get points.

Figure 5 illustrates the content of the course and indicators among five MOOCs. A2 is noticeable that its advantage is its excellent teaching design, which relative value is approximately 1.7, but it also has disadvantages. There is no weekly syllabus and review. Each indicator in A4 is outstanding all more than 1.0, because teachers make a detailed summary every week according to learners' situation. The advantage of A1 is that all key points of each week have been marked in red letters for Learners to identify. On the contrary, there were no weekly outline and review in A3. A5 teaching design is relatively deficient.

Figure 6 shows the teaching activities of A2 and A5 are better than A3 and A5. The relative value of teacher activities is about 1.3, because teachers have strong appeal in MOOC. And the number of learners is the largest. The maximum value can be found at above 1.4 in A4, because teachers are most prompt in replying to learners' questions on the discussion board. However, the disadvantage of A3 is that the lectures are comparatively dull and monotonous, and the amount of posting learners' questions is not high. The relative value of A5 is around 0.5, which is minimum among the five MOOCs. The reason is considered as the lowest number of learners enrolled in the course, which is only one quarter as many as that of A2. In addition, those learners posted the lowest number of questions on the discussion board.

Figure 7 explains why A4 performs best in teaching evaluation and feedback. Teachers in A4 focus on designing the moderate difficulty of homework and the variety of question types, which results in the max value at nearly 2.0. According to the learners' performance evaluation, teachers focus on the combination of process evaluation and summative evaluation, with the largest proportion of learners participating in the exam. Teachers in A2 pay more attention to learners' three aspects, the times of discussion, the assessment of homework, and the watching of videos. They do not just focus on referring to the scores of learners in the course test. Although the learners' performance is the minimum of all, it is obvious that the value of task design in A5 is relatively high, around 1.2. That means teachers in A5 do as good as teachers in A2 in accordance with task design.

From what has been analyzed above, during the production of MOOCs, we should pay attention to the advantage's elements, including C3 (Teaching Methods and Means), C4 (Content of the Course), and C6 (Teaching Evaluation and Feedback). Meanwhile, we should pay more attention to the disadvantage's elements, including C1 (Teaching Team), C2 (Teaching Goals), and C5 (Teaching Activities). In the element of C1 (Teaching Team), many abilities concerning teachers should be enhanced, for instance, multimedia application ability and curriculum development ability, which will directly improve the quality of MOOCs. In terms of C2 (Teaching Goals), teaching goals should be transmitted clearly. Before the MOOC starts, the modules and knowledge structure of the course should be introduced to the learners in advance, so that the learners can understand the overall objectives of the course and the learning objectives of each chapter. At the same time, the teachers should design the Teaching Goals in various aspects and guide the learners to develop comprehensively. When it comes to the C5 (Teaching Activities), attention should be paid to the introduction of video courses to arouse learners' interest, and the emphasis should be highlighted. In a word, we should not only focus on those advantages' elements C3, C4, and C6, but also on those disadvantages' elements C1, C2, and C5.

7 | CONCLUSION

With the worldwide spread of COVID-2019 in 2020, it is very difficult to eliminate it completely in a short period of time. MOOCs' education will be the dominant form of online learning for a long time. In such a situation, the teaching quality evaluation of MOOCs is conducive to standardizing the production of MOOCs and improving their teaching quality. To enable DMs to optimize their evaluation and improve the accuracy of decision-making, this paper proposes the information form of MGUHFLTS to evaluate five modern Chinese language MOOCs. MGUHFLTS is very suitable for group decision-making, because in group decision-making, DMs will adopt different granularity information in linguistic selection due to personal experience and preference. This paper is based on the MOOCs' evaluation index system, using the AHP method to determine the index weight. In this index system, MGUHFLWA operator is applied to aggregate the group decision information, and then MGUHFLTS–MABAC method is adopted to rank five courses. Finally, based on the evaluation results, the effect of each indicator on the MOOCs is analyzed one by one, and the suggestions for improvement are proposed.

In the future, we will extend the MGUHFLTS–MABAC method to some new fields, such as supplier selection,[40] Building location selection,[41] and teaching quality evaluation.[42]

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新文科理论与实践 2022年第2期（总第2期）

深入学习贯彻习近平总书记在中国人民大学考察时的重要讲话精神（笔谈）

理论前沿

学科研究

教育探索

典型案例

发展报告

新文科背景下电子商务本科专业的建设与发展

[illegible]

摘　要：[illegible]

关键词：新文科；电子商务；本科专业；学科交叉；数字经济

随着数字经济快速发展并成为国家战略，历经20年建设的电子商务专业迎来新的社会需求和挑战。2021年国家《"十四五"电子商务发展规划》明确指出，电子商务作为推动国民经济和社会发展的重要力量，未来5年从业人员将达到7000万人[1]，这对电子商务专业人才培养提出了更大的需求。另一方面，电子商务专业作为"工管融合、文理交叉"特色鲜明的典型新文科专业，《新文科建设宣言》也对其"守正创新"提出了新的更高要求。因此，本文总结电子商务专业20年的建设经验，探讨新文科背景下电子商务专业的未来发展，不仅对该专业，而且对学科交叉的新兴专业建设都富有意义。本文将逐一回答如下四方面问题：电子商务专业作为"新文科"特色的本科专业20年来是如何发展的？新文科对电子商务专业的新的更高要求是什么？新文科背景下建设什么样的电子商务专业以及如何建设？

[illegible]

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启功书

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■教育理论探索

国际教育认证导向的大学商学院使命凝练研究

宋文燕,秦中峰,郑嘉宁

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摘　要:使命是大学商学院发展的原动力,它能够引导和保证各高校的大学商科教育沿着战略方向发展,帮助高校商学院确立管理机制。文章首先介绍了三大国际认证商科教育的"使命"要求;其次,分析了已获得国际认证的典型中外高校商学院的使命,并对比总结其异同点,为北京航空航天大学经济管理学院使命的确立提供依据;最后,以北京航空航天大学经济管理学院为例,提出了商学院使命凝练过程,为其他同类型院校的商学院使命凝练提供一定的参考与借鉴。

关键词:商学院使命;欧洲质量改进体系认证;国际精英商学院协会认证;工商管理硕士协会认证;使命凝练
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高等教育质量是一个国家发展水平的重要标志之一[1]。2021年5月,习近平总书记在中国科协第十次全国代表大会上指出,"培养创新型人才是国家、民族长远发展的大计"。各个高校商学院要想提升教育质量,首先应该找到自己的定位,明确自身发展方向,合理配置资源,建立培养质量保证体系[2]。明确使命是大学商学院定位的核心。使命不能凭空产生,它是对大学商学院办学特色和发展历史的简明总结,是商学院发展的动力来源,更是商学院未来发展的指南。使命的形成需要具体凝练过程支撑,它不仅是对历史阶段的总结,更是对未来发展的展望。使命也是顶层设计与战略管理的开始,找到一个好的切入点和合适的载体,并在此基础上认真设计流程,是使命形成的核心。因此,高校应该重视商学院使命的凝练与完善过程[3]。

大学商学院使命的形成、修改与完善是在学习、讨论、调研、比较之后确定的。然而,目前一些高校商学院的使命确立过程比较简单,缺乏考虑国内外对比与教育发展趋势。因此,本文将依托国际三大认证标准,分析已获国际认证的部分国内外商学院使命的特点,结合北京航空航天大学(以下简称"北航")经济管理学院定位、办学战略、学院发展历史等,吸取学院各利益相关方的建议,建立了系统化的使命凝练过程,最终提炼出自身使命,以期为其他同类型院校的商学院使命凝练提供一定的参考与借鉴。

一、国际认证体系对商学院使命确立的引导

目前,全球共有三大商学教育认证体系,它们分别是AMBA国际认证、AACSB国际认证以及EQUIS国际认证[4]。三大商学教育认证对于全球商学院具有引导作用。

AMBA的中文全称为工商管理硕士协会,是专门针对MBA项目的认证体系。商学院要想获得AMBA国际认证,就需要先了解它的考察标准。AMBA的标准主要分为六大模块,即学院、师资、项目管理、学生、教学与评价。另有《AMBA国际认证指南手册》可供商学院参考,其中有对AMBA的介绍、相关申请流程以及AMBA的考察标准等。

AACSB的中文全称为国际精英商学院协会,是国际认证体系中时间最长、认证标准最高、参与会员最多的认证体系[5]。AACSB国际认证成立的目的是推动申请认证和已获得认证的学校提高自身管理水平。作为全球最具权威的商科认证,其核心理念是"使命驱动,持续改进",即强调使命的形成过程应是一个不断改进的过程。

EQUIS的中文全称为欧洲质量改进体系,其是由欧洲管理发展基金会发起并运行的。EQUIS侧重于对院校整体进行评估认证,即会考察学院的课程内容是否具有高度的国际化、学生是否具有国家化视野等。商学院要想得到EQUIS的最高评价,就要获得其五年期认证,获得五年期认证的商学院相当于已全面达到了EQUIS的认证标准。

截至目前,全世界只有1%的商学院同时获得了三重认证。AMBA、AACSB、EQUIS都是国际商学院认证权威机构,同时它们又各有侧重。具体差异分析见表1。

国际认证更看重商学院实现其使命的方法和过程。因此,各个商学院所确立的使命应当是立足于自身实际情况,并且区别于其他商学院使命。使命的两个主体是愿景与战略[6-7]。愿景反映的是商学院对自身发展

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通讯作者:秦中峰

表 1 三大国际认证侧重点对比表

	全称	总部	平均认证时间	推行时间	认证特点
AMBA	英国工商管理硕士协会	英国	相对容易	1967 年	注重体现商务和管理实践的发展
AACSB	美国国际商学院联合会	美国	5~7 年	1919 年	认证标准与教育质量密切相关
EQUIS	欧洲质量发展认证体系	比利时	1~2 年	1996 年	对院校整体进行评估认证

的美好期望,它为商学院的发展提供方向;战略则是商学院结合自身情况，并依据愿景而制定的办学方法与策略。大学教育具备结构等级化的特征,因此商学院的使命应具备多样化的呈现。国际认证可以帮助商学院开阔视野,不断改进商学院的管理机制,调整商学院的发展方向,为其注入新的教育理念,实现良性循环。

二、国内外著名商学院使命对比分析与借鉴

目前，全球范围内的商学院数量已经多达 1.3 万所,而全世界只有不到 1%的商学院能获得“三重认证”,总计不到 5%的商学院获得了国际认证[8]。此数据足以说明获得国际认证的难度之大，而国际认证对于商学院来说,是对其商学教育质量的一种权威认可。我们分别列举了已获得国际认证的国内典型商学院使命(见图 1，其中横坐标对应商学院获得的首个国际认证以及获得的时间)与获得国际认证的国外典型商学院使命(见表 2),并对比总结异同点,以期为北航经济管理学院的使命凝练提供参考。

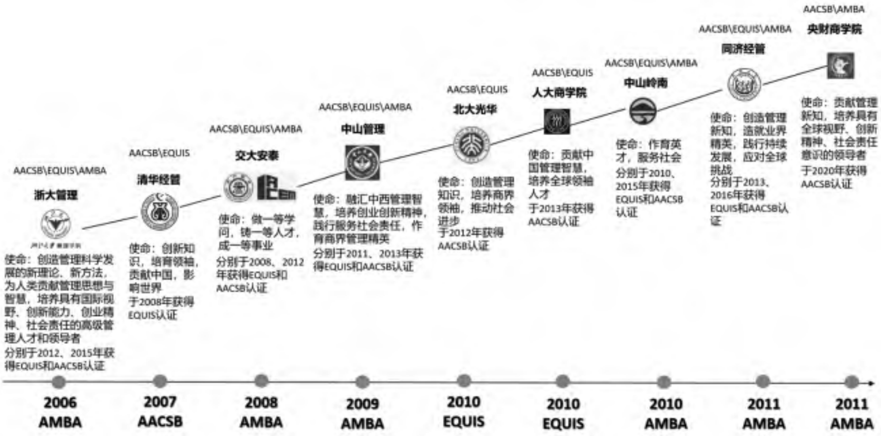

图 1 国内典型商学院获得首个国际认证的时间线及其使命

从上述国内外已获得国际认证的商科教育使命看,它们总体呈现三个特点:第一,国内外各商学院的使命核心都离不开“培养人才”和“提供知识”两个方面。不难理解,商学院作为管理类人才培养基地,其根本目的就是培养经济管理人才，传授经济管理知识。《国家中长期教育改革和发展规划纲要(2010—2020年)》中也曾明确指出要将培养创新型高素质人才设为高校工作的核心发展目标。因此,各高校商学院的核心使命为人才培养。第二,各高校的使命核心虽都是培养人才,但不同层次的大学提出的人才描述也不尽相同,例如清华大学对于使命核心的描述为“创造知识,培养领袖”,而同济大学对于人才的定义为“精英”。“精英”相较于“领袖”一词,略显逊色。名词的细微差异背后是高校对自身定位描述的谨慎态度。国内典型商学院使命中出现频率最高的词汇是“管理”“社会”和“培养”,而国外典型商学院使命中出现频率最高的词汇是“leaders”“ideas”。这说明国内商学院侧重于传授管理知识、培养职业管理人才。国外典型商学院则更侧重创意创造、培养商界领袖。第三,国外已获得认证的商学院使命都立足于全球性视野,例如哈佛商学院的使命是培养能够对世界有影响力的商界精英;麻省理工斯隆管理学院则是立足培养可以改变世界的管理型人才。相较于国外商学院,国内商学院则更侧重于培养能够贡献祖国、推动社会进步的管理型人才。国内部分获得认证的高校中,也有个别提及到国际化、全球性等字眼。因此,要获得国际认证,学院应当扩宽视野,有意识地向培养国际精英与领袖目标发展。高校商学院在使命确立的过程中,应当重视国际化发展,并且要结合自身实际,避免追求“大而全”,而应当追求“实且真”。另外,高校应当开阔视野,聚焦于国际化发展。

三、北航经济管理学院使命的凝练

国际认证是高校国际化发展道路中的必经之路,获得商学院国际认证是商学院国际化和国际竞争力的象征。参与国际认证,实现教育质量持续改进已经成为商学院在国际化进程中的重要环节。获得国际认证的关键要依靠使命的引领，需要进一步凝练与完善自身使命,从而为后续战略的制定提供重要输入。在本节中,我们以北航经济管理学院为例,介绍其使命凝练过程,为其他类似背景的商学院提供参考。

北航经济管理学院起源于 1956 年成立的航空工程经济系，依托学校强大的理工科背景和航空航天特色优势。为了凝练北航经济管理学院的使命,学院成立了使命凝练工作小组,院领导专门负责,各系教师代表积极参与，历经多次学院内外环境调研分析，对使命进行凝练。

首先，学院成立认证办公室,认证办公室根据内外环境、历史特色等因素提出使命的初步构想;其次,由学院党政办出台使命的修改流程和方法,再交由使命调研小组形成调研报告；系部职能部结合调研报告提出相关关键文字表述，再交由全体教职工进行讨论；提出不同的修改方案，然后开展系内的使命凝练比赛，比赛设立专家组开展评审工作，专家组成员主要包括院务会成员以及一些外校专家,评审选出最符合学院特征的使命,再交由认证办公室形成使命草稿，最后进行公示。具体使命凝练流程见图 2。北航经管学院的使命立足于国内环境、学术创新以及育人理念。

在国内环境方面，北航经济管理学院与国内多个企业建立了合作关系,服务国家战略。学院与中国航空规划建设发展有限公司建立了“航空工程管理”联合研究中心,双方在应急物流管理、物联网、工程管理等方面开展了深入协同创新合作;与中航工业集团、中航商飞、海尔集团、中粮集团等大型企业开展了较紧密的合作;与中航集团、中远集团、中关村科技园、北大纵横等大型国企和高科技单位共建产学研合作基地。此外,学院教师积极深入典型企业,开展本土化案例研究,发展并创新本土化管理学理论，成立中国企业案例研究中心,记录并探究中国企业所经历的经验与挑战,并以教学案例和案例研究的形式为学术界与企业提供支撑,形成了“四案一化”的特色,即案例开发、案例教学、案例

表 2 国外已获国际认证的典型商学院使命表

国外商科教育主体	使命
Harvard Business School	To educate leaders who make a difference in the world.
INSEAD	We bring together people, cultures and ideas to develop responsible leaders who transform business and society.
MIT SLOAN	To develop principled, innovative leaders who improve the world and to generate ideas that advance management practice.
Stanford Business School	To create ideas that deepen and advance our understanding of management and with those ideas to develop innovative, principled, and insightful leaders who change the world.
Yale School of Management	To educate leaders for business and society.
Northwestern Kellogg	To educate, equip and inspire brave leaders who build strong organizations and wisely leverage the power of markets to create lasting value.
Berkeley Haas	To help extraordinary people achieve great things.
OLIN Business School	To create knowledge, inspire individuals and transform business.

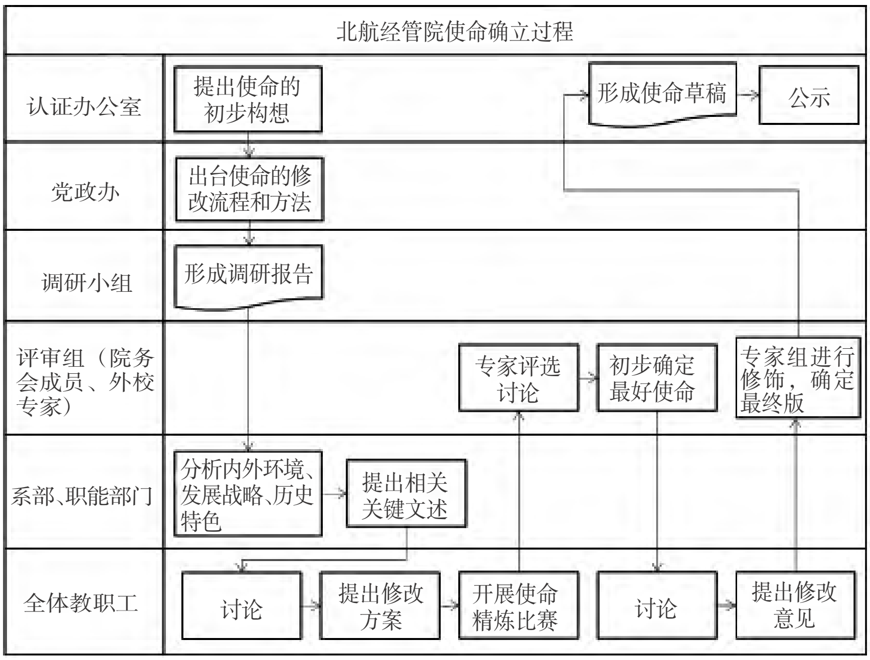

图 2 使命凝练工作流程图

论文、案例比赛与国际化，显著提升了学生的案例分析能力，带来了丰硕成果。

在学术研究和创新方面，学院在一些重要研究方向上比较具有优势，交通运输规划管理领域达到国际一流水平，取得具有国际重要影响的研究成果；复杂系统优化与仿真、复杂数据与大数据分析与应用、项目管理与风险决策等领域处于国内领先水平；信息管理、知识管理、运作管理、金融工程与风险管理等领域取得一批具有国际可比性研究成果。

在人才培养方面，北航经济管理学院始终以人才培养作为学院建设的中心，坚持科学精神与人文情怀并举，扎实基础与创新精神并重的育人理念，培育经管英才。全方位推进案例教学、实验教学、实践教学，打造“一案两实”新的教学模式。北航经管学院一直致力于培养既懂经济管理，又具专业技能、知识广博、勇于开拓、善于合作的复合型管理人才，培养具有全球化战略视野、开拓创新能力、领导能力和分析研究能力的高端经营管理人才。

依托北航历史和特色，学院突出自身优势和核心能力，关注国家重大战略需求和经济社会重大变革。在经过广泛讨论并听取二级教授、青年教师、在校学生代表、校友代表等利益相关者意见基础上，学院将使命确立为“服务国家战略，创新管理知识，培育经管英才”。

四、结论

本研究首先介绍了国际商科教育认证的“使命”要求，其次分析了已获得国际认证的典型中外高校商学院的使命，并对比总结其异同点，从而为北航经济管理学院使命的确立提供依据。最后，以北航经济管理学院为例，提出了认证导向的商学院使命凝练过程，在综合考虑国内环境、办学战略以及学术人才培养等层面后，最终确立为“服务国家战略，创新管理知识，培育经管英才”。从而，为其他同类型院校商学院的使命凝练提供参考与借鉴。

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乘风破浪，北航 MBA 创新发展之路

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摘要：北京航空航天大学（简称北航）MBA 项目依托学校空天信行业资源和学科优势，在全国 MBA 教育指导委员会指导下，锐意进取，开拓创新，经历了坚实的初创阶段（1998 年~2008 年），飞跃的创新阶段（2009 年~2016 年）和稳步的发展阶段（2017 年至今）。初创阶段解决了“从无到有”，对标国际一流标准，建立项目管理规范;，并依托学校行业优势，开创民航管理特色方向。创新阶段“从有到优”，开创性地构建“案例教学、实践教学和实验教学”（一案二实）的特色培养模式，并在北京地区首推提前面试，形成“三筛一选”的人才选拔体系。发展阶段“从优到强”，凝练项目使命定位，开发特色培养方向，依托产学研一体化大力开发双创培养模式。北航 MBA 教育项目（简称北航 MBA）始终探索创新实践，砥砺前行，乘风破浪，创新发展。

关键词：北航 MBA；创新发展；一案二实

北航 MBA 项目已培养毕业生 22 届，累计培养 MBA 毕业生超过 3700 人，目前在校生 700 余人。北航 MBA 的发展经历了三个阶段：1998 年~2008 年的初创阶段；2009 年~2016 年的飞跃创新阶段；2017 年至今的稳定发展阶段。北航 MBA 自创办以来，砥砺前行不畏艰难，锐意进取开拓创新，学生培养效果不断提升，项目品牌效应逐渐形成。

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一、坚实的初创阶段（1998 年-2008 年）

初创阶段解决了“从无到有”，对标国际一流标准，建立项目管理规范，并依托学校行业优势，开创民航管理特色方向。

（一）对标国际一流标准，建立项目管理规范体系

北航 MBA 项目按照国际认证标准，结合全国 MBA 教育指导委员会对 MBA 项目的要求，建立了北航 MBA 培养质量保证体系，加强了各个培养环节的质量控制和规范化管理。招生环节，面对创立初期的招生困难，增强宣传力度的同时不断规范招生流程和面试标准，生源质量和结构得到不断优化。课程教学环节，针对课程内容随意性大和教学内容与实践脱节等问题，借鉴学院与澳大利亚新南威尔士大学进行联合培养的项目经验，建立健全 MBA 课程教学规范化管理体系，设计了统一的教学大纲、讲义、试卷模板。教学质量保障方面，施行新开课试讲制度，构建教学质量评估体系和奖惩机制，从制度上为课程质量提供保障。学位论文环节，在实践中查漏补缺，不断完善开题、中检、答辩的流程和标准，全环节严控确保论文质量。

北航 MBA 通过对标国际一流商学院实现了课程体系的规范化，课程的教学目标完全一致、教学内容 70%以上相同、教材和参考书基本统一，教学方法和授课风格各具特色。从教学评估的结果来看，北航 MBA 的教学质量逐步提升，学生满意度明显增强。

基于这一阶段北航 MBA 的办学成果，时任中心主任的周宁教授在 2003 年全国第五批新增 MBA 院校管理学院院长和 MBA 中心主任培训会上做了经验介绍，得到一致好评。北航 MBA 也成为全国 MBA 教育指导委员会推荐的规范化管理典型，接待了包括清华大学、南京大学、中科院研究生部、中央财经大学、中国科技大学在内的 14 所院校的 40 余人来中心交流经验。2008 年，《北航 MBA 教育质量保证与持续改进体系》一文获得由全国 MBA 教指委举办的“纪念改革开放 30 周年中国 MBA 教育创新研讨会”优秀论文奖。

（二）依托学校行业优势，开创民航特色方向

北京航空航天大学是新中国第一所航空航天高等学府。学校特色鲜明，行业优势明显，在航空航天领域非常有影响力。依托学校行业优势，2004 年，北航 MBA 与加拿大 Concordia 大学 John Molson 商学院合力打造“国际水准、国内一流”的民航管理方向的 MBA 项目，开创国内 MBA 教育特色方向之先河。

依托北航的航空航天优势，北航 MBA 紧扣民航的管理需求适时开展民航管理特色方向。师资方面，采用国外师资和国内师资相融合的方式，部分专业课程

包括民航运输管理、航线规划与管理、机场运营与管理等由国外师资教授，且每门课程配有专门的课程辅导教师。课程组织方面，考虑到民航管理的特殊性，采用集中式授课方式，参考 EMBA 的授课方式，每个月组织四天课程。学生方面，主要学员来源于国航、南航、东航等航空公司。民航管理方向 2004 年首次招生，招收到 47 名学生，充分显示了民航特色方向的吸引力。班级组建方面，北航 MBA 针对民航管理的同学单独组班。国际交流方面，同学有机会获得国际互换学生全额学费（9000 美元/每人）资助。培养效果方面，这些学生将学到的相关知识运用到工作实践中，获得了很好的成效，由此大部分学生很快晋升到管理岗位。

目前，特色方向已成为各高校 MBA 的发展趋势，更能体现出品牌价值，这是各高校 MBA 项目差异化发展的必然之路。北航 MBA 开创的民航管理特色方向，瞄准民航管理的特殊需求，为具备行业优势的兄弟院校发展 MBA 特色方向提供了经验借鉴。

二、飞跃的创新阶段（2009 年-2016 年）

飞跃的创新阶段“从有到优”，开创性地构建“案例教学、实践教学和实验教学”（一案二实）的特色培养模式，并在北京地区首推提前面试，形成“三筛一选”的人才选拔体系。

（一）“一案二实”的特色培养模式

北航 MBA 倚靠空天信行业资源和学科优势，以案例教学、实验教学、实践教学作为突破口，经过多年的教学改革实践，创建了“一案二实”的创新教学模式，构建了“案例开发、案例教学、案例论文、案例大赛及本土化”四案一化的案例教学培养体系，搭建了“平台-内容-师资-方法”四位一体的实验教学培养体系，形成了“课程教学、培养过程、校企合作和创新实践”四个层次相融合的实践教学培养体系。改革项目取得了卓有成效的成果，“一案二实”培养模式已成为北航 MBA 鲜明的特色。

1、“四案一化”的案例教学体系

2010 年 9 月成立“中国企业案例研究中心”，旨在扎根于中国商业社会管理实践，建设具有“国内一流、国际接轨、研究与教学并重”特色的案例团队。以课堂案例教学为基础，提升学生分析问题能力和综合管理决策能力；以案例竞赛为教学延伸，提供学生综合训练平台；以案例论文改革为突破点，引领案例教学的改革，促成案例开发能力的提升，形成“四案”的教学模式。对标国际一流，坚持本土化原创案例的开发和教学应用，不断提升教师素质、学生能力、平台的管理

水平，最终形成如图 1 所示的 “四案一化”的案例教学体系。

案例课堂教学层次，创新多元化案例教学方法。依照国际标准规范案例课堂教学，制定案例课堂教学规范，采用纳入考核指标、规范案例来源、推行案例公开课、单案例评估监控等措施建立闭环的质量保障体系。以问题为导向，采用应用自主开发案例、案例主人公进课堂转变教学方式，引入视频案例等手段，创新案例实验、案例沙盒、即兴案例等案例教学方法，激发学生高度参与，增强案例课堂教学效果，促进学生实践能力的提高。北航 MBA 现已获得 12 项创新教学团队、精品课程等案例教学研究成果，以案例教学为特色的一系列课程获得包括留学品牌课程、精品课程建设项目和教学成果奖等。

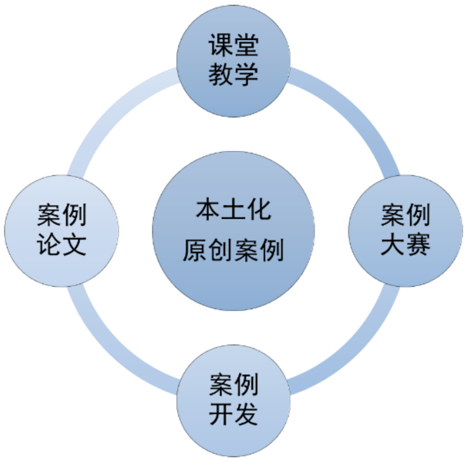

图 1 北航 MBA“四案一化”案例教学培养体系

学生案例比赛层次，学生案例大赛获得省级以上奖励 8 项。通过倡导学生自发成立案例俱乐部、举办新生案例比赛、校园案例突围赛，组队参加全国管理案例精英赛（全国 MBA 院校），与台湾科技大学（以下称台科大）管理学院联合举办“管院杯”案例比赛，并在此基础上联合组队参加台湾地区 EMBA“商管联盟杯”案例竞赛，多层次的案例比赛活动使学生得到学习和锻炼。北航 MBA 已获得包括全国管理案例精英赛总决赛冠军、季军和中国华北赛区冠军、TiC100 智慧城市与物联网创新创业案例大赛金奖、台湾地区商管联盟杯金奖等国内外省级以上案例大赛冠军 8 次，学生综合管理实战能力显著上升。

教学案例开发层次，团队聚力开发原创本土案例。学院出台了《经济管理学院案例教学奖励办法》，鼓励教师开展案例教学和案例开发。组织师生联合开发案例，建设特色案例库，促进以教师为先导的、师生在企业实践中教学相长的实践能力提高。教师与 MBA 合作撰写全国获奖本土案例 55 篇，其中 50 篇案例获得 MBA 百篇优秀管理案例，数量全国排名第 2，另有 7 篇分别由世界最知名哈佛和毅伟案例库收录，成为全国商学院的示范典型。北航 MBA 已经形成了一批高水平的案例开发教师和团队，多次在各种全国性案例教学会议上和各个兄弟院

校介绍经验。

案例型学位论文层次，制定案例型论文写作规范。依据全国 MBA 教指委关于 MBA 论文的要求，参照学校专业硕士论文规范，制定并出台了《关于专业硕士学位论文撰写案例型学位论文的管理规定》，重点明确了案例型学位论文的内容结构与撰写格式，这是迄今为止国内 MBA 院校首家出台的专业硕士案例型学位论文管理规定，是一项创新举措。在学院的鼓励下，共有 55 篇学位论文转化为全国获奖优秀案例。

开发并应用本土化原创案例，增强案例教研实力。北航 MBA 案例开发团队坚持扎根中国本土管理实践，建立中国本土原创案例库，引导教师透过本土管理实践构建中国情景下的管理理论，促进学生运用中国特色管理理论和方法服务于企业实践，并推动师生对本土企业实践的深度思考和研究。这些极具中国特色的本土化案例在案例课堂上使用，有效解决了国际案例与中国管理实践脱节的问题，增强了案例教学的针对性和实用性，极大地提高了学生的参与热情，从而有效地强化了案例教学的效果。

2、“四位一体”的实验教学体系

实验教学方面，基于北航 MBA 的学科特色和实验条件，在“实验设计体系化、实验资源共享化、实验环境场景化、实验方法多元化”的思路引导下，构建了国内领先的实验教学平台，完善各类多层的实验教学内容，培育交叉融合的实验教学队伍，探索多元创新的实验教学方法，搭建了北航特色的“平台-内容-师资-方法”四位一体实验教学体系，持续深化 MBA 实验教学改革，如图 2 所示。

北航经济管理学院发挥管理科学与工程一级重点学科优势，依托学院五个省部级重点实验室/基地，构建了 9 个专业实验室。学院将优质实验资源嵌入 MBA 人才培养中，搭建了 12 个**国际一流、国内领先的 MBA 实验教学平台**。

基于校研究生教改重点课题“管理学专业硕士实验教学体系的研究与实践”，配合学院 MBA 培养方案和课程体系，整合、优化实验教学课程内容，逐步形成了“模块化、多类型、多层次”的实验教学课程体系，培育团队式实验教学队伍，探索了沙盘演练法、角色扮演法、体验式教学法、参与式教学法、项目驱动法等**多元化教学方法**在 MBA 实验教学中的应用。

针对 MBA 特色，在教师承担的重大重点科研项目中提取关键科学问题形成实验研究项目，**将优质科研成果转化为实验教学项目**，并配合专任教师和专业实验技术人员进行实验指导。北航 MBA 展开的一系列师生创新一体化研究型实验，例如，基于国家 973 计划项目“路网交通拥堵的形成机理与传播特性”，开发了

“视觉听觉干扰与驾驶绩效”、“社会化出行路线规划”等实验项目；基于国家 863 计划项目“面向社交网络的信息传播规律及用户行为演化研究”，开发了“基于微博的网民情绪分析”实验项目；基于国家自然科学基金重点项目“大型复杂产品研制过程运作管理”，开发了“生产现场管理综合评价实验”实验项目；基于国家自然科学基金面上项目“社会化商务中的消费者行为和定价策略研究”，开发了“基于眼动轨迹的消费者行为研究”实验项目。这些研究型实验教学项目面向 MBA 开设，使学生的**创新能力得到了有效提升**，在国内商学院产生了较大影响。

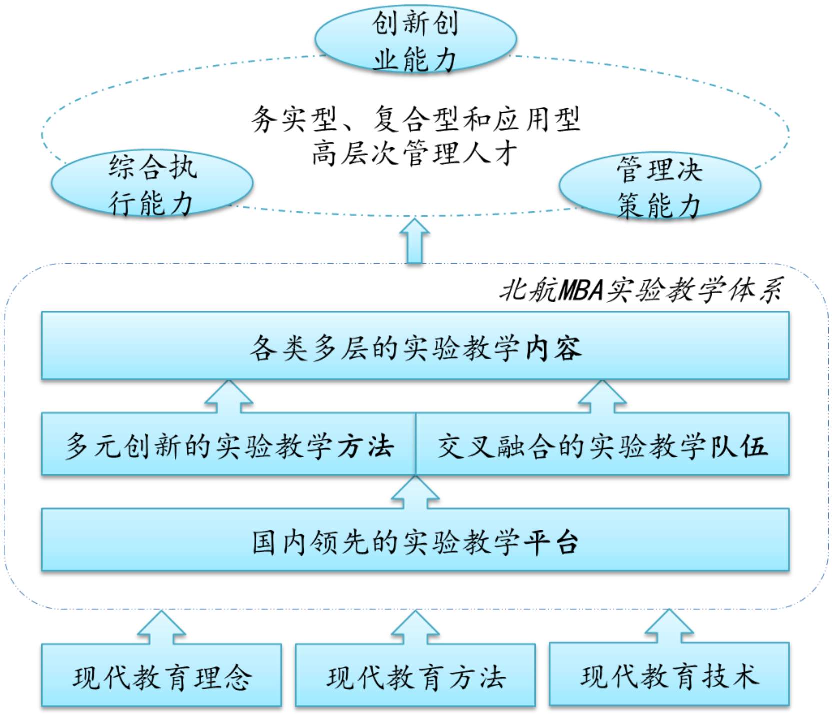

图 2 北航 MBA 实验教学体系

学院 MBA 实验教学学时数逐年增加至 288 学时，实验层次有所提高，实验类型由原来的演示验证型实验为主，逐步增加了体验型、设计研究型和综合型实验。实际开设的 MBA 实验课程有 18 门，MBA 教学中含有实验单元的课程占比达到 42%，开设 MBA 实验课程的专业教师人数达到 15 人。

3、“四个层次”的实践教学体系

在实践教学方面，北航 MBA 构建了“四个层次”的实践教学培养体系。北航经管学院在实践教学中不断探索和尝试，强调“MBA 教育从实践中来，再回到实践中去”，在 MBA 培养的全生命周期——从入学到就业——全过程设置相应的实践环节，倾力打造全程化、开放性实践教学体系。按照请进来、走出去、再请

进来、再走出去的质量提升循环，遵循课程教学有实践内容、师资队伍有实战专家、过程培养有实践环节、论文考核有实践应用的原则，形成“课堂教学、培养过程、校企合作和创新实践”四个层次相互融合的实践教学培养体系，如图 3 所示。

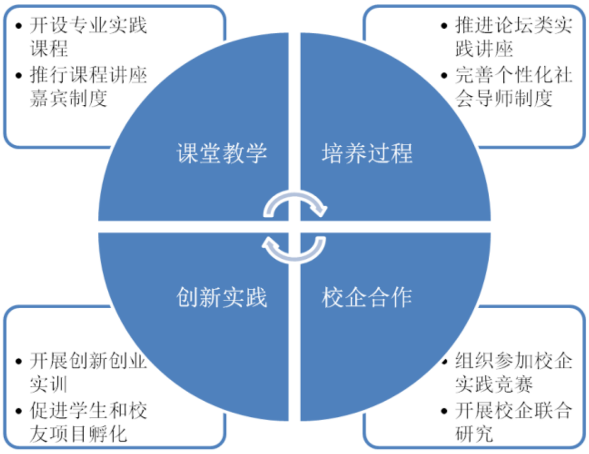

图 3 北航 MBA“四个层次”实践教学培养体系

课程中增设实践内容，丰富课堂教学体系。北航 MBA 项目开设了实践性较强的课程，并且鼓励任课教师加强与业界的联系，邀请大中型企业的经理、高管或者创新型企业的创始人到课程中讲述公司运营中的经验或者存在的问题。北航 MBA 教育中心制定了《关于 MBA 课程教学中邀请讲座嘉宾的规定》，严格控制讲座嘉宾质量，讲座嘉宾制度通过嘉宾实践经验分享，丰富学生对中国情境下的管理实践活动认知，提高学生的实操能力。

开设论坛类实践讲座，实施个性化社会导师制。论坛讲座分为知行论坛和高端论坛。知行论坛邀请企业高管，分享企业管理经验，开拓 MBA 学生的职业之路。高端论坛邀请国家层面有影响力的专家，或从国家战略层面解读政策，或从人生角度提升素养，让 MBA 学生开阔视野，树立人生之路指南针。北航 MBA 教育中心在传统的社会导师制基础上，实行精细化管理，推行个性化的社会导师制。北航 MBA 教育中心制定了《工商管理专业研究生社会导师执行方案》、《MBA 社会导师工作职责》、《MBA 学生社会导师制执行守则》等管理制度。目前，社会导师规模已达到 200 余人，覆盖行业广，管理层次高，有助于学生未来发展。

依托优势行业资源，推进校企合作实践。学院组织北航 MBA 积极参与各类校企合作的创新实践比赛，包括研华科技公司的 TiC100 大赛、与中航国际联合举办的“中航国际杯”互联网+创业大赛、与晶赞科技联合举办的“中银易商杯”大数据时代下的商务模式创新大赛等，切实培养学生的创新能力和实际动手能力。学院致力于开展以学生专业知识与企业实战需求相结合的课题合作，增加产学研合作项目，面向企业现实问题，以学生之所学参与到企业之所用中，锻炼学生理

论联系实际及团队合作能力，使得 MBA 的培养更加面向中国企业实践。

（二）北京地区首推提前面试，形成“三筛一选”选拔体系

2009 年，北航 MBA 在北京地区首先推出“提前面试”，通过创新复试选拔制度吸引优秀生源。北航 MBA 坚持以培养目标为评价和筛选生源的标准，不断地改进遴选程序和方法。通过提前面试、联考、正常批面试、复试环节层层筛选，实施了，逐渐形成“三筛一选”的考生选拔体系，逐年稳步提升生源质量。

北航 MBA 的“三筛一选”选拔体系对报考学生进行提前面试、联考、正常批面试、复试环节层层筛选和选拔，稳步提升生源质量。

一筛：筛选提前面试申请资料；核验申请资料真实性，增加教育背景、管理经验、创新创业的考察比重，通过综合评定甄选出具有培养潜力的考生，给予其面试资格。

二筛：通过提前面试考察考生综合素质；通过由学校考官、企业考官组成的面试考官组，对学生的综合素质进行考评，最终确定面试通过名单。

三筛：通过全国联考检验考生学习能力。

一选：通过复试加强考生的思想政治和道德品质考核，为此分别设置笔试（英语听力、时事政治）和面试（综合素质、英语口语、思想品德）考核。

北航 MBA 通过实施“三筛一选”选拔体系，生源质量不断提高，目前招生新生中硕士和博士占比达到 2.6%，本科占比 95.7%，大专占比仅为 1.7%。

三、稳步的发展阶段（2017 年-至今）

稳步发展阶段“从优到强”，凝练项目使命定位，开发特色培养方向，依托产学研一体化大力开发双创培养模式。北航 MBA 经历了飞跃发展之后，自 2017 年开始将发展目标瞄准 CAMEA 认证，以此为契机，重新思考项目使命定位，并探索新的创新之路。

（一）凝练项目使命定位，开发特色培养方向

北航经管学院的使命形成具有长期的历史积淀。在经管学院发展的早期阶段，尽管没有明确提出使命陈述，在实际行动中已经表现出使命导向。1992 年 7 月，顾昌耀院长在学院董事会成立大会上做了题为“遵循产学合作原则，办好北航管理学院”的报告，提出要**“主动面向企业”、“产学合作共同开展管理学术研究”**等重要战略发展方向。2010 年 9 月，学院分党委正式启动“经管学院文化建设工程”。 2011 年 6 月，学院开展了经管学院第二期文化建设，在由党支部牵头组成 7 个课题组研究、汇报、讨论和凝练后，确定学院使命为**“致力于经济管理**

知识和智慧的创造与传播，培养具有国际视野和社会责任感的创新人才，立足中国实践，引领和推动经济社会发展与变革。”2017 年 6 月，将发展目标瞄准 CAMEA 认证，学院先后动员各系教师、组织学院二级岗教授、青年教师代表，回顾了学院的发展历史与现状，分析了经管学院所面临的外部环境，对学院的使命和战略进行了研讨，初步凝练出学院的使命：**扎根中国本土，服务社会需求，创新管理知识，培养业界精英**。2017 年 10 月，北航经管院举办了“迎校庆 65 周年，学院使命专题研究”交流评审会。天津大学张维教授、清华大学钱小军教授、北航人文与社会科学研究院院长蔡劲松教授和校党委宣传部谭华霖部长等校内外专家和部分学院领导、资深教授组成评委会对学院使命专题研究成果进行评议。根据专家的建议，从北航经管管理教育肩负的历史使命、国家经济社会发展的现实需求、学校与学院的学科基础、学生与雇主的需求导向等几方面将学院使命聚焦为“**服务国家战略，创新管理知识，培育经管英才**”。

在学院使命“服务国家战略，创新管理知识，培育经管英才”的指导下，北航 MBA 始终把“服务国家战略”作为项目使命的立足点，强调在实践中“创新管理知识”，将学生培养成能够更好地服务国家战略的“英才”。为此，北航 MBA 的项目使命：秉承北航“德才兼备，知行合一”的校训，培养具有全球视野、社会责任、科学精神与人文素养的业界精英。

基于北航经管学院服务国家战略的使命，并考虑到项目所处的北京地区发展定位特点，以及结合北航的品牌和资源优势，北航 MBA 定位于吸引来自前沿科技创新行业、先进制造业和高端服务业的生源。北航 MBA 学生在这三类行业的生源占比 70%以上，以以金融和管理咨询为代表的高端服务业占比 36%，互联网为代表的 IT 行业占比达到 29%，以航空航天为代表的先进制造业占 12%，如图 4 所示。结合项目的外部环境和自身优势，北航 MBA 的市场定位为：以互联网为代表的 IT 行业、以航空航天为代表的先进制造行业、以金融和管理咨询为代表的高端服务业中具有管理潜质的青年人才。

北航 MBA 的人才培养定位是：把具有管理潜质或有才能的人，培养成“勇于创新、富于责任、精于实务、善于合作”的复合型高级经济管理人才。在这一人才培养目标的指引下，北航 MBA 向 IT 行业、金融、民航等当前经济发展引领性行业输送了大量中高级管理人才。北航 MBA 毕业生就业主要集中在金融、互联网、信息技术、管理咨询等热门行业，且一批毕业生已经成长为上述领域的领军领导人才。例如，央企中国煤炭科工集团党委常委、总会计师蒋占华，首都医科大学纪委书记侯瑾，北京自动化技术研究院党委书记兼院长赵力行等。

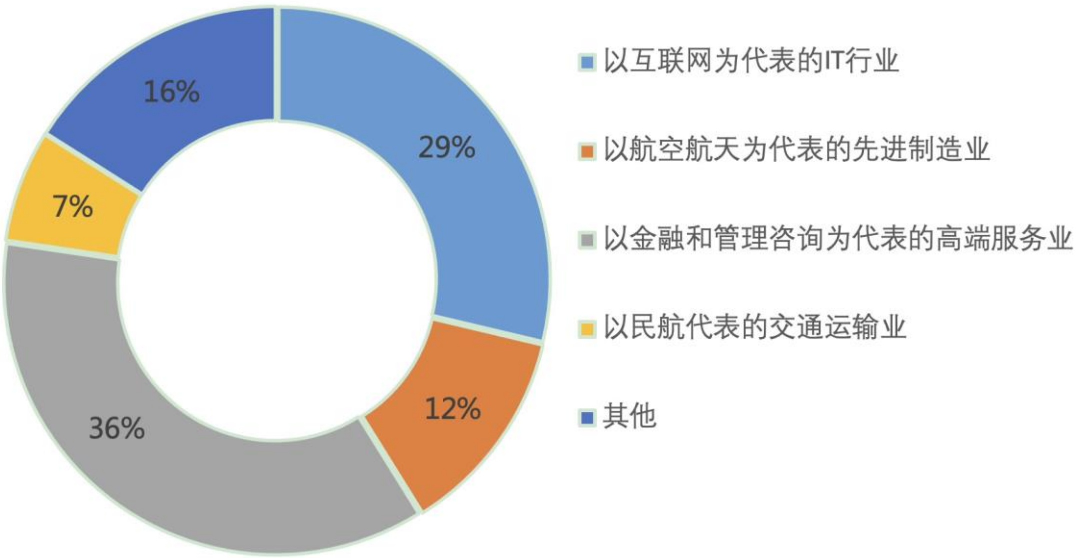

图 4 北航 2019-2021 级 MBA 学生的工作单位与行业信息分布

学院积极学习国内外 MBA 教育的现状和发展趋势，积极了解市场信息，不断围绕使命，审视项目的市场定位、培养目标和整体设计等，创设六大特色方向。敏锐把握市场环境的变化，项目整体设计不断根据市场需求和自身资源进行调整和改进。利用学校学科优势和行业资源，在管理科学与工程、应用经济学和工商管理交叉融合的学科平台下，重点培养具有技术背景的 MBA，开发创新与创业管理、大数据与商业分析、金融科技、民航管理、项目管理、技术转移等 6 个特色选修方向（如图 5）。其中，创新与创业管理应对目前国家提倡的创新发展战略；大数据与商业分析，则是将大数据技术应用于同学们所在行业和企业，提高其数据分析水平和决策支持水平；金融科技则是技术驱动的金融创新，体现北航优势；民航管理和项目管理均是管理科学与工程学科的传统强势专业；技术转移则是响应北京市目前需求新增的专业培养方向。

图 5 北航 MBA 特色方向

（二）依托产学研一体化，开发双创培养模式

北航 MBA 以培养方案课程体系、创业训练营和创新创业大赛等为抓手，打造“培养方向中有创新创业、培养环节中有创新元素、搭建校内校外竞赛平台、引导创业项目落地实施”的闭环培养模式。

培养方案方面，培养方向中有创新创业，培养环节有双创元素。培养环节中的知行论坛邀请创新创业相关嘉宾，社会实践增设创新创业大赛，时刻激发 MBA 同学们的创新创业激情。北航 MBA 的创新创业管理每年都吸引很多同学报名。

课程建设方面，推进创新创业课程开发，夯实创新创业理论基础。围绕创新创业方向，开设一系列专业课程，包括创新思维、商业模式、创业基础与实务、技术与产品创新管理、领导力开发等。2018 年，北航 MBA 教育中心联合北航投资有限公司，开设了创业学分课程《创业基础与实务》，邀请优秀的创业校友回到母校，跟有创业想法的学生面对面交流，分享经验与心得。

以赛代练方面，创造校内双创比赛平台，积极参加校外创业大赛。自 2017 年起，北航 MBA 组织暑期创业训练营，并搭建校内的创新创业大赛平台——创乐萌创新创业大赛，激发学生的创业热情，助力学子的自主创业之路，挖掘并培养我航的创新创业人才。2015 年，北航 MBA 学生在 TiC100 智慧城市与物联网创新创业案例大赛中获得金奖；2018 年，在北航-北理工全球创新创业大赛中获得优胜奖；2019 年，在可口可乐杯第二届京津冀 MBA 尖峰时刻创业企划大赛中获得二等奖；2020 年，在第十八届“光明优倍”杯中国 MBA 创业大赛中获得北方赛区二等奖；2021 年，第十九届“光明优倍”杯中国 MBA 创业大赛获得最佳创意奖。

案例开发方面，挖掘创新创业典型案例，探索中国创新创业实践。北航 MBA“一案二实”的教学模式渗入到教学过程，挖掘学生的创业案例发展成教学案例，并将其用于教学中供其他同学借鉴。目前已有典型创新创业案例，例如伊太智联科技有限责任公司是北航 MBA 同学和北航计算机学院教授联合创建，正在推广孵化。

四、结语

经历了二十多年的持续发展，在学校学院的大力支持和全国 MBA 教指委的指导下，北航 MBA 项目在初创期打下了扎实的规范化管理基础，并探索了特色方向之路，在飞跃创新期形成了“一案二实”的特色培养模式，在稳定发展期凝练使命定位，开发特色培养方向。北航 MBA 项目始终探索创新实践，砥砺前行，乘风破浪，创新发展，以期能够力争用最好的成绩回报社会，为中国 MBA 发展贡献绵薄之力。

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学术型与专业型经管类硕士生培养质量多元评价体系构建

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摘要:克服“五唯”顽瘴痼疾、优化评价体系是当前我国研究生教育工作的重要任务。学术型硕士和专业型硕士是两类不同的研究生培养类型,然而很多高校并未对两类研究生采取差异化的培养和评价,使得人才培养的“同质化”问题凸显。文章明确区分了这两类硕士学位的利益相关方、培养目标、培养环节和方式、质量评价标准和方法,基于过程导向的柯氏评估模型的思路,运用调查问卷和专家访谈的方法,从课程教学、学术锻炼、实践培训和论文答辩等多个环节,构建了两类硕士生培养质量的多元评价体系。提出要依据“需求导向”分类确定培养目标、建立“1 + X”导师制度和指导模式、强化“研究型”和“实践型”两类不同导向的人才培养机制等建议。

关键词:研究生培养质量;评价指标;学术型硕士;专业型硕士;柯氏评估模型
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一、引言

硕士研究生教育既是我国学位与研究生教育的重要组成部分,也是培养高层次人才和落实国家创新发展战略的主要途径之一。伴随着规模扩大而来的培养质量问题不断凸显,对研究生教育质量的负面评价成为社会关注的热点和高校亟待解决的难题[1][2]。党的十九大强调要“实现高等教育内涵式发展”,说明提高和保证研究生教育质量已经成为当前学位与研究生教育发展的关键任务。此外,克服“五唯”顽瘴痼疾,优化教育评价体系正成为我国教育工作的重中之重。而现在我国硕士生培养的问题就集中体现为培养理念和培养方法的单一以及评价指标的片面和“一刀切”,尤其是针对“学术型硕士”和“专业型硕士”(为行文方便,文中也用“学硕”和“专硕”来简称)这两种不同的硕士学位而言。虽然国家已明确学术型和专业型两类学位在培养目标、培养模式、文凭效力和发展方向等方面应有明显不同,但目前很多高校的硕士生培养过程、质量评价和就业指导等并未充分考虑二者的明显差异[3],例如在培养方案设计和实施中重合度很高,课程差异不大,专业型硕士的职业实践和技能训练不够系统和深入等,导致两种培养思路的硕士生培养未取得预定目标和效果。

本文以经济管理类学科硕士生培养为案例,通过深入分析学术型和专业型两类硕士生的培养目标、培养过程和利益相关方需求,基于过程导向理念和流程管理方法(即柯氏评估建模法[4]),将硕士生培养全过程划分为不同的环节和教育任务,据此构建一套硕士生培养质量的全过程、多元评价体系,为促进我国学位与研究生教育的多样化发展、产出更多优秀的学术型和应用型高层次人才提供理论依据和实践方法。

二、区分学术型和应用型的硕士生质量全过程评价新模式

(一)学术型硕士与专业型硕士的区别

国务院学位委员会 2010 年下发的《关于印发〈硕士、博士专业学位研究生教育发展总体方案〉的通知》(学位〔2010〕49 号)指出“到 2020 年,实现我国研究生教育从以培养学术型人才为主转变为学术型人才和应用型人才培养并重,培养质量明显提高,研究生教育能够更好地适应经济社会发展需要和满足人民群众接受研究生教育的需求。”原则上,学术型硕士教育以培养教学和科研人才为主要目标,而专业型硕士教育则是培养经济社会进步和行业市场发展急需的应用型人才,二者在利益相关方、培养目标、培养环节

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和方式、质量评价标准和方法等方面都存在较大差异。

1. 利益相关方的差异

学术型硕士教育主要培养的是擅长开展高等教育和创新型研究的人才，其利益相关方主要是高校、科研单位以及一些具有优良学术环境的大型企业、高新技术企业、留学人员创业园和科研生产型事业单位（通常设置博士后科研工作站）；而专业型硕士教育的突出特点是理论性与职业性的紧密结合，获得专业学位的人，主要不是从事学术研究，而是从事具有明显职业背景的工作，如工程师、医师、律师、会计师、公务员、中小学或社会性教育机构的教师等，其利益相关方主要是政府、企业单位、事业单位等非科研型机构[5]。

2. 培养目标的差异

学硕与专硕之间的利益相关方不同，导致两类人才的培养目标之间也存在显著差异。学术型学位按专业学科设立，以学术研究为导向，偏重理论研究和创新，核心目标是使研究生能够胜任高校的教学和科研任务，培养经济社会发展所必需的高层次、创新型科研人才；而专业型学位以专业实践为导向，重视管理实践和技术应用，旨在培养在某一专业（或职业）领域掌握坚实的基础理论和宽广的专业知识、具有较强的解决实际问题的能力、能够承担专业技术或管理工作、具备良好职业素养的高层次、应用型专门人才[6]。

3. 培养环节和方式的差异

培养过程依据培养目标而确定，因此对于两类硕士生的培养环节和方式设计，也应体现出差异性和特色性。学硕的培养方案和课程设置侧重于强化基础理论的学习和学术素养的塑造，重点培养学生从事创新性科学研究的理念与能力；而专硕的课程设置则不同，不再拘泥于理论知识的灌输，而是以实际应用能力培养为重点，以学生未来职业发展为中心，由各个课程模块组成未来职业所需的知识与能力系统。为此，我国许多高校的专硕教育都在施行“双师制”指导方式。“双”可以是一位、两位或多位，只要导师或导师组既有娴熟的教学能力、一定的学术科研水平，又有丰富的企业实践经验和精湛的专业应用能力，就可称为“双师型”导师[7]。

4. 质量评价标准和方法的差异

学硕与专硕在利益相关方、培养目标、培养环节和方式方面的差异使得他们自身需具备的知识与能力有所不同，因此培养质量评价标准和方法也应体现特色性。例如，学硕需要有坚实的基础理论知识、扎实的科研基本功、优秀的科技论文研读和撰写能力，掌握一定的科研实战经验，学会凝练关键科学问题并独立开展创新性研究工作。而专硕除了应具有坚实的基础理论和宽广的专业知识，还应当重点考查其应用能力和职业素养的改善，在培养过程中应注重团队学习、案例分析、现场调研、模拟训练、实验操作等方法或环节的落实[8]。在评价方法和观测指标上，学硕可依据其课程成绩、科研成果质量、学术奖励级别等；而专硕则更应体现评价的多元性，例如，综合参考其校内导师评价、校外导师评价、职业资格证书获取等多种依据或来源，增加对其人际交往能力、行业认知水平等综合素质的考查，在必要时采用现场观摩其在实习单位表现等评价手段等[9]。

（二）过程导向的培养质量多元评价方法——柯氏评估模型

柯氏评估模型，又简称柯氏四级培训评估模式，这四个层级依次为学习层、反应层、行为层和结果层，如今该模型已成为教育培训领域运用最广泛的评估工具，为全过程评价培训或学习效果提供了科学的衡量途径[10]。将柯氏评估模型运用于硕士生培养质量评价中，能够对学生在全过程培养中进行教学反应、学习感受、行为改善、培养成果等多元评估，丰富了研究生培养质量评价的维度、视角和指标，据此构建的评价体系能够有效弥补其他模型在多元、全过程评价方面的缺陷（见表1）[11]。

表1 本文柯氏评估模型四大维度含义及代表性指标或指标类别

维度名称	维度含义	代表性指标或指标类别
学习层	考查学生所掌握的基本知识、技能、素养和思维方式等	基础知识水平 思考能力 学术创新思维
反应层	考查学生对研究生教育各环节的反应和态度，以及对于研究生阶段学习的积极性和学习过程的参与度	科研的积极能动性 实习实践的积极能动性 课堂参与和互动
行为层	考查学生对于所学知识、技能和思维方式的运用，包括科研课题参与或实习期间对于在校所学知识的使用等	综合学习能力 伦理道德与社会责任 实习单位项目实训
结果层	评估研究生在校期间所获的主要成果，包括获奖情况、学位论文成果、专利以及其他科研或实践成果	学位论文成果 科技类获奖情况 实习实践成果

（三）硕士生培养质量全过程评价模式

本文以我国高校经济管理类学科的硕士生为研究对象，深入分析并明确区分学术型和专业型两类学位不同的利益相关方、培养目标、培养环节和方式、质量评价标准和方法等的差异，据此分别设计出科学、针对性强的培养质量评价指标，实现两类硕士生的全过程、科学化评价。利益相关方需求的不同使得学硕与专硕的培养目标存在显著差异，而培养方案依据培养目标而制定，因此两类硕士生所经历的培养环

节和考核评价机制也会有所差别，这正是本文研究的核心，如图1所示。这一全过程评价模式的落脚点在于培养质量评价体系。

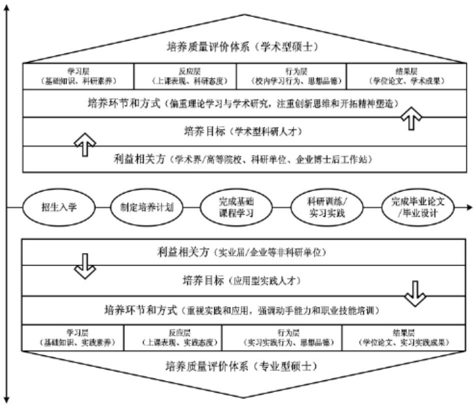

图1　两类硕士生培养质量全过程评价模式和评价体系构建思路

三、两类硕士生培养质量评价体系构建

本文将基于柯氏评估模型，通过学习层、反应层、行为层、结果层等四个维度来评价硕士生的培养质量，通过对全国高校经管类学院师生的较大规模实证研究，确定评价指标及其权重。

(一) 实证调研的对象与方法

1. 文献调研和专家访谈

本文实证调研共分为三个阶段，分别是文献调研筛选初步评价指标、专家访谈确定评价指标体系、问卷调研确定指标权重。

首先，文献调研阶段查阅的文献包括我国硕士学位授予标准(1981年版)[12]、13所国内外一流大学经管类专业的“硕士研究生培养方案”和硕士研究生学位授予标准、研究型大学学生就学经验调查[13]、欧盟高等教育资格框架[14]、美国研究生学位授予标准[15]、《教育部关于做好全日制硕士专业学位研究生培养工作的若干意见》(教研〔2009〕1号)、《教育部关于进一步规范工商管理硕士专业学位研究生教育的意见》(教研〔2016〕2号)等。其中，13所国内外一流大学包括北京大学、清华大学、中国人民大学、北京航空航天大学、复旦大学、上海交通大学、南京大学、中国科学技术大学、西安交通大学、哈佛大学、麻省理工学院、斯坦福大学、加州大学伯克利分校等。

其次，选择清华大学、北京大学、北京航空航天大学、上海交通大学、西安交通大学等5所国内“双一流”高校经济管理类学科的共9位专家进行访谈和专家论证，对研究的初步指标进行筛选，目的是提高指标质量、降低指标数量，选择其中最关键、最能反映研究生培养质量的评价指标。专家遴选的标准包括：在经济管理教学和研究领域具有一定的活跃度和影响力，担任所在学科或专业的负责人或带头人，对“破五唯”和研究生培养质量多元化评价有深刻理解和洞见，对本次调研有充分的兴趣和时间投入等[16]。

专家访谈采用德尔菲法[17]，受访谈专家被要求对初步指标提出修改、删除和补充建议，并对指标体系的层级结构提出改进意见。调研人员以反馈匿名的形式与专家进行三轮问卷和访谈，向各位专家征询意见，每轮征询后综合所有专家意见形成指标体系的最终改进方案，然后在下一轮将改进方案反馈给所有专家，以促使专家之间形成沟通机制，修正以前的看法，逐渐缩小观点差异，达成一致意见。

经过上述两阶段调研，本文分别针对学硕和专硕构建起了四个层级培养质量评价体系。四个层级自上而下依次是柯氏维度层、培养环节层、教育任务层、观测指标层，详见表2和表3。柯氏维度层包含学习层、反应层、行为层、结果层等四个维度；培养环节层则包含研究生全过程培养的各阶段或各能力要素；教育任务层是为了完成各培养环节或掌握各能力要素而需高校开展的教学、科研训练、实践训练的具体任务；观测指标层包含最细化的指标，每个指标能够直接观察、测量，抑或数据可通过较简便的方式获取[18][19]。

2. 指标权重问卷调研

指标权重度量的是各项指标对于硕士生培养质量评价的重要性，不仅是利用指标体系科学、量化开展培养质量评价的必备要素，还能够反映不同指标间的相对重要性程度，从而揭示出对于硕士生培养质量贡献最大的培养环节、教育任务和具体工作，进而指导学位与研究生教育改革实践。为此，对上文所列国内9所“双一流”高校的经管类专业的二年级以上在读硕士生和已毕业硕士生开展问卷调研，基于“很不重要－1，不重要－2，一般重要－3，很重要－4，非常重要－5”等5个语义评估值，对两类硕士生培养质量评价指标进行重要性程度打分[20]。共发放问卷750份，其中，学硕问卷(335份)仅对学硕发放，专硕问卷(415份)仅对专硕发放，以保证评价主体的适宜性和准确性。回收问卷685份，剔除不完整、明显不认真、不诚实的答卷后，实际回收有效问卷633份，总有效回收率为84.4%，其中，学硕有效问卷253份，专硕有效问卷380份。为了进一步增强调研的大样本性，提升调研结果的代表性和外部效度，本文采用Bootstrap方法进行再抽样，即从实际观测到的数据集中随机抽取原始样本组成新样本，最终学硕问卷和专硕问卷反馈样本均达到5000份[21]。

最终得到的两类硕士生培养质量评价指标及其权重如表2和表3所示。其中，量化数据来源表示可观测指标的数据来源或计算方法，据此可为确定第四级指标量化值从而定量评估研究生培养质量提供具体而可靠的实践操作依据。每个指标后面括号是归一化后的权重(若某指标只有一个下级指标，则该下级指标的权重为1，不予标注)；为直观、全面地体现每个观测指标的重要性，最后一列呈现其五分制的权

表 2　学术型硕士生培养质量评价指标体系

柯氏维度层	培养环节层	教育任务层	观测指标层	量化数据来源	权重得分
1. 学习层(0.248)	1.1 基础知识(0.298)	1.1.1 基础知识水平(0.542)	1.1.1.1 外语水平(0.267)	①②	4.437
			1.1.1.2 计算机知识与技能(0.255)	①②	4.215
			1.1.1.3 自然科学类课程学习表现(0.248)	①	4.114
			1.1.1.4 人文社会科学类课程学习表现(0.230)	①	3.842
		1.1.2 核心专业课程学习(0.458)	1.1.2.1 核心专业课程学习表现	①	4.205
	1.2 综合素质(0.312)	1.2.1 行动能力(0.260)	1.2.1.1 解决实际问题的方法和措施	③	4.826
		1.2.2 思考能力(0.260)	1.2.2.1 独立思考和分析问题的方法和措施	③	4.826
		1.2.3 价值观(0.245)	1.2.3.1 思辨能力的展现和看待问题的角度	③	4.534
		1.2.4 沟通能力(0.235)	1.2.4.1 与他人沟通的情况和在师生中的受欢迎程度	③	4.312
	1.3 科研素养(0.390)	1.3.1 学术创新思维(0.527)	1.3.1.1 创新思维和科研观点独特性的展现	③	4.807
		1.3.2 学研结合能力(0.473)	1.3.2.1 用学术思维解决实际问题的能力展现(0.258)	③	4.656
			1.3.2.2 实证研究的能力展现(0.253)	③	4.575
			1.3.2.3 案例分析的能力展现(0.247)	③	4.433
			1.3.2.4 将课程知识应用于科研的能力展现(0.242)	③	4.331
2. 反应层(0.246)	2.1 上课表现(0.453)	2.1.1 课堂参与和互动(0.508)	2.1.1.1 课程出勤率和课堂活跃程度	①③	3.742
		2.1.2 课堂责任担当(0.492)	2.1.2.1 课代表或大作业组长的任职情况	①③	3.621
	2.2 科研态度(0.547)	2.2.1 科研的积极能动性	2.2.1.1 参与导师课题组科研活动的积极性(0.344)	③	4.566
			2.2.1.2 主动承担导师课题的情况(0.336)	③	4.465
			2.2.1.3 参与学校学术报告和交流活动的频次(0.320)	③	4.253
3. 行为层(0.260)	3.1 思想品德(0.338)	3.1.1 个人优秀品质(0.352)	3.1.1.1 刻苦学习和学术钻研精神的展现	③	4.660
		3.1.2 伦理道德与社会责任(0.352)	3.1.2.1 志愿服务的参与情况	③	4.660
		3.1.3 思想政治素养(0.296)	3.1.3.1 党建活动政治学习的参与情况	③	3.931
	3.2 校内学习行为(0.334)	3.2.1 基础课程修读(0.486)	3.2.1.1 必修基础课程的学习成果	①	3.831
		3.2.2 综合学习能力(0.514)	3.2.2.1 完成导师交付任务的能力展现(0.352)	③	4.553
			3.2.2.2 学习新事物和新知识的效率(0.352)	③	4.553
			3.2.2.3 总学分绩水平(0.296)	①③	3.831

3.行为层(0.260)	3.3 学术论文发表(0.328)	3.3.1 一般期刊论文(0.294)	3.3.1.1 一般期刊论文的发表情况	⑤	3.521
		3.3.2 本领域核心期刊论文(0.353)	3.3.2.1 本领域核心期刊论文的发表情况	⑤	4.242
		3.3.3 顶级期刊论文(0.353)	3.3.3.1 顶级期刊论文的发表情况	⑤	4.242
4.结果层(0.245)	4.1 学位论文成果(0.345)	4.1.1 学位论文开题报告(0.315)	4.1.1.1 开题报告的评价结果	③	3.921
		4.1.2 学位论文中期检查(0.330)	4.1.2.1 中期检查的评价结果	③	4.132
		4.1.3 学位论文答辩(0.355)	4.1.3.1 论文答辩的评价结果	③	4.444
	4.2 其他科技成果(0.335)	4.2.1 校级科技类奖项(0.143)	4.2.1.1 校级科技奖的获得情况	⑤	3.842
		4.2.2 省部级科技类奖项(0.147)	4.2.2.1 省部级科技奖、教育部科技成果奖等的获得情况	⑤	3.943
		4.2.3 国家级科技类奖项(0.151)	4.2.3.1 国家自然科学奖、技术发明奖、科技进步奖等的获得情况	⑤	4.055
		4.2.4 导师课题任务完成(0.162)	4.2.4.1 导师课题的完成质量	③	4.362
		4.2.5 学生科技竞赛(0.140)	4.2.5.1 科技竞赛成果和获奖情况	⑤	3.743
		4.2.6 专利成果(0.132)	4.2.6.1 各类专利的获得情况	⑤	3.532
		4.2.7 软件著作权成果(0.125)	4.2.7.1 软件著作权的获得情况	⑤	3.321
	4.3 实践成果(0.320)	4.3.1 实践期间表现	4.3.1.1 社会实践单位的综合评价	④	3.921

注:① 课程成绩,包括平时成绩和期末总成绩等;② 相关资格考试(如外语、计算机、职业资格等)成绩;③ 学校负责人量化评分或直接提供数据,负责人包括导师、思政负责人、教学科研负责人等;④ 实习实践单位负责人量化评分;⑤由学校制定量化制度,如期刊分级及分值、科技奖项分级及分值等。

表3 专业型硕士生培养质量评价指标体系

柯氏维度层	培养环节层	教育任务层	观测指标层	量化数据来源	权重得分
1.学习层(0.249)	1.1 基础知识(0.312)	1.1.1 基础知识水平(0.486)	1.1.1.1 外语水平(0.256)	①②	4.043
			1.1.1.2 计算机知识与技能(0.263)	①②	4.165
			1.1.1.3 自然科学类课程学习表现(0.244)	①	3.822
			1.1.1.4 人文社会科学类课程学习表现(0.237)	①	3.711
		1.1.2 核心专业课程学习(0.514)	1.1.2.1 核心专业课程学习表现	①	4.043
	1.2 综合素质(0.304)	1.2.1 行动能力(0.259)	1.2.1.1 解决实际问题的方法和措施	③	4.874
		1.2.2 思考能力(0.259)	1.2.2.1 独立思考和分析问题的方法和措施	③	4.874

1. 学习层(0.249)	1.2 综合素质(0.304)	1.2.3 价值观(0.241)	1.2.3.1 思辨能力的展现和看待问题的角度	③	4.431
		1.2.4 沟通能力(0.241)	1.2.4.1 与他人沟通的情况和在师生中的受欢迎程度	③	4.431
	1.3 实践素养(0.384)	1.3.1 职业发展能力(0.500)	1.3.1.1 职业资格证书的获得情况	②③	4.431
		1.3.2 产学研结合能力(0.500)	1.3.2.1 帮助实习单位解决生产问题的能力展现	②③④	4.431
2. 反应层(0.247)	2.1 上课表现(0.298)	2.1.1 课堂参与和互动(0.508)	2.1.1.1 课程出勤率和课堂活跃程度	①③	3.741
		2.1.2 课堂责任担当(0.492)	2.1.2.1 课代表或大作业小组长的任职情况	①③	3.624
	2.2 实习实践态度(0.325)	2.2.1 实习实践的积极能动性	2.2.1.1 实习实践期间的积极性和主动性(0.511)	④	4.323
			2.2.1.2 参与学校组织的业界讲座或企业人士座谈会的频次(0.489)	③	4.144
	2.3 职业素养(0.377)	2.3.1 职业精神(0.342)	2.3.1.1 团队精神的展现(0.336)	③④	4.767
			2.3.1.2 工作责任感的展现(0.336)	③④	4.767
			2.3.1.3 进取心和工作激情的展现(0.328)	③④	4.655
		2.3.2 职业能力(0.336)	2.3.2.1 人际交往能力的展现(0.333)	③④	4.454
			2.3.2.2 判断和决策能力的展现(0.333)	③④	4.454
			2.3.2.3 计划和执行能力的展现(0.333)	③④	4.454
		2.3.3 职业规划(0.332)	2.3.3.1 未来规划的合理性和清晰度	③④	4.334
3. 行为层(0.259)	3.1 思想品德(0.339)	3.1.1 个人优秀品质(0.350)	3.1.1.1 刻苦学习和学术钻研精神的展现	③④	4.665
		3.1.2 伦理道德与社会责任(0.341)	3.1.2.1 志愿服务的参与情况	③	4.544
		3.1.3 思想政治素养(0.309)	3.1.3.1 党建活动和政治学习的参与情况	③	4.122
	3.2 校内学习行为(0.331)	3.2.1 基础课程修读(0.495)	3.2.1.1 必修基础课程的学习成果	①	4.122
		3.2.2 综合学习能力(0.505)	3.2.2.1 完成导师交付任务的能力展现(0.308)	③	3.911
			3.2.2.2 学习新事物和新知识的效率(0.342)	③	4.342
			3.2.2.3 总学分绩水平(0.350)	①③	4.453
	3.3 实习实践行为(0.330)	3.3.1 课程实践任务完成(0.504)	3.3.1.1 行业认知水平(0.340)	④	4.343
			3.3.1.2 基本实践操作技能的展现(0.330)	④	4.232
			3.3.1.3 实践报告的写作质量(0.330)	③④	4.232
		3.3.2 实习单位项目实训(0.496)	3.3.2.1 对实习单位实际问题的把控力和解决情况	④	4.232

4. 结果层(0.244)	4.1 学位论文成果(0.342)	4.1.1 学位论文开题报告(0.315)	4.1.1.1 开题报告的评价结果	③	3.911
		4.1.2 学位论文中期检查(0.331)	4.1.2.1 中期检查的评价结果	③	4.124
		4.1.3 学位论文答辩(0.354)	4.1.3.1 论文答辩的评价结果	③	4.446
	4.2 其他科技成果(0.318)	4.2.1 校级科技类奖项(0.145)	4.2.1.1 校级科技奖项的获得情况	⑤	3.631
		4.2.2 省部级科技类奖项(0.145)	4.2.2.1 省部级科技奖、教育部科技成果奖等的获得情况	⑤	3.631
		4.2.3 国家级科技类奖项(0.141)	4.2.3.1 国家自然科学奖、技术发明奖、科技进步奖等的获得情况	⑤	3.520
		4.2.4 导师课题任务完成(0.162)	4.2.4.1 导师课题的完成质量	③	4.042
		4.2.5 学生科研竞赛(0.141)	4.2.5.1 科研竞赛成果和获奖情况	⑤	3.520
		4.2.6 专利成果(0.137)	4.2.6.1 各类专利的获得情况	⑤	3.412
		4.2.7 软件著作权成果(0.129)	4.2.7.1 软件著作权的获得情况	⑤	3.211
	4.3 实习实践成果(0.340)	4.3.1 实习实践期间表现	4.3.1.1 实习实践单位的综合评价	④	4.322

注: ① 课程成绩,包括平时成绩和期末总成绩等; ② 相关资格考试(如外语、计算机、职业资格等) 成绩; ③ 学校负责人量化评分或直接提供数据,负责人包括导师、思政负责人、教学科研负责人等; ④ 实习实践单位负责人量化评分; ⑤ 由学校制定量化制度,如期刊分级及分值、科技奖项分级及分值等。

重得分。

(二) 实证调研结果分析

分析表 2 和表 3 数据可知,在第一级的柯氏维度层上,学硕和专硕的学习层、反应层、行为层和结果层的权重都是大致相等(约等于 0.25) 的,表明四个维度同等重要,从而证明研究生培养质量改善应着眼于全过程和全方位,注重基本知识与素养、学习态度与积极性、知识与技能实际应用、学术与实践成果最终产出等各个环节和阶段,任何维度都不应偏废。

在学习层下辖的二级指标中,学硕的科研素养培育和专硕的实践素养培育分别得到最高的权重。因此,学硕教育要注重加强学术创新思维训练,鼓励研究生通过不同的方式和机会,展现和提升创新思维能力和科研观点的独特性,强调科研工作不能循规蹈矩,而是勇闯国际学术前沿。专硕教育则要兼顾职业发展能力和产学研结合思维两个方面: 一是通过鼓励他们扩充专业知识、考取必备的职业资格证书来提升他们的职业竞争力; 二是加强他们在实习单位的项目实训和职业技能培训,增强他们解决企业实际生产问题的能力。在反应层下辖的二级指标中,学硕的科研积极能动性和专硕的职业素养(职业精神、态度和规划等) 的相对重要性更高。良好的学术态度和科研能动性的培养,主要靠平时学校和导师对研究生承担高水平课题任务和参加高质量学术活动的鼓励和要求来实现。而专硕良好职业素养和精神的形成,则应兼顾多个方面,需要校企多领域协作,为他们配备校内和校外两个导师,综合校内教学和校外实习实践,从而系统性提升他们的团队精神、工作责任感、人际交往能力、判断决策能力、计划执行能力等。

在行为层维度中,各二级指标的权重相对平均,都接近 0.33,例如,学硕的思想品德、校内学习行为和学术论文发表等三个方面同等重要,而专硕的思想品德、校内学习行为和实习实践行为的权重也基本均等,这与传统观点认为的研究生在校期间应该更加注重发表论文不同。加强学生的思想政治和品德教育,一直是我国作为中国共产党领导的社会主义国家开展高等教育的重要任务。习近平总书记在 2018 年全国教育大会上强调,要在加强品德修养上下功夫,教育引导学生培育和践行社会主义核心价值观,踏踏实实修好品德,成为有大爱大德大情怀的人。教育部近年来也多次发文,要求高校加强思想政治教育。在结果层维度中,与各级

科技类奖项、科技竞赛、专利相比，学位论文成果的权重更高，对学硕和专硕而言皆是如此。这表明对于硕士生而言，加强基础性科研和实践训练、扎实提升学位论文的质量是比其他产出更核心、更关键的成果。

四、高校硕士研究生培养质量改进建议

结合上文构建的全过程评价模式、指标权重大小和受访专家提供的意见，本文提出以下硕士人才培养质量的改进建议。

（一）依据“需求导向”分类确定培养目标

“需求导向型”培养目标是指高校要根据经济社会发展的最新需求不断改进研究生的培养理念与机制，因材施教，同时要充分引导学生明确未来发展方向与路径[22]。由两类硕士生不同的利益相关方可知，专硕教育旨在培养在某一专业领域具备较强解决实际问题能力的应用型专门人才。因此，学校除了对专硕开设提升专业知识与职业技能的课程以外，还应建立并深化学校和其他利益相关方交叉融合、协同育人的机制，将“把企业搬进校园”和“从校园走进企业”两个方面的机制和模式进行有机融合，通过实行企业家进课堂、综合实践实习训练体系建设和创新创业教育引导等着重培养学生将理论所学应用于具体实践的方法。而学硕教育则以培养教学和科研高层次创新人才为主要目标，所以为激发学硕的科研兴趣，学校应为他们提供更多接触本领域国际发展前沿的机会，如定期举办高水平科研人才面对面沙龙和讲座活动，开展国际化教学与学术交流，邀请国际顶尖专家学者进行短期讲学、科研合作和交流访问，实施国内外高水平导师协同育人机制等。

（二）建立“1 + X”导师制度和指导模式

培养目标、培养过程和评价标准的多元化，其最终目标还是巩固和强化通识型、复合型人才的塑造，促进从单领域专业知识教育向综合能力教育的转变。例如，当前许多专家学者建议的 π 型人才培养改革是强调“信息技术 + 专业知识”的两专多能的人才知识结构培育[23]。由于研究生培养以导师课题组为基本单位，导师的知识结构或培养方式是否具有多元性和复合性至关重要。“1 + X”导师制[24]是指为每一名硕士生配备多名专业背景、知识结构和学术研究方向均不同的导师，其中可设置一名主导师，其他作为副导师，负责研究生不同知识领域、不同能力类型和不同思维方式的教育。除了负责学业发展的主导师以外，还可为学硕配备专门的科研导师，用以提升他们的科研素养和创新思维能力；为专硕配备专门的实践导师，用以提升他们的实践素养和职业发展能力，从而能够有效促进研究生教育方式的多样化，提高不同类型硕士生培养的投入产出比。

（三）强化“研究型”和“实践型”两类不同导向的人才培养机制

当前存在的学硕和专硕培养同质化的问题，其重要原因是在课程设置和教学理念上“一刀切”，未充分考虑二者不同的需求和导向。因此，应继续深化并齐头推进科研导向的教学改革和应用导向的教学改革，分别构建“研究型教学”和“实践型教学”两种不同的人才培养机制。研究型教学应注重提取面向国家重大战略需求的科学问题，设计面向国际学术前沿的教学项目，注重培养学生的创新精神和科研思维，开展以培养学生创新能力为主、鼓励学科专业交叉融合的科研训练导向的教学模式。而实践型教学则应重点提取东方企业情境下、贴近中国企业的管理实践问题或技术解决方案，通过将“把企业搬进校园”和“从校园走进企业”有机结合，重点开展综合实践实习训练和创新创业教育引导[25]。

五、结论和意义

基于关键指标的评价是高等教育质量考核的主要方法。鉴于我国硕士生培养及其质量评价中普遍的指标片面性、重结果而轻过程，以及未充分考虑学硕和专硕差异等问题，本文运用过程导向的思路和方法，通过分析比较学硕和专硕在利益相关方、培养目标、培养环节和评价标准上的差异，基于过程导向的柯氏评估建模方法构建了区分两类硕士生特点的培养质量评价体系，通过对全国主要一流高校硕士生的问卷调研，确定了各层次指标的权重，使指标体系适合量化评价和问题诊断；基于专家访谈和问卷调研结果，提出了若干硕士人才培养质量改进的建议。

本文在设计学硕教育任务和评价指标时，以塑造崇高学术理想和培养原创性科研能力为核心，紧密围绕“双一流”建设对人才培养的要求；在上述评价指标的指引下，学硕一方面尽力提高读硕期间科研成果的前沿性；另一方面，通过理念培养和有针对性的锻炼，坚定最终走向科研道路的决心，未来取得更优秀的学术成果。更多硕士生选择从事科研事业，将为我国科技进步注入更多新鲜血液，将极大提升学术型人才培养质量，推动“双一流”建设方案稳步实施。而专硕教育任务和评价指标则以解决实际问题能力为核心标准，以培养社会特定职业背景所需的高层次技术与管理人才为目标，引导学生通过利用基础性研究成果来创造出新产品、新技术和新设计，促使其未来就业后充分发挥知识的再创新价值，开发更多社会价值和应用价值高的成果，更好服务经济社会发展。

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Multi－DimensionalEvaluation System Construction for Cultivation Quality of Academic and Professional Postgraduates: Based on Process－oriented Kirkpatrick Model

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Abstract: It is the top priority for the current academic and professional graduate education to resolutely tackle the longstanding problems of education evaluation, which prefers scores, further education, diplomas, academic papers and academic titles to actual contributions. Many colleges and universities have not adopted differentiated training objectives, teaching methods and evaluation standards in the two different systems of academic graduate education and professional graduate education, which is not conducive to the implementation of diversified and personalized training concepts. On the basis of a clear distinction of the academic and professional degrees in terms of the stakeholders, training objectives, curriculum and evaluation criteria, this paper adopts the process－oriented Kirkpatrick modeling approach to design specific and targeted educational tasks and evaluation indicators at the aspects of graduate curriculum and teaching, academic exercise, practice training and thesis defense, and has established a multi－dimensional evaluation system for the cultivation quality of graduate students. Suggestions on the improvement of graduate students' cultivation quality were offered, including setting demand－oriented cultivating objectives, developing a so－called "1＋X" mentoring pattern, and achieving the effective connection between the phases of undergraduate, master and doctoral education.

Key words: graduate student cultivation quality; evaluation indicators; academic graduate students; professional graduate students; the Kirkpatrick model

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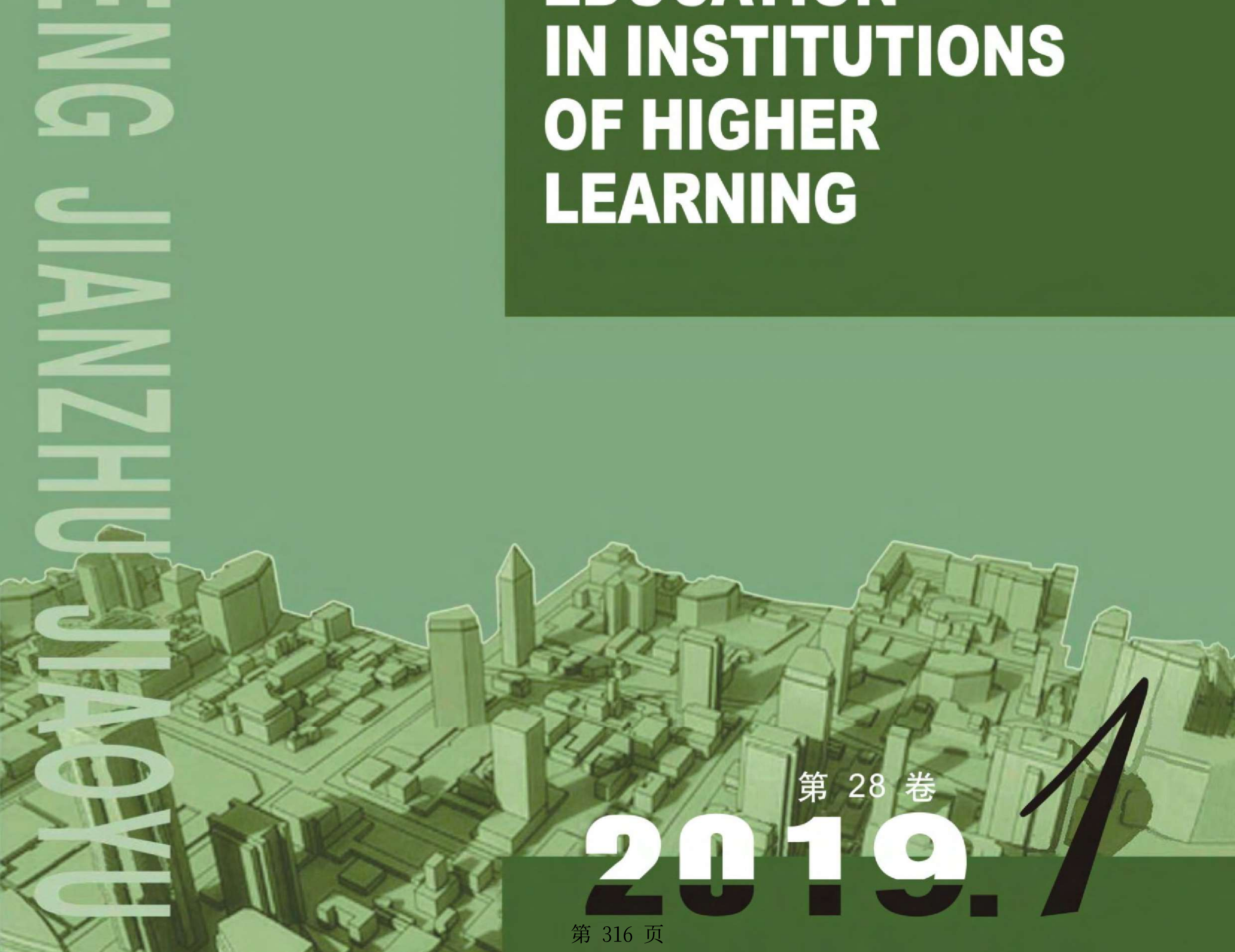

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"一带一路"建设背景下高校工程管理专业人才培养模式研究

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摘要: "一带一路"建设给中国的对外开放提供了新的历史机遇。工程管理专业人才需要全面提升知识和能力水平,拓宽国际视野,树立更强的国际合作与交流意识。结合"一带一路"建设中与基础设施建设有关的议题,基于对工程管理学科内涵和边界的深入分析,凝练出契合"一带一路"建设的工程管理人才的五大新特征,包括三大知识技能和两大意识理念。在此基础上,提出了当前和未来工程管理人才培养的新举措,其核心是充分整合国家各领域、各阶层的资源和优势,实现全社会对工程管理人才的协同培养。

关键词: 工程管理;"一带一路";人才培养;专业教学

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2013年9－10月,国家主席习近平在出访中亚和东南亚国家期间,先后提出共建"丝绸之路经济带"(一带)和"21世纪海上丝绸之路"(一路)的重大倡议,得到国际社会的高度关注。2015年3月,国家发改委、外交部和商务部联合发布《推动共建丝绸之路经济带和21世纪海上丝绸之路的愿景与行动》(以下简称《推动共建一带一路愿景与行动》),明确了将"打造政治互信、经济融合、文化包容的利益共同体、命运共同体和责任共同体"作为"一带一路"的建设发展目标,并将"基础设施互联互通"作为"一带一路"建设的优先领域和沿线各国的重点合作领域,事实上确立了大型基础设施建设在"一带一路"建设中的关键地位[1]。2017年5月,"一带一路"国际合作高峰论坛在北京举行,习近平主席出席开幕式并发表主旨演讲,强调"设施联通是合作发展的基础",并明确提出基础设施建设是未来"一带一路"资金支持的重点。

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“一带一路”建设对我国工程管理人才培养提出了新的要求。首先，国家战略越来越向大型、复杂基础设施建设项目倾斜，要求国内工程建设管理人才要具备新的知识与能力结构[2]。习近平主席强调，“要着力推动陆上、海上、天上、网上四位一体的联通，聚焦关键通道、关键城市、关键项目，联结陆上公路、铁路道路网络和海上港口网络”，“践行绿色发展的新理念，倡导绿色、低碳、循环、可持续的生产生活方式”①。此外，“一带一路”沿线各国大多是发展中国家或新兴经济体，普遍存在基础设施短缺、老旧、亟待维护改造等问题，而这些国家的高级工程管理人才普遍不足，需要从中国向国际工程项目所在国不断引入高级人才，这也是中国工程管理人才的外部需求因素[3]。可以预见，随着“一带一路”建设的稳步、扎实推进，大型基础设施工程管理人才需求将会越来越大。

在深入思考“一带一路”倡议与基础设施建设有关议题的基础上，通过对工程管理学科内涵和边界的深入分析，凝练出契合“一带一路”倡议的工程管理人才若干新特征，并提出当前和未来工程管理人才培养的新举措。

一、工程管理学科的内涵与边界

工程管理（construction management）可理解为针对工程建设行业特殊生产模式进行管理的理论、方法和实践。工程行业生产模式的特殊性导致工程管理的理论与方法同其他行业的管理相比亦有较大差异，也由此形成了工程管理的专业化特点，以及对工程管理专业人才的需求。狭义的工程行业一般指土木工程和具有土木工程建设过程的行业（如水利、交通、市政基础设施等），而广义的工程行业的内涵则可用习近平主席的“陆上、海上、天上、网上”的表述来全面表征，即包括土木、环境、化工、核能、海洋、陆路交通、港口航道、航空航天等多个行业。

由于工程行业大多以项目作为主要生产与运作方式，因此项目管理是工程管理专业的核心知识与能力体系。目前国际权威项目管理知识体系是美国项目管理学会（Project Management Institute，PMI）所定义的十大知识领域（以前曾为九大知识领域），分别是整合管理、范围管理、时间管理、成本管理、质量管理、风险管理、人力资源管理、沟通管理、采购管理和干系人管理[4]。其中，时间、成本和质量是项目的三大主要目标，因此时间管理、成本管理和质量管理为项目管理知识体系的核心，其他知识领域是为了实现上述三大目标（或三大管理任务）而开展的项目管理的主要工作与活动。除此之外，工程项目管理还包括职业健康与安全管理、环境管理、投融资管理等其他重要分支，也是构成工程管理专业核心知识与能力体系的重要部分。

当前学术界和实业界对工程管理学科的边界（或内涵）一般有两种认知：一是理解为涉及工程项目全寿命周期的管理，包括项目前期策划与管理、实施期项目管理和使用期设施管理；二是理解为涉及参与工程项目的各个单位（利益相关方）对工程的管理，包括投资方、开发方、设计方、施工方（即施工承包方，可含分包方）、供货方和项目使用期的管理方（即物业方）等。显然，这两种边界划分方式也构成了工程管理人才的核心知识与能力结构，如图1所示。因此，我国高校工程管理专业的课程设置和人才培养模式可按照上述两种边界认知（学科界定）方式中的一种，并结合PMI的项

①来源：习近平，携手推进“一带一路”建设——在“一带一路”国际合作高峰论坛开幕式上的演讲，2017年5月14日，北京。

目管理知体系，进行统筹规划和整体设计。

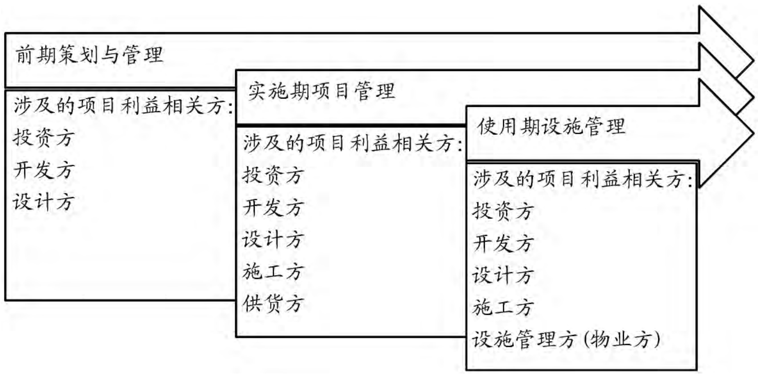

图1　工程管理专业的内涵和边界示意图

二、“一带一路”背景下工程管理人才素质特征分析

对外工程项目承包一直是中国“走出去”的关键环节和主要实践领域，而“一带一路”的提出大大增加了对外工程承包项目数量，也提高了对工程项目及其管理过程的质量要求，为工程管理人才的特质和能力带来了新的挑战和考验。《推动共建一带一路愿景与行动》指出，“强化基础设施绿色低碳化建设和运营管理，在建设中充分考虑气候变化影响”“促进企业按属地化原则经营管理，积极帮助当地发展经济、增加就业、改善民生，主动承担社会责任，严格保护生物多样性和生态环境”。此外，工程建设行业是典型的资本密集型行业，“设施联通”必须要“资金融通”先行，而金融体系建设和金融监管合作一直是“一带一路”倡议的关键主题之一。亚洲基础设施投资银行的创立与完善、金砖国家开发银行的筹建和上海合作组织融资机构的建立等，都是“一带一路”倡议下的重要金融合作举措。

通过对上述“一带一路”倡议内容的解读，结合对当前工程管理学科新的发展趋势以及学科内涵与边界的分析[4-8]，笔者认为，新时期工程管理专业人才应是“高超知识技能+优秀意识理念”的复合型、国际化人才，不仅必须掌握与项目管理、工程技术、经济金融有关的专业理论知识和实践能力，还要能够在全球化背景下，适应信息技术广泛应用、伦理标准逐步提高、工程项目及其管理日益复杂等多方因素的综合挑战。具体而言，“一带一路”背景下工程管理专业人才素质特征表现在以下五个方面。

第一，项目管理知识与技能。工程管理人才应熟悉国际工程项目管理的基本模式、惯例和方法，包括全球合作和跨国经营中的招投标与合同管理、风险管理、投融资管理、人力资源管理、法律与伦理管理，掌握工程所在国的语言、文化传统和民风民俗等。事实上，未来中国整个经济管理类人才培养也应以提升国际合作能力和在跨国企业中的竞争力为基本导向。

第二，工程技术知识与技能。工程管理人才应具有与其所在工程项目的类型与特点相一致的工程技术知识，即成为“厚基础、宽口径”和“管理和技术并举”的通识性人才，在“陆上、海上、天上、网上”各个维度都能胜任工程管理岗位。除了传统的建筑施工技术外，工程管理专业还应根据所在高校特色和未来特定需求，有目的地增加港口与海洋工程技术、航空航天工程技术和信息管理与工程技术等教学模块。

第三，经济金融知识与技能。工程管理人才要具备符合其岗位需求的经济金融类知识，尤其要掌握国际项目投融资和全球经济合作的知识与能力，帮助项目解决国际合作下的成本压力、会计结算、外汇交易和金融风险等问题。

第四，纵向全局意识与理念。工程管理人才应具备基础设施全寿命周期管理意识，并掌握其主要技能。要改变以往仅关注项目实施某一个阶段（如施工阶段）的意识倾向，要具备对工程项目的全寿命周期进行统筹管理的能力，包括前期策划管理、中期实施管理（分为设计与建造两个阶段）和后期运营与维护管理（参见图1），并能将这三阶段的管理进行有效整合，全局把控。此外，还要能灵活适应并处理由工程项目复杂化引发的新的技术流程和人员管理问题，善于运用信息化、虚拟化等手段降低技术和管理风险。

第五，伦理责任意识与理念。工程管理人才应树立很强的工程伦理意识，能运用绿色建筑、节能减排和低碳环保等管理与技术手段帮助所在企业充分履行社会责任，实现工程建设行业乃至全人类的可持续发展。近年来，中国对外工程承包项目屡屡曝出伦理“丑闻”，严重阻碍了国家“走出去”和企业经营全球化的总体步伐，给国际工程管理学界和业界敲响了警钟[9]。在属地化经营中，要特别注重实现工程所在国当地的经济发展、社会进步和环境保护，促进当地民众的自我实现，以及人类社会与生态环境的共同繁荣[9]。

上述五个方面也构成了“一带一路”倡议下我国高校工程管理专业人才素质的五个维度，包括三大知识技能型维度（即项目管理知识、工程技术知识、经济金融知识），以及两大意识理念型维度（即纵向全局意识和伦理责任意识），如图2所示。

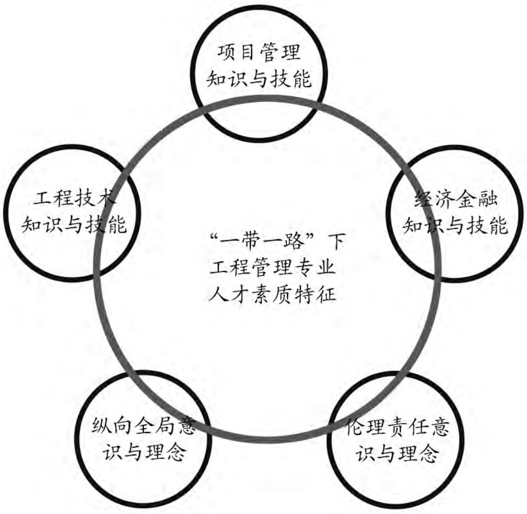

图2　“一带一路”背景下工程管理专业人才素质特征结构图

三、“一带一路”背景下工程管理人才培养的新举措

如上所述，“一带一路”倡议对优秀工程管理人才的需求大增，也对其提出了新的、更高的要求，主要体现在三大知识技能和两大意识理念维度上。为了实现工程管理专业学生在这五大维度上的提升，需要采取新的举措和方法。

首先，应进一步开阔工程管理专业学生的国际视野，增加其国际合作与交流的意识和能力，培养真正具备“上国际大舞台”水准的工程管理人才。目前，国内高校针对国际工程管理知识与技能的教育，大多以课堂传授为主，学生的国际视野及国际交流意识仍有待拓展和提升。通过加强“一带一路”所在国高校间的相互联系与协作，让学生走出课堂开阔眼界，积极搭建教育科研交流平台，可有效突破上述传统教学的局限。2015年5月，“丝绸之路沿线国家教育合作交流会”在西安举行，成立了以西安交

通大学为首的“丝绸之路经济带大学联盟”。国内高校以此为借鉴，积极探索高等教育合作新模式，加快高等教育国际化进程。建议未来在各级政府和高校的共同努力下，建立更多以我国高校为核心的“一带一路”大学联盟，着重在语言、文化、伦理等人文领域和计算机、工程、管理、金融等专业领域加强合作与交流。

其次，应进一步增加工程管理专业实习与实践环节的比重，丰富其内容，建立“理论+实践”并举的工程管理人才技能体系[10-11]。事实上，无论是管理、技术、经济和金融知识，或全寿命周期管理和伦理责任意识，只有在具体工作实践中才能慢慢习得，因此，未来工程管理知识与技能的教育，不应仅停留在课本上，还应鼓励和帮助学生走出课堂。建议在上述“一带一路”沿线各国高校教育科研合作基础上，设立国际人才培养实践基地，促进工程管理专业学生国际间的社会实践、专业实习、人文交流与学术合作[12]。

再次，顺应当前高校普遍推行的大类招生要求，进一步加强通识性经管类和技术类课程教学，形成以“厚基础、宽口径”为支撑的工程管理核心竞争力培养模式。2017 年以来，国内众多高校开始实施本科大类招生，打破传统院系和专业壁垒，做到既加强通识教育、培养“宽口径、厚基础”的人才，又充分尊重学生专业兴趣，赋予学生选专业的自主性，减少未上大学前选专业的盲目性。建议各高校工程管理专业充分发挥大类招生的政策优点，以培养胜任“陆上、海上、天上、网上”的全能型人才为目标，在本科初始阶段加强通识性的经管类、技术类和法律类课程教学，后期则根据学生兴趣与爱好，丰富选修课程和实践环节，打造具有专业核心竞争力的通识型工程管理人才[13-14]。

最后，国内各高校之间还要就工程管理人才培养加强合作，改单兵作战为协同作战，源源不断向国家输送有特定优势的工程管理人才。无论是国际人才培养实践基地的建立，或高等教育合作模式(如成立“一带一路”高校联盟的成立)的形成，都需要大学之间，特别是国内大学之间协作，通过发挥各自的优势，集众校所长，尽可能提升工程管理人才培养质量。此外，当前国内高校在工程管理专业的学科划分上区别明显，或在经管学院，或在建筑工程或土木工程学院。上述区别导致各校的工程管理毕业生的知识结构差异较大，而各校教学各有所长，又各有所短，因此，建议加强国内高校间的联系，施行“开放型、互通型大学”建设制度，促进各校课程体系和培养方案的共享，设计联合培养办法，实现各校间学分互认，教学效果和价值最大化，最终达到所培养的工程管理人才知识结构更加科学、更加全面。

四、结语

“一带一路”倡议下，中国的对外开放进入了更广阔的舞台，面临的挑战更为严峻。作为“一带一路”倡议亟需的人才，工程管理专业人员需要全面提升自身的知识和能力水平，树立更强的国际化、全局性和伦理责任观念。

分析表示，要培养适应“一带一路”倡议所需的工程管理人才需要政府、行业和企业的强有力支持，搭建合作平台、进行学术交流、开展海外实践等都需要大量的资金支持，学生出国留学实践、实现不同高校间学分的互认等工作需要国家的政策支持。高校需要在充分整合内部资源的前提下，积极获取国家、地方政府和相关企业的支持，最终实现全社会各阶层对工程管理人才的协同培养[3]。

“一带一路”倡议下工程管理人才培养的新举措，符合当前中国高等教育的大趋势，如大类招生、深入国际化、构建大学联盟等。高校在该领域的尝试、创新和改革，既能顺应当前大势，借风起航，达到事半功倍的效果，又可为未来国家高等教育体制改革提供可借鉴的有益经验，充当先行军，起到良好的

示范先行作用。

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Talent training mode of construction management in colleges and universities under the Belt and Road Initiative

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Abstract: The Belt and Road Initiative (BRI) provides China with new historical opportunities for its opening-up process. Construction management professionals, who are desperately needed in the practices of BRI, should comprehensively raise their level of knowledge and capability, expand global horizon, and establish stronger awareness of international cooperation and communication. Based on the issues concerning infrastructure construction incorporated in BRI, as well as a profound analysis of the connotation and boundary of the construction management discipline, this paper extracted five new features of construction management professionals in compliance with BRI, which includes three knowledge skills and two ideological concepts. Then, the paper proposed new measures for the present and future education of construction management professionals. Its core lies in the full integration of resources and advantages among the country' s various fields and social levels, as well as the realization of a collaborative training mechanism of construction management professionals within the entire society.

Key words: construction management; the Belt and Road Initiative; talent training; professional teaching

(责任编辑　梁远华)

电子商务概论课程思政教学研究与设计

王洪海　陈　浩

摘要：立德树人是高校的根本任务，课程思政是立德树人的重要抓手。文章通过介绍山东财经大学电子商务概论课程思政建设实践，提出了电子商务概论课程思政教学目标，从而构建课程思政教学设计整体框架，并总结电子商务概论课程思政教学评价和建设效果。

关键词：电子商务概论　课程思政　立德树人　教学研究与设计

一、课程教学目标

面向数字经济发展需求，电子商务概论以课程知识、能力和素质目标为纲，融入《高等学校课程思政建设指导纲要》思想，夯实课程思政教学设计，遵循“寓价值观引导于知识传授和能力培养之中”的原则，启发学生树立正确的世界观、人生观、价值观，全面提高人才培养质量和立德树人成效，践行“三全育人”，实现如下课程教学目标。

首先，课程知识目标：正确理解电子商务相关概念，掌握互联网思维、商业模式设计、网络营销、电子交易、电子支付与安全、物流与供应链管理等基础知识，了解电子商务发展现状、对经济管理的影响及未来的发展趋势。

其次，课程能力目标：培养学生对电子商务相关模式进行批判性思考的能力，基于新技术和新思维提出电子商务新模式、新业态的能力，独立提出问题、分析问题和解决问题的能力，电子商务项目策划、团队协作和应用实践的能力。

最后，课程思政目标：基于对中国国情、经济社会发展实践的了解，以实际行动落实电子商务国家战略；理解电子商务在国家大众创业万众创新、乡村振兴、一带一路实施过程中的重要作用；增强学生的四个自信，培养学生的爱国意识、法律意识和责任意识；掌握科学的方法论，养成勤奋学习、诚实守信、勇于创新的精神；帮助学生树立正确的世界观、人生观和价值观，主动承担社会责任。

二、课程思政教学设计整体框架

（一）课程思政教学设计理念

电子商务概论课程思政教学设计遵循“寓价值观引导于知识传授和能力培养之中”的原则，同时紧密结合电子商务理论与实践的前沿成果，深入挖掘与当代大学生成长成才过程中所必需的思政元素，融合多种教学方法开展课程思政元素设计，做到专业教育与思政教育的同向而行，使学生由单一的知识掌握延伸至内心情感与专业知识相融合的新教学目标，在知识传授的同时，全面提高人才培养质量和立德树人成效，践行“三全育人”。

（二）课程思政教学设计思路

课程坚持思政案例引领的设计思路，通过应用典型案例等教学素材，激发学生的家国情怀，培养学生的法律意识、责任意识和创新精神，以“润物无声”的方式，将正确的理想信念、价值追求和家国情怀巧妙地融入教学内容，有效地传递给学生。

课程坚持面向国家社会经济发展需求的设计要点。首先，坚持以“四个自信”“三全育人”“四个面向”培养学生正确的世界观、人生观、价值观；其次，围绕社会主义核心价值体系，引导学生践行社会主义核心价值观；最后，以创新精神和职业规范为指导，增强电子商务从业者的责任感，培养诚实守信、创新进取的职业品格和行为习惯。依据思政设计要点，将具有思政元素的典型案例、学术文章、时事与要闻、文件与讲话，融入课堂教学过程。课程思政要点、思政载体与教学过程的融合，如图 1 所示。

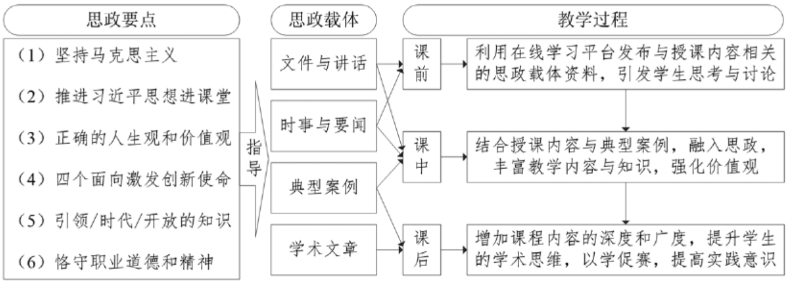

图 1　思政要点、思政载体与教学过程融合示意图

（三）课程思政教学实施路径

以培养经济管理理论扎实，掌握电子商务相关理论与实务、现代信息技术、电子商务运营管理方法和创新创业实践的应用复合型人才教育目标为纲领，结合“三全育人”的思政教育目标，通过专业基础课电子商务概论的思政设计，从学生知识体系完善、学生素质培养和学生能力提升等方面，实现思政教育与专业教育的融合，如图 2 所示。

三、课程思政教学方法

（一）案例式教学

电商领域有较多生动且具有代表性的典型案例，教师可选择其中部分内容，以学生为主体，实施案例式教学，便于学生理解相关知识，同时进一步将法律意识、文化自信、科技创新等思政元素融入相关知识点的教学环节。

（二）研讨式教学

根据学生兴趣围绕特定主题，实施以学生团队为主，教师参与的研讨式教学。学生以小组为单位开展专题研究，进行汇报，教师点评讲解，组织课堂讨论，激发学生对相关专题的深度思考，帮助学生树立正确的价值观，有助于学生开拓思路、创新性思考。

（三）启发式教学

教师结合教学内容和电商最新热点，课前适当分配部分问题，然后由学生以个人或小组形式自主学习，寻找答案。在关键环节或学生遇到问题时，教师要予以点拨和诱导。

（四）科教融合式教学

教师应将团队在电商领域取得的科研成果和实践成果引入到课堂教学，向学生介绍电商领域发展最新成果，引导学生参与讨论，指导学生参加电商领域相关比赛，提高学生的科学素养、创新精神和实践能力，推动学生掌握科学的思维方法。

（五）线上线下混合式课程思政教学

利用智慧树等在线教学平台，提供中国精神、新发展格局、科学思维、职业精神等专题视频，根据课程教学需要有选择地引入学习环节。教师应采用线上线下相结合，混合式教学手段，实现线上阅

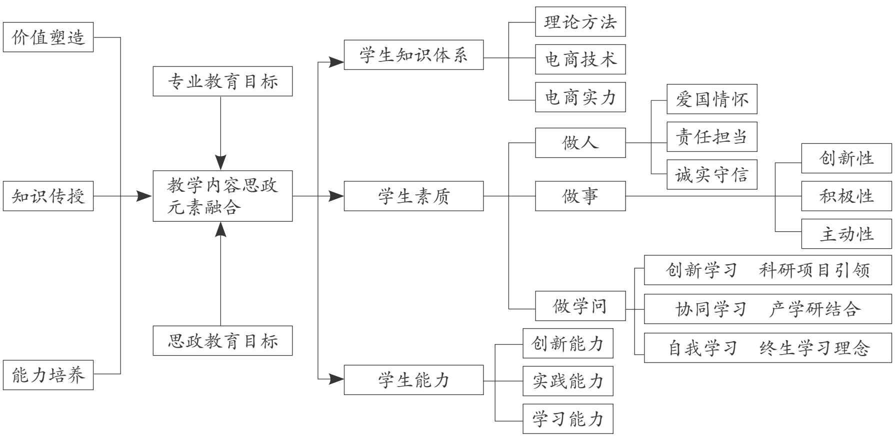

图 2　课程思政实施路径

读思考，线下讨论、总结的闭环学习，巩固与夯实学生的学习效果。

四、挖掘课程思政元素

电子商务概论蕴含的思政元素包括坚持四个面向服务国家需求、增强四个自信强化爱国精神、求真务实勇担责任、具备法律意识坚守职业道德等。挖掘课程中其蕴含的思政育人元素，能够使学生以专业知识为基础，提炼升华到与专业相关联的理想信念问题，从而达到知识传授，并实现价值引领的目的。具体的思政元素及其对应教学重点，如表 1 所示。

表 1　《电子商务概论》课程思政元素及教学重点

章节	思政元素	教学重点
第一章 电子商务基础知识	基于阿里巴巴的发展历程案例，了解建设数字中国的意义与面临的困难，激发学生的创新使命感。	电子商务在企业管理、数字经济发展中的地位与作用，判断电子商务发展趋势。
第二章 电子商务战略	以京东、淘宝、拼多多、苏宁易购战略助力乡村振兴为案例，强调将个人、企业需求与国家战略需求融为一体，全面服务国家。	电子商务战略制定方法，商业计划书制作，以及大学生互联网创业逻辑与机会。
第三章 电子商务商业模式	以拼多多和国家“一带一路”为案例，将“三农”“一带一路”和“国际国内双循环”战略带入课堂；增强学生以商务模式创新来服务国家需求的意识。	电子商务商业模式基础与分类；电子商务盈利模式分析；农村电子商务发展；跨境电子商务模式、路径与问题。
第四章网络营销	以电商失信行为和《电子商务法》为切入点，培养产权意识、法律意识，强化职业道德，遵守职业法律。	网络营销基本概念、理论和方法；网络消费者维权途径；不同国家的知识产权法。
第五章 电子商务交易	以平台垄断的“二选一”与大数据杀熟为案例，引导学生把国家与个人价值要求融为一体，追求爱国、敬业、诚信、友善、公正、公平。	电子商务交易中价格机制；电子交易中的欺诈与规避；电子合同的设立等。
第六章 电子支付与安全	以支付宝与蚂蚁金服为案例，要服务经济主战场，规避国家重大金融风险，要应守正创新。	电子商务支付体系、工具和模式；第三方支付；移动支付；电子商务支付安全。
第七章 电子商务物流管理	以华为芯片危机和顺丰物流发展为案例，树立确保与完善国家供应链、产业链安全的目标；积极参与构建全球命运共同体。	供应链管理及其方法；订单履行概述；物流管理；电子商务物流配送；跨境物流与国际贸易摩擦。

五、课程教学评价和建设效果

电子商务概论课程在校内实施混合式教学改革，学科前沿动态与电商最新实践的广泛引入，拓展了学生学习广度，教师学术成果和企业运营实践的有效融入，增加了学生学习深度，增强了学生服务电商产业的能力。课程积极融合线上线下教学资源，实现了课程教学知识点的全覆盖，以及重点难点的有效互补。教师引导学生由被动学习向线上主动学习和线下研讨启发式学习转换，补充与电子商务相关的国家战略知识，及时回答学生提出的困惑，合理满足学生的学习诉求，学生课堂参与度显著提高。

课程组将双创元素、学术研究热点与电商最新实践融入课程教学，有效提升了学生培养质量。课程组还通过引入国家战略和时事热点，提高了学生的参与度，通过典型案例的深入剖析，强化了学生对知识点的学习。在电子商务相关知识点学习中引入思政教育，使学生在丰富专业知识、提升专业技能的同时，成长为践行社会主义核心价值观的高素质人才。

六、结语

在电子商务概论课程思政项目建设过程中，高校教师不仅仅是传授知识的教书匠，还是铸魂育人的工程师。在教学科研过程中，高校教师要自觉增强政治意识，坚守立德树人理念，同时提升教书育人本领，做社会主义核心价值观的模范践行者和积极传播者。

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