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Evaluation Framework for an Interdisciplinary BIM Capstone Course in Highway Engineering*

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This study aims to develop an evaluation framework for improving interdisciplinary BIM (Building Information Modeling) education in highway engineering. The evaluation framework is designed based on the Context-Input-Process-Product (CIPP) model and applied in an interdisciplinary BIM capstone project at Chongqing Jiaotong University. Four project teams with a total of 52 students from 9 different majors were involved in the highway and its service area design after centralized training. Mixed research methods were used for data collection, including a questionnaire survey for students and semi-structured interviews for team leaders and instructors through purposive sampling. The results indicate that: (1) all students have a deep awareness and interest in learning BIM and joint design; (2) BIM software training and its theoretical knowledge should be incorporated into BIM capstone courses; (3) BIM coordination meetings in the design process play an important role in reducing model collisions and redesign work while the instructor's performance has no significant impact on this aspect; and (4) prior knowledge of teamwork experience has the greatest correlation with performance of joint design. This evaluative study provides a paradigm to evaluate and improve BIM capstone projects in highway engineering. Educators who are interested in BIM education and highway engineering can refer to this capstone course and its evaluation process.

Keywords: BIM; education; CIPP; highway engineering

1. Introduction

Abundant evidence has revealed that the development of BIM, a new way to create, share and utilize facility life cycle data [1], can effectively improve performance and efficiency in highway engineering. The innovation of BIM provides a solution to complicated design problems in highway alignment and facilities maintenance [2, 3]. Advantages such as design errors elimination, construction duration reduction, automated sustainability analysis, and dynamic cost estimation, encourage governments and clients to advocate for the use of BIM in their infrastructure projects [4].

The great progress of applying BIM to highway engineering identifies new requirements for BIM practitioners. For example, an investigation in Germany showed that BIM projects require personnel with methodical abilities, interdisciplinary thinking, a process orientation and a comprehension of super-ordinated interdependencies [5]. Various studies [5–7] have indicated that to implement BIM requires education in BIM expertise and personnel training. An appropriate organizational structure, a well-defined training and education program, and a sufficient BIM budget, including software and hardware investment, are the key factors to facilitate BIM implementation [8].

However, training BIM personnel in undergraduate education is still in its infancy. Despite some researchers having addressed educational hindrances in the architecture, construction and engineering industries [9–11], there are limited studies that are devoted to improving BIM education in highway engineering. Therefore, it is imperative to improve the educational paradigm and guide civil colleges and universities to train students in BIM-based skills.

To efficiently and accurately improve BIM education in highway engineering, it is necessary to evaluate the whole process from capstone implementation background, educational input, and practice quality to learning effect. Among various evaluation models (e.g., 360 degree evaluation [12]; Brinkerhoff's Six-Stage Model [13]; Stufflebeam's Context, Input, Process, Product (CIPP) Model [14]; Kirkpatrick Evaluation Model [15]), CIPP is the most practical way to apply the evaluation stage of the particular capstone course under investigation in this study. In order to guide educators in their implementation of this new course, it is necessary to clarify the students' needs before

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implementation of the course, and what resources should be invested in in the implementation process. At the same time, the particularity of this BIM course lies in its strong practicality, so it also needs to be combined with opportunities for practical application besides the training. Therefore, it is necessary to evaluate problems in the actual operation process. Finally, the results of the whole input should be evaluated to guide the next educational design. The CIPP model was considered a perfect match in addressing this situation. This paper aimed to establish a framework based on CIPP to evaluate an interdisciplinary BIM capstone course in highway engineering.

2. Literature Review

2.1 BIM Education

Educators have integrated BIM into existing curricula since BIM became popular in the construction industry. A study at Metropolia University of Applied Sciences presents the current state and strategies of BIM integration into an academic context, based on collected feedback and recommendations provided by the participating educators [16]. Bina Nusantara University delivered BIM in two semesters spanning the early stages, and studied the feedback of students; the results showed a combination of various delivery methods was the most effective strategy to accompany a design studio with BIM [17]. Similar studies have introduced BIM into the curriculum of Civil and Structural Engineering students by applying BIM into creating structural analytical models [18, 19]. Major research efforts are devoted to exploring the integration of BIM into the architectural, engineering and construction (AEC) industries [7, 10, 20], while education research related to integrating BIM into highway engineering is still blank.

BIM education is always interdisciplinary and now the focus has shifted to research into teaching frameworks for BIM education. A BIM-enabled pedagogy was developed and tested in a Building Materials and Construction Methods class and compared with traditional drafting-based modeling pedagogy [21]. Rodriguez et al. (2017) proposed a conceptual BIM education framework for all construction stakeholders including the client [22]. Ambrose (2007) explored ways to prepare architecture students for digital practice that focused on virtual building model and database management [23]. Sundfor and Selvaer (2016) adopted "Situated Learning" and "Reflective Practice" teaching methods to facilitate the transformation of students into skilled BIM technicians in the AEC industry [24].

As for BIM education evaluation, Ahn and Kim (2016) examined the degree of awareness and acceptance of BIM and BIM education among architecture students in Asia through a questionnaire that focused on recognition, interest, and experience with BIM and Industry Foundation Classes among students participating in a design workshop [25]. Research by Mathews (2013) introduced collaborative BIM applications into a built environment curriculum and investigated the influence of BIM collaboration on learning in a qualitative way by analysing students' responses in their blogs, and concluded that the collaboration had been highly successful in terms of meeting the project brief [26]. Zhang et al. (2018) studied the assessment for BIM training results in a capstone course among Civil Engineering and Management students by a cohort of faculty advisors aided by external industry reviewers [7].

In the existing research, many scholars have studied how to integrate BIM features into the original curriculum, but the evaluation of such integration is under-researched. Moreover, research that takes highway engineering as the context is also limited. This paper proposes an evaluation framework for integrating BIM education into highway engineering curriculum as an example of effective practice.

2.2 Education Evaluation Models and the Selection of CIPP

Abundant education evaluation models have been developed and applied in educational research, the more widely used examples of which are Brinkerhoff's Six-Stage Model, Stufflebeam's CIPP Model, and Kirkpatrick's Levels of Evaluation Model. Through comparing models, the most suitable evaluation model was selected for the BIM capstone course in this study.

The Kirkpatrick model is often used to assess training effectiveness using Reaction, Learning, Behavior, Results [15]. For example, Vizeshfar et al. (2018) evaluated a volunteers' training program of first aid based on Kirkpatrick's model [15]. The reaction level tested the students' satisfaction with training content. The learning level tested their knowledge, while the behavior level tested students' performance pre-test and post-test. The result level tested the achievement against the objectives of the training course. Similarly, Ayub et al. (2015) evaluated the acceptance of Massive Open Online Courses amongst students [27]. The reaction level surveyed the learners' perspectives on the program. The learning level measured their improvement of knowledge, skills or attitudes. The behavior level answered questions of how the learners applied their knowledge, skills and attitudes into the future. The last level measured the overall results

Table 1. Comparison of three evaluation models

Category	Advantage	Disadvantage
Kirkpatrick model	Training effectiveness	Cannot evaluate course preparation
360 Degree model	Can provide comprehensive view of an object	The evaluation object is unique
CIPP model	Can evaluate every link of implementation	The cycle is long and the whole process should be tracked

and impacts of the training. These cases indicated that the Kirkpatrick model provided mutually corroborating evidence for the effectiveness of the training or program carried out. The 360 degree evaluation collects feedback from subordinates, peers, and supervisors. For example, Cormack et al. (2018) evaluated the clinical competence and progress preparation in an online nursing program, and a 360 degree evaluation was selected to assess students' improvements across a graded rubric, standardized patient survey scores, student reflections and preceptor evaluations. This model evaluated a specific theme from different perspectives of different people to provide a holistic view [12].

Corresponding to the letters in the acronym CIPP, this model's core concepts are Context, Input, Process, and Product evaluation [14]. The CIPP model is used to improve rather than prove, so it has been widely used by educators and researchers. For example, Azari and Kim (2016) identified a checklist of evaluation indicators for Integrated Design Teams of Green Buildings and then organized this into an evaluation model [28]. They found the CIPP model to be a perfect match, so the CIPP-based integration evaluation framework was constructed. By applying the CIPP evaluation model, Ali et al. (2018) evaluated a proposed interactive case-based learning system for medical education [29]. Al-Shanawani (2019) evaluated the self-learning curricula of a kindergarten in Saudi Arabia, and the findings revealed that the objectives of the curricula were moderately correlated to the context and the input, and the process, while the product also moderately contributed to the educational needs and to the Saudi community [30]. Ouda et al. (2019) conducted an evaluation of stakeholder capacity in the implementation of a millennium village primary school meal project [31]. Al-Khathami (2012) constructed a self-administered questionnaire based on the CIPP format to seek trainees' perceptions about a Saudi Diploma in Family Medicine program [32]. Jones et al. (2016) introduced a nurse-led Parkinson's service at Canberra Hospital and Health Services with the objective of improving the care and self-management of people with a diagnosis of Parkinson's disease and related movement disorders; CIPP was used to evaluate the service implementation [33]. These evaluation cases were conducted in different fields but all were conducted by going through the context, input, process, and product areas to improve the program quality.

Flowing from the above literature review, the advantages and disadvantages of the three models are summarized in Table 1. The comparison indicates that CIPP in this interdisciplinary BIM capstone course was the most suitable. It could not only explain how this innovation course was implemented through CIPP, but it could also evaluate it.

2.3 Knowledge Gaps

Current research has not yet touched on the teaching paradigm of BIM applications in highway engineering, let alone evaluated it. Research about highway engineering-oriented BIM teaching is limited, and the teaching content and key rules of this course were not clear. Furthermore, there was no available research on the evaluation of the whole process of BIM course teaching and design, even though such evaluation is important in improving the overall BIM course. The CIPP evaluation model is a full-cycle evaluation, and its evaluation results can be used to improve the quality of both the curriculum and teaching. Therefore, this study has applied the CIPP model to a highway engineering-oriented BIM teaching evaluation, and has studied ways to improve teaching for students and teachers.

In this paper, the CIPP evaluation model is used to measure the whole process of this education paradigm. The first component is the Context evaluation, which addresses needs and opportunities for BIM education from the student perspective. The Input evaluation is based on the BIM curriculum and analyses what students and instructors think about the Software studying arrangements and the teaching of theory. The Process evaluation consists of students' peer evaluation, which assesses the execution of BIM meetings, as well as the instructor's performance. The purpose of the Product evaluation is to focus on the improvement of students' skills and it identifies the role of prior knowledge.

3. Methodology

3.1 Research Design

To integrate BIM technology into interdisciplinary highway engineering, pre-training for students is important since the design process is different from their previous design experience, which was separated. Practical synergized design is combined with the training course to deepen the understanding of students. After the synergized design process, student teams give a presentation, which is assessed and scored by instructors, who are made up of university teachers and software company consultants.

Based on the features of a comprehensive interdisciplinary BIM synergized design process, this study applied the CIPP evaluation model to assess the lifecycle of the whole process. The first stage was conducted in advance of the synergized design to investigate the social context, and after the synergized design was in operation, the evaluation considered the influence factors for improvement of the next iteration of the program. The evaluation was concerned with the following main questions: *What motivates students to participate in interdisciplinary design? What is the capstone system? How do teamwork and instructors affect the design process? And to what extent does prior knowledge help the design performance?* In order to answer these questions, this study constructed and utilized the CIPP evaluation method to explore teaching effects and student performance in the context of synergized design. Each process used questionnaires or semi-structured interviews as data gathering tools. Table 2 shows the CIPP Evaluation framework of BIM interdisciplinary design.

3.2 Data Collection

To enrich insights into the various and complex phenomena and processes in this BIM capstone course, mixed methods research, merging qualitative and quantitative data, was applied in this evaluation framework. The mixed methods research includes a combination of complementarity, completeness, developmental, confirmation and diversity factors, which together allow for the deeply analysis of students' performance and course progress (Venkatesh et al. 2013). Fig. 1 provides an overview of the mixed methods research.

Specifically, this research collected its initial data before the training and design, to investigate the social background and the enthusiasm or reasons for the students' participation (Questionnaire 1, https://www.wjx.cn/jq/28817316.aspx, and see Appendix 1). The latter was important, because the cognitive attitude of students in the study's context (Chinese higher education) determines

Table 2. CIPP Evaluation framework of BIM interdisciplinary capstone

Stage	Aim	Indicators
Context	Background and Necessity Analysis, Talent Training Plan and Objectives	BIM social environment BIM opportunity Self-interest of BIM Self-interest of joint design
Input	Teaching curriculum design, funding, teaching staff, venues	Software teaching Theoretical teaching Classroom condition Computer equipment
Process	Schedule and quality inspection, teamwork, instructor guidance	BIM team meeting Instructor performance Collision and rework
Product	Joint Graduation Design Achievements and Teaching Effectiveness	Design result Correlation analysis

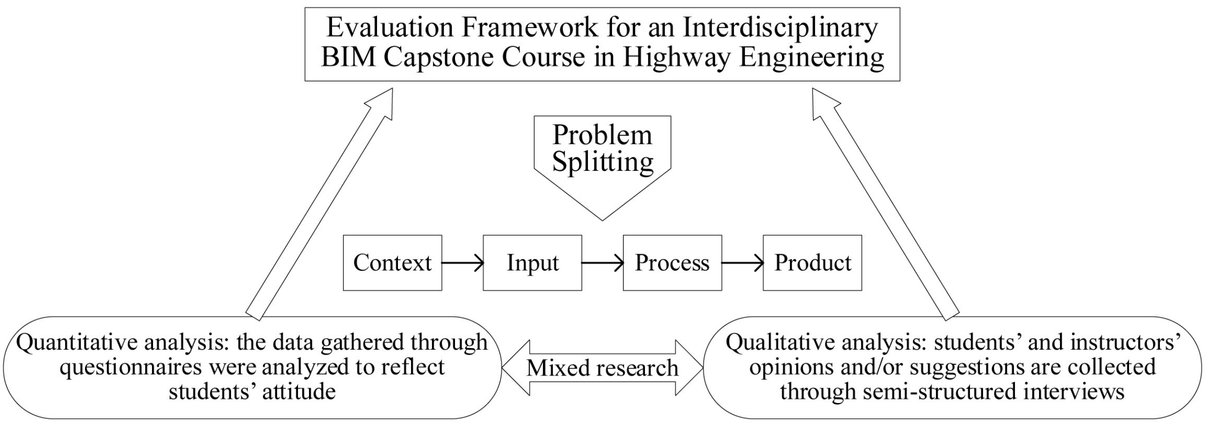

Fig. 1. Mixed methods of evaluation framework.

Table 3. Purposive Sample and Semi-structured interview outline – Student leaders and Instructors

Personnel	Label	Question
Student team leaders	L1, L2, L3, L4	How do you evaluate classroom training? How do you evaluate the work of other majors? How do you evaluate your mentor's guidance? What growth have you gained?
Instructors	T1, T2, T3, C1, C2	How do you evaluate your classroom training? How do you evaluate the students' cooperation? What do you think instructors should do during the students' design process? What do you think of the students' performance?

Note: Leader (L), University teacher (T), Company consultant (C).

the acceptance of this teaching mode to a certain extent. This was a random survey amongst general student groups. Both quantitative and qualitative approaches were incorporated to collect students' views during the second data collection stage. Questionnaire 2 was designed to gather data on the attitudes of the students and teachers who were involved in the synergized design (https://www.wjx.cn/jq/29503965.aspx, and see Appendix 2). At the same time, four team student leaders and five instructors were screened and invited to do a semi-structure interview. The questionnaires used a Likert scale from 1 = very little, 2 = little, 3 = not necessarily, 4 = much to 5 = very much. The tool used to collect the data was https://www.wjx.cn/. The semi-structured interviews each lasted about one hour. The outline is shown in Table 3.

3.3 Course Description

The information development of highway engineering (including roads, bridges, tunnels and facilities along the route) is inseparable from the promotion of BIM technology. Among students who have received three years of traditional civil engineering education, it is necessary to carry out an interdisciplinary BIM capstone project to cultivate comprehensive design skills. Through teaching and practice, students can gain an understanding of BIM and master BIM software.

In this case study a teaching paradigm was proposed that applied BIM technology to interdisciplinary design in highway engineering, based at Chongqing Jiaotong University from January to June 2018. Fifty-two students from nine majors first received general training, and then they designed in groups. There were four groups, each consisting of 13 members. The main composition of the members was the same, but the specific topics were different. The course included pre-school instructional training, a mid-term joint design process, and a final report summary. Nine school teachers from different majors were responsible for assisting in the

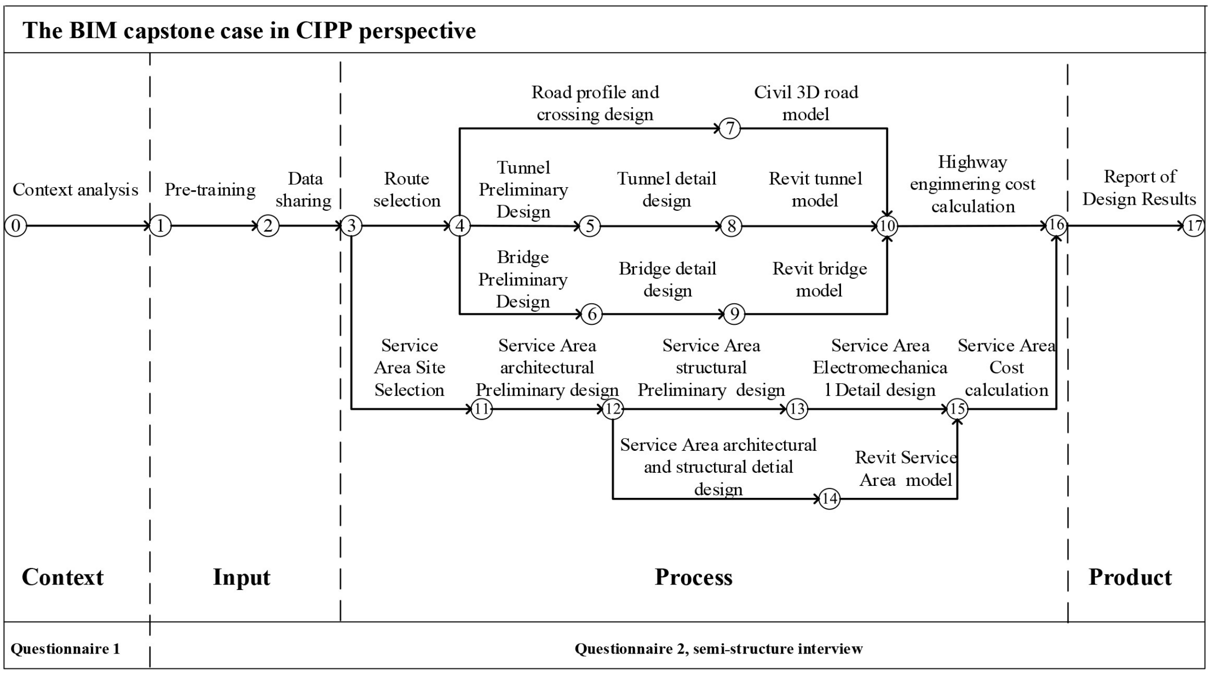

Fig. 2. The whole design process of the Interdisciplinary BIM Capstone course.

management of the process and lectures, and four consultants from software companies were responsible for teaching software operations. The highway and its service area were designed as skill and knowledge 'carriers', covering road engineering, bridge engineering, tunnel engineering, engineering cost, architecture, structure, electrical and professional. All majors were required to complete the construction drawing design and the forward design of the 3D model. The whole design process (including the CIPP evaluation superimposed) is shown in Fig. 2.

The CIPP framework was applied as follows:

Context: Investigate the background of interdisciplinary BIM capstone implementation and organize students from different majors to join the cross-professional joint design team.

Input: This course involved 12 consecutive days of course training, a total of 48 hours, including three sessions of software training and theoretical knowledge training.

Process: After the training, students entered the group design process, from route selection, service area location selection, and construction drawing design to BIM model design. Throughout the process, students of all majors were responsible for the design content of their major, and each major had one or two instructors assigned.

Product: Reporting and displaying the overall project according to the group.

4. Results

4.1 Context

As part of context evaluation the BIM social background and students' interest in the program were investigated to ascertain the motivation and needs of students. Four questions, related to BIM social environment, BIM Opportunity and resources, Self-interest of BIM technology, and Self-interest of interdisciplinary design, were asked in Questionnaire 1. Questionnaire 1 (see Appendix 1) was randomly distributed to the final year undergraduate students, majoring in civil engineering, before the joint design began, and 118 students at Chongqing Jiaotong University participated. Table 4 shows the context evaluation results.

The average answers of the four questions were above 4.0, which indicates that the students in civil engineering-related majors recognized the background of BIM. Students also showed great interest in the interdisciplinary design program, either because of the opportunity to learn BIM skills or to gain a comprehension of the design mode. This recognition is an important guarantee for the promotion of BIM courses in the school.

4.2 Input

In BIM education, how to construct BIM curriculum is of key importance. It is not only conducive to a theoretical understanding of emerging technologies for students of different majors, but also to mastering software operation and team cooperation. Through the evaluation of the curriculum in this case study, key factors were identified to guide the BIM educators. The input evaluation measured software study arrangements, theoretical teaching, classroom conditions, and computer equipment in the form of four questions. Questionnaire 2 was distributed to all 52 students who participated in the joint design training and practice; 37 questionnaires were returned, a recovery rate of 71.15%. Meanwhile, semi-structured interviews about the curriculum were conducted.

50% of students agreed and 36.11% students strongly agreed with the teaching input related to the hardware configuration (i.e., classroom conditions), while fewer students were satisfied with the curriculum quality. The feedback suggests that some students were dissatisfied with the software study arrangements. To further analyze the specific

Table 4. Statistical results of the context evaluation (N = 118)

Indicators	Mean	Standard deviation	Median
BIM social environment	4.50	1.15	4
BIM Opportunity and resources	4.22	0.76	5
Self-interest of BIM technology	4.47	0.66	5
Self-interest of interdisciplinary design	3.96	1.22	4

Table 5. Statistical results of the input evaluation (N = 37)

Indicators	Mean	Standard deviation	Median
Software study arrangements	3.47	1.13	4
Theoretical teaching	3.61	0.93	4
Classroom conditions	4.11	0.65	5
Computer equipment	4.06	0.73	5

Table 6. The summarized responses of the semi-structured interviews

Question category	Personnel	Response
The capstone course arrangement was. . .	L1, L2	The course includes software technology training for nine majors. Although it is not in-depth, it enables students to understand the work content of the other eight majors.
The capstone course arrangement was. . .	L1, L3, L4	It's more like a universal education, which is conducive to teamwork in the later period.
The Hardware facilities was. . .	L1, L2, L3, L4	The hardware facilities are very good, the key is that the version of the software used and cloud storage device should be planned in advance.
The key point of teaching should be. . .	T3, C1, C2	The course arranges the process of engineers in real design work, imitating the overall design of highway engineering. This gives students global awareness.
The key point of teaching should be. . .	T1, T2	Theoretical teaching helps students master the process of joint design, the collaborative mode of various specialties and key technology nodes.
The key point of teaching should be. . .	T1, T3, C1	In Revit software teaching, the most important thing is to learn how to create "family" and parametric control.

reason of students' attitudes, semi-structured interviews were conducted. The summarized responses of the semi-structured interviews are shown in Table 6.

Responses indicated that dissatisfaction could be attributed to two possibilities: either the timing and time distribution between software and theoretical teaching, or the lack of understanding of students' own tasks. Based on the semi-structured interview results, the key content of the course related to teaching input can be constructed in the way shown in Fig. 3.

4.3 Process

The process evaluation begins with design work of Road Engineering after the initial training, and ends with the graduation report phase. It tracks the design process, focusing on quality and schedule. In this study, BIM meeting and instructors performance were evaluated by students in the questionnaire. During this stage, students started independent joint graduation design in groups. Because the performance of each group was different, this study used a statistical method to analyse the performance of different groups and studied its impact on the design results. Statistics of BIM meetings conducted by different groups and instructors are presented in Table 7.

The BIM meetings were not mandatory for all students but were based on students' voluntary organization according to project needs, and neither was it mandatory for the instructor to supervise. Statistical results show that groups that organized and participated in BIM meetings had fewer collisions and rework. This was mentioned by several students in the interviews:

L1: In the process of participating in the group discussion, we can not only learn the design process and design difficulties of other majors, but also communicate in time, which helps me to put my own design task in the role of the overall team, and arrange the next work.

L3: Because the design group does not have a mandatory BIM meeting mechanism, the frequency of meetings and attendance of our team are not fixed, which is not conducive to communication between members. Another team has regular BIM group meetings every week, requiring full participation, thus avoiding the rework when service area elevation changed.

T1: In the course of the case, we found that if we put forward a student or tutor role responsible for the overall route design, participated in the early stage, and coordinated the design of roads, bridges, tunnels and service areas, it would greatly improve the design efficiency and avoid design problems.

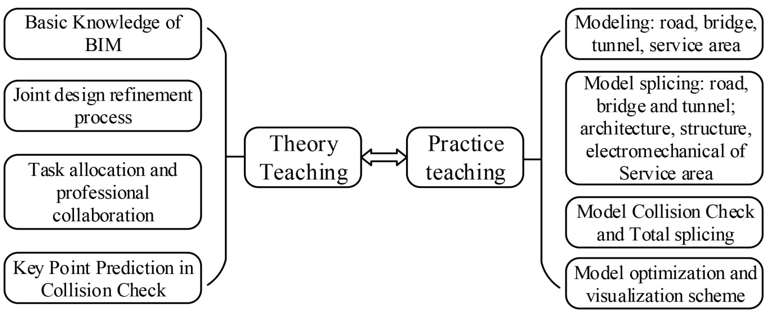

Fig. 3. the BIM capstone course as the input.

Table 7. The process results

Indicators	Team	N	Mean	Standard deviation	Median
BIM team meeting	Team 1	13	4.69	0.95	4
	Team 2	10	2.47	1.53	3
	Team 3	7	2.56	1.42	3
	Team 4	7	3.44	1.13	3
Instructor performance	Team 1	13	2.52	1.22	2
	Team 2	10	2.45	1.42	2
	Team 3	7	2.24	0.57	1
	Team 4	7	2.06	0.86	2
Collision and rework	Team 1	13	2.17	1.13	3
	Team 2	10	3.61	0.93	4
	Team 3	7	4.11	0.65	5
	Team 4	7	4.06	0.73	5

Table 8. Correlations of performance of joint design and prior knowledge

No.	Indicators	Performance of joint design
1	Teamwork experience	0.732**
2	Prior BIM training or studying	0.133
3	Professional software skills (such as AutoCAD)	–0.097
4	One single specialty course design	0.182
5	Academic achievement	0.163

Note: **p < 0.01, N = 37.

There was no significant difference in terms of the assistance instructors offered in each group according to the survey results, because the instructors in each group were the same. However, some comments were made about the role of teachers during the interviews:

L1: The design codes of civil engineering are constantly updated. In order to ensure that we use the latest codes, especially when it comes to BIM technology, instructors play a vital role.

L2: This kind of interdisciplinary design is new and difficult for us. We want the instructors to tell us where we are.

L3: Throughout the design process, the tutor-centered meeting can contact the students in the same majors from different teams, compare the design progress horizontally, contrast progress and quality with reference, and discuss the same design problems found. However, this kind of instructor-centered meeting is rare.

L4: In fact, although we are involved in the design of the same project, the difficulty of each professional design content is uneven. The design requirement should balance the task between nice majors.

T2: Under this teaching plan, the teacher only plays a role in guiding and supervising the quality in this process, and can't participate in the design process of students. In this process, students themselves explore different cooperation modes of different groups and feedback of their design results, which can guide schools to improve their next teaching plan.

4.4 Product

The products are not only the students' presentations, but also the improvement of students' abilities. The products include construction drawings, BIM models, instructions and cost documents. The prior knowledge measure was intended to explore the relationship between the students' Comprehensive Quality, such as the teamwork experience, prior BIM training or studies, professional skills, and academic achievement. The prior knowledge measure consisted of a questionnaire with five Likert scale questions.

From Table 8, the correlation between Performance of joint design and Teamwork experience was 0.732, and showed a significant level of 0.05, meaning it showed a significant positive correlation between Performance of joint design and Teamwork experience. However, Prior BIM training or studying, Professional software skills, One single specialty course design, Academic achievement and Performance of joint design were uncorrelated.

Through correlation analysis between the students' prior knowledge and performance of joint design, this study further provided insight into how to improve joint design effectiveness. The case study shows that students' ability to participate in community activities before graduation design had the most significant positive impact on the effect of graduation design. Therefore, this could allow schools to enhance the cultivation of students' teamwork ability to promote joint communication skills in a real work context.

5. Discussion

This paper aimed to find out how to evaluate BIM training within a capstone course in highway engineering. The context evaluation suggested great interest in BIM education amongst Chinese students, which helped the educators set the curriculum goals and promote it. This context result is in line with a BIM awareness and acceptance investigation by architecture students in Asia [25]. And in terms of teaching input, BIM capstone project input was considered to be the bottleneck of BIM technology development [34]. The input evaluation in this study further analysed the teaching approach of the BIM capstone course, based on a curriculum quality and hardware configuration evaluation, which suggested that the educators should build a bridge between theory teaching and software teaching. This paper has further explored the mode of cooperative design for students in process evaluation. Because students design in groups at this stage, a comparison between BIM control groups was implemented. Groups with a higher acceptance of meetings had less design rework and fewer collisions. Students reinforced the importance of BIM meetings in interviews, which allowed them to understand the design of other majors in an interdisciplinary process. Zolfagharian et al. (2013) thought that "a user-friendly interactive model that provides a conducive learning environment is needed to enhance students' learning capabilities [35]." This view was confirmed by the results of this paper. There was little difference in the results of questionnaires from each group with regards to instructor performance in process evaluation, as they were only required to play a supervisory role. As Salleh and Fung (2014) have mentioned, one of the barriers to BIM implementation is a lack of seeking consultation [8]. In the interdisciplinary BIM capstone course, the instructors should grasp the overall schedule of design and prompt students at key points in time, whilst giving them an opportunity to consult. The output of the curriculum was varied, including students' learning, students' design achievements, and the improvement of the curriculum system. This paper has discussed which student abilities have a significant impact on the design results. The results show that the more experience students had in teamwork, the better their designs and personal experiences were. Research by Garcia-Martin et al. (2015) has indicated that there is a correlation between the motivational profiles of students and their perception of teamwork competence [36]. This provides educators with ways to improve the effectiveness of the curriculum.

Meanwhile, since interdisciplinary BIM capstone courses are burgeoning, this paper has also articulated how to design the curriculum in a broad sense. Fig. 2 divided curriculum input into theory and practice, and further listed the basic knowledge and software learning arrangements. By applying CIPP, the BIM capstone course was chronologically divided into four phases, which allowed for the clarification of the curriculum and could enable educators to prepare and execute capstone courses in stages. Moreover, the BIM capstone course could be seen as a combination of lectures, training and real-world practical design, and it introduced the idea of collaborating with consultants of a software company so they can provide software training in a laboratory. This may overcome the gap between traditional teaching and engineering practice and integrate the resources between industry and university. Ultimately, if this approach leads to excellent BIM personnel, it is also likely to improve the efficiency of highway design.

6. Conclusion

This paper has constructed an evaluation framework of a BIM interdisciplinary capstone course in highway engineering, based on the CIPP model. Quantitative and qualitative research methods were used to construct evaluation questionnaires and semi-structured interviews. Taking the interdisciplinary joint design of Chongqing Jiaotong University in 2018 as an example, the attitudes of teachers and students participating in the design were collected. This paper has provided a paradigm for applying a CIPP model to engineering evaluation, expanded the application scope of this framework, and also helped educators to design a teaching plan that combines theory with practice, in order to evaluate the overall effect of teaching, and to improve the next iteration of the course and the teaching within it.

The case study has indicated that students have a deep awareness of, and interest in, learning BIM and joint design; it has further suggested that software training and theoretical knowledge should be combined in BIM capstone courses. The results of this study can provide a reference point for educators in developing BIM capstone courses in highway engineering. By comparing the four groups, BIM meetings, as part of the design process, played an important role in reducing model collision and rework while instructor performance had no significant impact; this result can help to optimize the student design process. Through a correlation analysis, the study found that the prior knowledge of teamwork had the greatest correlation with performance of joint design, while Prior BIM training or study, Professional software skills, One single specialty, course design and Academic achievement had no correlation; the results can assist educators in motivating students and improving their design aided by teamwork.

In the future, more cases of schools or more student groups can be added. Future educators can also consider adding BIM construction technology, and BIM operation and maintenance management to the capstone to enrich the full cycle management of BIM.

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Appendices

Appendix I. A Survey of Students' Willingness to Participate in BIM Joint Design

No	Question
1	Governments and companies have introduced many policies that require the use of BIM technology.
2	In normal learning, it is difficult to get in touch with BIM technology.
3	In my usual study life, I found BIM is a very hot topic. I am very interested in BIM technology and would like to learn relevant knowledge.
4	I really want to know the working mode of the joint design in the actual work with other disciplines.

Note: The questionnaire is with Likert scale from 1 = very little, 2 = little, 3 = not necessarily, 4 = much to 5 = very much.

Appendix II. A Survey of Interdisciplinary Joint Design Based on BIM

No	Question
1	What's your major in the interdisciplinary joint design?
2	Before graduation design, I would like to know the working mode of joint design with other majors in actual work.
3	Before graduation design, I had participated in BIM related training or internship.
4	Before graduation design, I had participated in many student work and often worked with classmates to plan activities.
5	Before graduation design, I am skilled in professional skills such as CAD drawing and professional software.
6	Before graduation design, I have completed the course design of this major, and the design quality is high.
7	My academic performance.
8	During the training phase, the unified software learning can meet my software requirements in the design.
9	During the training phase, I am satisfied with the classroom condition of the laboratory.
10	During the training phase, I am satisfied with the computer equipment of the laboratory.
11	In the design process, I am very clear about the tasks of each stage arranged by the instructor.
12	At the beginning of the design, I have a clear understanding of the model and process of the entire joint graduation design.
13	During the design process, my discussions with other professions were very timely.
14	In the graduation design, the tutor played a leading role in my design.
15	In the graduation design, we have work together to reduce rework and collision modifications.
16	This graduation design, the group discussion is very helpful for my design.
17	This graduation design, I learned the basic operation of this professional BIM software.
18	This graduation design, I mastered the working mode of joint design with other professions under real working conditions.
19	This graduation design, my teamwork ability has improved significantly.
20	Overall, my graduation design is of very high quality.

Note: The questionnaire is with Likert scale from 1 = very little, 2 = little, 3 = not necessarily, 4 = much to 5 = very much. The options of the first question are Road engineering, bridge engineering, tunnel engineering, engineering costing, architecture, structure, water supply and drainage, heating and ventilation, and electrical engineering.