EVALUATION OF IMMERSIVE PROJECT-BASED LEARNING EXPERIENCES

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ABSTRACT

Digitalization is transforming the real estate and construction (REC) sector and a key feature of this transformation is Building Information Modelling (BIM) - the virtual representation of all building-related information. By enabling the creation of digital twins of real buildings, BIM generates opportunities to do many things in new and better ways including education and training. Specifically, BIM offers the possibility of data rich virtual environments in which project-based learning experiences can be designed. Researchers at Tallinn University of Technology, Tampere University and the University of Bologna are currently developing a prototype BIM-enabled Learning Environment (BLE) with the intention of providing more realistic, immersive and integrated learning experiences. In addition to the BLE platform itself, pilot learning modules are being created to demonstrate the potential for this approach and, to determine their effectiveness, evaluation tools are being designed. This research investigates existing, applicable evaluation models and derives an evaluation model and tools specifically adapted for the immersive project-based learning experiences provided through the BLE. A literature review was conducted to identify existing evaluation models. A comparative content analysis approach was employed to identify their specific use cases, implementation requirements, advantages and disadvantages for deployment within the BLE context. The BLE pilot learning modules were analysed in terms of their defining characteristics and the key features of evaluation models applicable to them were identified. The identified features were then integrated to derive a new evaluation model and a corresponding set of evaluation tools considering the contemporary principles of Engineering Pedagogy.
The research results include:

1) Defining characteristics of the BLE pilot learning modules and the challenges these pose for evaluation.
2) Existing evaluation models and their applicability to the immersive project-based learning experiences of the BLE.

3) An outline of the evaluation model and appropriate evaluation tools for the BLE learning modules.

An evaluation model together with supporting evaluation tools are proposed that will assist educators and trainers in evaluating the impact of their activities for effective engineering education. This research also serves as a guide for the development of future BLE learning modules and for evaluating their effectiveness.

KEYWORDS

Engineering education, evaluation, project-based learning, virtual environment, CDIO Standards: 11, 12

INTRODUCTION

Digitalization is transforming the real estate and construction sector and a key feature of this transformation is Building Information Modelling (BIM) - the virtual representation of all building-related information. By enabling the creation of digital data equivalents (digital twins) of real buildings, BIM generates opportunities to do many things in new and better ways including education and training. However, educators now face the challenge of educating students to ensure that their professional competencies are properly aligned with the emerging, digitalised REC industry (Du et al., 2017; Hwang & Safa, 2017; Tranquillo et al., 2018). Fortunately, students' motivation, satisfaction, and academic and professional performance have all been found to improve when education is mediated through technological innovations such as BIM (Ferrandiz et al., 2018). Thus, BIM both imposes challenges for REC education and also opportunities for improving it as it offers the possibility of data rich virtual environments in which project-based learning experiences can be designed.

Researchers at Tallinn University of Technology, Tampere University and the University of Bologna are currently developing a prototype BIM-enabled Learning Environment (BLE) with the intention of providing more realistic, immersive and integrated learning experiences. In addition to the BLE platform itself, pilot learning modules are being created to demonstrate the potential for this approach. To determine their effectiveness, evaluation tools for these modules need to be designed. This research investigates existing, applicable evaluation models and derives an evaluation model and tools specifically adapted for the immersive project-based learning experiences provided through the BLE.

In the following section of the paper, the research methodology is outlined. The results of a literature review of existing evaluation models is then presented. The key characteristics and features of the BLE and each of the three pilot modules developed to be delivered with the BLE platform are then described. The common characteristics and evaluation need of the pilot modules are then analysed and a proposed evaluation model and tools are outlined before the findings are summarised and conclusions are drawn.

METHODOLOGY

A literature review was conducted to identify existing evaluation models. A qualitative, comparative content analysis approach was employed to identify and understand their specific use cases and implementation requirements as well as their relative advantages and disadvantages for deployment in the context of the BLE modules. The BLE itself and its pilot modules were then defined according to their contents, teaching methods, learning outcomes, etc. to allow their analysis in terms of their defining characteristics and the key features of evaluation models applicable to them. The identified, applicable features of existing evaluation models were considered in outlining an appropriate evaluation model and evaluation tools in light of the contemporary principles of Engineering Pedagogy.

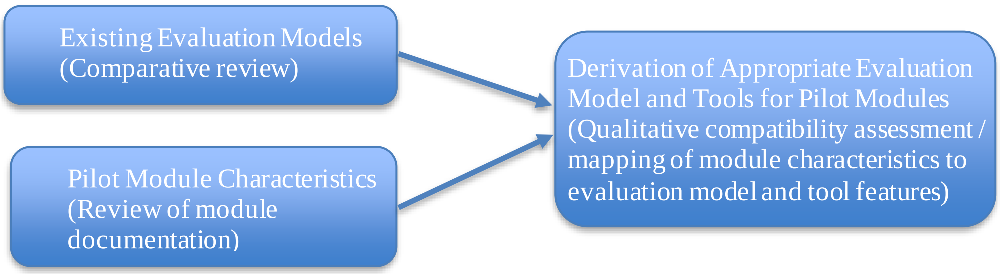

Figure 1. Flowchart of research methodology

REVIEW OF EXISTING EVALUATION MODELS

Olowa et al. (2021) found that the use of evaluation approaches in engineering education was generally low and little evidence of evaluation models being used in relation to BIM education interventions was available. This appears to be a long-term problem as Walder (2017) observed that, while the evaluation of pedagogical innovation is crucial, innovative pedagogical practices are usually not systematically evaluated. According to Walder (2017), professors who innovate frequently set the goal of developing additional skills that go beyond what they learned in traditional teaching, and it's critical to use the right evaluation methodology and avoid comparing what was done before with the results obtained after the pedagogical innovation has been implemented. Looney (2009) emphasizes that an evaluation approach that does not consider a program's original features may ignore important learning objectives targeted by this innovative program. Therefore, in the next section, the predominant contemporary evaluation approaches are reviewed together with their characteristics and relevance to evaluating BIM-enabled education.

Evaluation Models

Academic evaluation models are specific frameworks or methodologies which assist evaluators (researchers or practitioners) to design evaluation criteria and instruments for the purpose of measuring, ensuring, monitoring, controlling and improving academic related activities (Olowa et al., 2021). These activities are not necessarily limited to just teaching and learning which had been the case before the mid-sixties (Nevo, 1983) but encompass other incidental actors and actions within the context where they are performed. According to Stufflebeam (2003), academic evaluation is "…the process of delineating, obtaining, providing, and applying descriptive and judgmental information about the merit and worth of some object's goals, design, implementation, and outcomes to guide improvement decisions, provide accountability reports, inform institutionalization/dissemination decisions, and improvement decisions, and understanding of the involved phenomena". Evaluations are part of logical human activity and are similar irrespective of the approach adopted (Scriven, 1966). However, there are subtle and salient differences that are worth considering if the goal of the evaluation is to be realised. Many contemporary evaluation approaches have emerged and a selection of these are reviewed below.

Tyler's objectives-based evaluation

The objectives-based approach is particularly useful for evaluating programs that are narrowly focused and have clear, measurable goals (Stufflebeam & Coryn, 2008). Stufflebeam & Coryn (2014) opine that it is the most adopted approach among evaluators possibly because it is the easiest to use and appeals to common sense. However, what gives it its popularity is also its drawback in that it is considered too narrowly focused to be useful in evaluating a programme wholistically (Stufflebeam & Coryn, 2008). It is also not useful for formative evaluation as findings are only available at the end of the programme being evaluated. As such it cannot be used in process improvement and susceptible to giving a false positive (Stufflebeam, 1983).

Wheeler's model

Wheeler's model of curriculum development and evaluation is an amendment of Tyler's model (Cheng-Man Lau, 2001). Wheeler introduced the concept of continuity and developed a cyclic and flexible model of following steps: (1) define objectives and goals, (2) design learning experiences, (3) select course content, (4) organise learning experience, (5) evaluate.

Taba's inductive model

Taba's inductive model was first proposed by Hilda Taba in 1971 for curriculum design and evaluation, described in her thesis Curriculum Development: Theory and Practice in 1962 (Laanemets & Kalamees-Ruubel, 2013). The model considers the following six factors, to guide curriculum design and evaluation: (1) external factors (stakeholders), (2) content, (3) objectives, (4) teaching strategies, (5) learning experiences, and (6) evaluative measures. This model can be used in assessment and context and process evaluation, taking account of the expectations of stakeholders.

Context Input Process Product (CIPP) model

The CIPP approach was conceived and conceptualised by Stufflebeam in 1969 based on his experience with the funding and implementation of the Columbus project funded through the Elementary and Secondary Education Act of 1965 (ESEA). The perceived deficiency in applying the prevailing evaluation techniques at the time (especially the Tylerian model) informed the development of CIPP by Stufflebeam and his colleagues to include both context and process evaluations in addition to the input and product evaluations that were already in use (Stufflebeam, 1983). As such, the CIPP model allows for some sorts of interim procedural evaluations (formative evaluations) especially where academics cannot easily determine the change in students' behaviour due to an intervention. Although the CIPP model was primarily developed for projects meant to improve educational access to the less privileged and to overhaul the general system of elementary and secondary education in the USA, several authors and authorities have adapted the approach for evaluating different objects (Anh, 2018; Stufflebeam, 2003).

Scriven's consumer-oriented approach

Scriven (1966) suggests two roles of evaluation for curriculum builders and argued that the two are equally useful depending on the goal of the exercise. The first he referred to as instrumental and the second as consequential. Instrumental evaluation involves "…the instrument itself; in the case of a particular course, this would involve evaluation of the content, goals, grading procedures, teacher attitude, etc.," (Scriven, 1966). Consequential evaluation deals with "…examination of the effects of the teaching instrument on the pupil, and these alone. It involves an appraisal of the differences between pre- and post-tests, between experimental group tests and control group tests, &c., on a number of criteria parameters" (Scriven, 1966). He argues that substituting instrumental evaluation with consequential evaluation is not the best. He however emphasised that these are roles of evaluation and not procedures of evaluation. In giving processual outline of how to carry out evaluation, Scriven (1966) states that establishing the relationship between goals and course content, goals and examination content; and course content and examination content are important to a successful evaluation.

Stake's responsive evaluation

This approach was developed in the late 1960s as a replacement for "pre-ordinate" or experimental approaches, which paid little attention to the process and implementation of programs and had little engagement from stakeholders, including the beneficiaries, during the evaluation (Nyathi, 2020). The approach aims to expand the relevance of evaluation outcomes to a broader audience by de-emphasising goal-oriented approach to evaluation to provide different value perspectives of the stakeholders in reporting the success and/or failure of a program. According to Stake (1975) in Nyathi (2020), this approach is particularly useful during the early stages of a program, when stakeholders want to know what works and what doesn't, as well as how to improve program execution. Given the regular stakeholder communication and participation, one of the advantages of responsive evaluation is that practitioners do not need to wait for results until the evaluation is concluded but may start using findings during the process (Stufflebeam & Coryn, 2008).

Guba's constructivist, naturalistic evaluation

Guba's constructivist, naturalistic evaluation proposed a set of judgment criteria for constructivist evaluations that are akin scientific rigor, validity, and value standards (Stufflebeam & Coryn, 2008). The constructivist versions are credibility or trustworthiness, transferability beyond the studied context, dependability or reliability, and confirmability of data and data sources (Stufflebeam & Coryn 2008). One of the main points of these criteria is that the reliability and utility of an evaluation should be considered from the perspective of the evaluation report's users. Also, data are to be traced to their source and verified, and conclusions are to be assessed for logic, plausibility, and reasonableness. The strengths and weaknesses of this approach are well documented in (Nevo, 1983; Stufflebeam & Coryn, 2008).

Patton's utilization-focused evaluation

Stufflebeam & Coryn (2014) described Patton's utilization-focused evaluation as one of the four "eclectic" evaluation approaches whose use case is primarily informed by findings. Other forms of eclectic evaluations are Owen's evaluation forms approach; the cluster evaluation approach; and various participatory forms of evaluation (Stufflebeam & Coryn, 2014). Stufflebeam & Coryn (2014) further state that eclectic evaluation theorists get their ideas, style, and taste from a wide variety of places. Their methods are tailored to meet the objectives and preferences of a diverse variety of evaluation clients and evaluation projects, with the goal of analysing a program without being bound by the limitations of a single model or methodology. As a result, evaluators that take an eclectic approach use whatever philosophical foundation, conceptual structure, and methods most conducive to attaining specific evaluation goals and satisfying the needs of specific evaluation clients.

Experimental design

The goal of the experimental and quasi-experimental design approach to program evaluation is to arrive at unbiased findings about the success or failure of a program (Stufflebeam & Coryn, 2014). Individuals, groups, or other units are randomly assigned to one or more conditions; a special treatment is given to one group and none (or an alternative treatment) to another;

treatment conditions are held constant throughout the evaluation; and finally, a conclusion is reached (Stufflebeam & Coryn, 2014). Experimental and quasi-experimental design approaches have been used on diverse range of objects including employment; criminal justice; health care; cultural enrichment programs for children; preschool, elementary, and secondary education; distance education etc.

Case study evaluation
Investigators in case studies look extensively at the context, including program participants' demands, inputs, operations, intended and unintentional impacts, and any other processes (with all their intricacies) that are producing outcomes (Stufflebeam & Coryn, 2014). The portrayal of events, testimonies, stored data, and personnel participating in program implementation and direction are all prioritized so that stakeholders have the knowledge they need to understand the program and make necessary modifications. This data will unavoidably portray the multifaceted nature of the environment in which a program is taking place (Stufflebeam & Coryn, 2014). The authors surmised that an in-depth, noninterventionist investigation of a case and the issuance of illuminating report are the hallmarks of a case study evaluation.

Processes in evaluation approaches
Usually, evaluation approaches contain suggestions for several procedures or stages for implementing evaluation projects or programmes. The number of steps in the models varies, ranging from three to ten steps or processes (Olowa et al., 2021). These steps or processes are observed to be dependent of the philosophical background of the evaluation approach. Nevo (1983), in his review of major evaluation approaches in education, argued that there is no consensus among evaluation experts on the "best" process to use when conducting an evaluation. He, however, observed that most evaluators agree that all evaluations should include some level of interaction between evaluators and their audiences both at the start of the evaluation to identify evaluation needs and at the end to communicate the results. Nevo (1983) concluded that the technical activities of data gathering, and analysis are not sufficient for evaluation.

Evaluation Models in Engineering Education
In their review of over three hundred engineering articles and twenty-four general evaluation publications, Olowa et al., (2021) observed that engineering educators have been found to employ a variety of methodologies for evaluating engineering education for a variety of reasons, across a variety of time periods, and with differing degrees of complication. Major approaches they found include Accreditation Board for Engineering and Technology ABET, Baseline interview, longitudinal studies and portfolios, Web-based course for course evaluation questionnaires, Course panels and instructor reflective memos, QUESTE-SI (Quality system of European Scientific and Technical Education for Sustainable Industry), Student grades and SAPA (self- and peer-assessment). They further state that only the CDIO (Conceive-Design-Implement-Operate) standards, ABET, QUESTE-SI, and other educational board models appear to assist engineering education. The CDIO's creators argued that the model is more consistent, thorough, and detailed than other national and international standards such as UNESCO. The 12 CDIO standards form a solid basis for evaluation.

BIM-ENABLED LEARNING ENVIRONMENT AND PILOT MODULE DESCRIPTIONS

In this section, the salient features of the BLE and of the 3 pilot courses designed to demonstrate these features are set out.

The BIM-enabled Learning Environment (BLE)

The BLE is a web-based platform currently under development with the specific purpose of providing a host environment for learning experiences that leverage BIM for education and training. It does this by enabling the following types of function:

- BIM functions - such as: BIM model viewing, editing, sharing, data extraction, a common data environment for project data, simulation of the BIM work flow, example project data resources, etc.
- Virtual learning functions - such as: user registration, learning materials hosting, assessment, feedback, file upload, file download, etc.
- Collaboration functions - such as: group formation, communication channels, live interactions, collaborative file viewing and editing, etc.

The BLE is intended to enable immersive and integrated learning experiences on the basis of realistic project data and a realistic industry work flow that fully utilizes BIM. As BIM ensures comprehensive, organised and readily accessible project data that are mostly referenced to building objects (walls, beams, columns, windows, doors, floor slabs, pipes, etc.) represented in a virtual, 3D model of the building, project data can be easily visualized and understood. It thus enables realistic and quite complicated project scenarios to be presented to and efficiently grasped by students.

This supports experiential learning activities where data input to the learning activity is real (or, at least, realistic) project data and is drawn from similar sources as would be the case in industry. Of course, this project data must be prechecked and simplified to remove inconsistencies and unnecessary details which could confuse learners. By carrying out the learning activity, the project data is further processed and the output data feeds back into the BIM work flow. The project data are thus elaborated and the project progresses in a similar fashion as it would in the 'real world'. In this way, the learning activity resembles a meaningful task in a genuine work context.

An initial set of 3 pilot modules is being developed to demonstrate the BLE, its functions and, more widely, the concept of BIM-enabled learning. Each pilot module focuses on different aspects of the BLE capabilities and is being collaboratively developed under the leadership of one of the partner universities as follows:

1. Pilot Module 1 - BIM-enabled Construction Site Organisation - led by University of Bologna;
2. Pilot Module 2 - BIM-enabled Project Risk Management - led by Tallinn University of Technology;
3. Pilot Module 3 - BIM-enabled Design Management - led by Tampere University.

The pilot modules will be developed to systematically cover everything that the 3 types of users (instructors, learners, system administrators) need to know and they will represent the standard practice for future BLE learning modules. They are each described in more detail below.

A comprehensive evaluation model and tools are needed in order to establish whether these pilot modules meet expectations in terms of their efficient achievement of learning objectives, etc. and the current research aims to derive such an evaluation model and tools.

Pilot Module 1 - BIM-enabled Construction Site Organisation

This module addresses the benefits of applying BIM technology for the organisation of construction site organization and logistics. The module is delivered in four phases as follows:

Phase 1. Learners are introduced to the principles and theory of BIM
Phase 2. Learners are introduced to relevant software packages that enable them to apply BIM within the context of construction site organization.
Phase 3. Learners work in groups, each group assigned to a different building site case in order to determine an efficient construction site layout (crane types and positions, materials stores, site offices and facilities, etc.) for that building case.
Phase 4. Learners review, compare, discuss and reflect on their derived solutions.

It should be noted that, as BIM models and associated data are created and further elaborated in the course of the learning activities, they are then expected to be deposited into the model and data repository and thus increase the example project data resources available to users of the BLE.

Pilot Module 2 - BIM-enabled Project Risk Management

Learning activities for this module proceed as follows:
Initial instructions:

- Key steps in the process of project risk management;
- Instructions and information for participation in the learning activities.

The learning activities comprise a series of risk management workshops held at different project stages. Students work through a guided, detailed project risk management process (including both qualitative and quantitative risk analysis) on the basis of real project data within a BIM work flow.

Pilot Module 3 - BIM-enabled Design Management

This pilot module involves a multidisciplinary simulation of the concept design stage of a construction project, where students are organised into stakeholder groups (Client, Architect, BIM coordinator, etc.) and, to an extent, students' specialisations (architecture, construction management, structural engineering, etc.).

A single project scenario is given and the stakeholder groups work sequentially and in collaboration to analyse, simulate and integrate the building design using a BIM model and other available resources. Faculty members and industry mentors advise the students throughout the development process.

DERIVATION OF AN EVALUATION APPROACH AND TOOLS

The aim of an evaluation model and tools is to evaluate the following aspects of the teaching and learning process: the extent to which learning objectives are achieved, and the effectiveness of the teaching-learning experiences provided, identifying areas for improvement and supporting further development of the module design and implementation, realizing learning outcomes more efficiently.

Common Module Features, Teaching Methods and Learning Objectives

The described modules have common features based on multidisciplinary principles of problem-based learning, where students have to solve real-world problems and make informed decisions using simulations. Additionally, the principles of John Boyd's OODA-Loop (Observe-Orient-Decide-Act) for informed decision-making is one of the foundations of active learning in all modules. Accordingly, inductive teaching methods, like case studies, "just-in-time" teaching, "on-board" teaching, team-based learning, problem solving, and active learning methods are used for supporting critical and creative thinking, and meaningful learning. The learning objectives of the described modules should cover all the levels of Bloom's Taxonomy ensuring the acquisition of basic knowledge in specialty and supporting skills of analysis and evaluation along with collaboration and cooperation. While the assessment methods used rely mostly on self-evaluation, peer-evaluation and reflection, thus learning portfolios will be introduced along with the formative and summative assessment of an instructor.

Proposed Evaluation Model and Tools

A model for evaluation consists of three basic components: inputs (resources of the program: program staff, funding, time, partners, materials, etc.), outputs (the model, training, methodology, etc.), and outcomes (knowledge, attitudes, awareness, skills, behavior, educational quality, impact, etc.). Within the present research, both qualitative and quantitative evaluation tools may be used. The proposed tools will be elaborated with the aim of evaluating the described modules on the basis of CDIO standards and the integration of suitable evaluation models.

CONCLUSIONS

Development process of a prototype BIM-enabled Learning Environment (BLE) with the intention of providing more realistic, immersive and integrated learning experiences have been analysed. In addition to the BLE platform itself, pilot learning modules are being created and introduced to demonstrate the potential for this approach and, to determine their effectiveness, the principles of creation of evaluation tools are described. This research paper presented existing, applicable evaluation models and derived the principles of evaluation models and tools that will be specifically adapted for the immersive project-based learning experiences provided through the BLE.

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REFERENCES

Anh, V. T. K. (2018). Evaluation Models in Educational Program: Strengths and Weaknesses. *VNU Journal of Foreign Studies*, *34*(2), 140–150.

Du, J., Zou, Z., Shi, Y., & Zhao, D. (2017). Simultaneous Data Exchange between BIM and VR for Collaborative Decision Making. *Congress on Computing in Civil Engineering, Proceedings*, *2017-June.* 1–8.
Ferrandiz, J., Banawi, A., & Peña, E. (2018). Evaluating the benefits of introducing "BIM" based on Revit in construction courses, without changing the course schedule. *Universal Access in the Information Society*, *17*(3), 491–501.
Hwang, S., & Safa, M. (2017). Learning Advanced Decision-Making Techniques and Technologies through a Collaborative Project. In K.-Y. Lin, N. M. El-Gohary, & P. Tang (Eds.), *Congress on Computing in Civil Engineering, Proceedings* (Vols. 2017-June, pp. 35–42). American Society of Civil Engineers.
Läänemets, U., & Kalamees-Ruubel, K. (2013). The Taba-Tyler Rationales. *Journal of the American Association for the Advancement of Curriculum Studies*, *9*(2), 1–12.
Lau, D. C. M. (2001). Analysing the curriculum development process: Three models. *Pedagogy, Culture and Society*, *9*(1), 29–44.
Looney, J. W. (2009). Assessment and innovation in education. In *OECD Education Working Papers* (Vol. 24, Issue 24).
Nevo, D. (1983). *The Conceptualization of Educational Evaluation: An Analytical Review of the Literature*. *53*(1), 117–128.
Nyathi, N. (2020). *An Overview of Responsive Evaluation*. https://medium.com/@nqabuthonyathim/an-overview-of-responsive-evaluation-4a7996bc3356
Olowa, T., Witt, E., & Lill, I. (2021). *Evaluating Construction Education Interventions* (M. . Auer & T. Ruutman (eds.); ICL 2020, pp. 497–508).
Scriven, M. (1966). *Social Science Education Consortium. Publication 110, the Methodology of Evaluation.* https://eric.ed.gov/?id=ED014001
Stufflebeam, D. L. (1983). The CIPP Model for Program Evaluation. *Evaluation Models*, 117–141.
Stufflebeam, D. L. (2003). The CIPP Model for Evaluation. In *International Handbook of Educational Evaluation* (pp. 31–35). Springer Netherlands.
Stufflebeam, D. L., & Coryn, C. L. S. (2008). Evaluation Theory, Models, and Applications. In *JAMA* (second, Vol. 299, Issue 22). Jossey-Bass.
Tranquillo, J., Kline, W. A., & Hixson, C. (2018). Student-created canvases as a way to inform decision-making in a capstone design sequence. *ASEE Annual Conference and Exposition*, *2018-June*.
Walder, A. M. (2017). Pedagogical Innovation in Canadian higher education: Professors' perspectives on its effects on teaching and learning. *Studies in Educational Evaluation*, *54*, 71–82.
Witt, E., Olowa, T., & Lill, I. (2021). Teaching Project Risk Management in a BIM-Enabled Learning Environment. In Auer, M. E. & T. Rüütmann (Eds.), *ICL2020 – 23rd International Conference on Interactive Collaborative Learning* (AISC 1328, pp. 162–173). Springer Nature Switzerland AG 2021.

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