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Designing a Seamless STEM Learning Environment: IN-STEM for Collaborative Problem Solving

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Abstract: In this paper, we propose and introduce the design principles of a Seamless STEM learning environment namely IN-STEM, present the key features of the system and the methods of system development and evaluation. The proposal will inform the pedagogical design of STEM learning in various contexts and STEM teacher education, and fill in the blank on the design and development of inquiry-based and seamless STEM learning environment.

Keywords: Seamless learning environment, IN-STEM, collaborative problem solving

1. Introduction

The changing pedagogies and evolving technologies have merged to create various CSCL opportunities in Science, Technology, Engineering, Mathematics (STEM) education. Meanwhile, with the advocacy of the development of 21st-century skills, the cultivation of self-directed learning skills, critical thinking skills, problem solving skills, information and communication technology skills, and collaborative learning skills have received growing attentions in many countries (OECD, 2018). Along with this trend, "new skills"- Collaborative Problem Solving (CPS) skills are emphasized in the PISA 2015 framework. Recently, a bulk of STEM education practices have been carried out. However, more efforts are needed to improve STEM education. Few studies were reported to enhance teachers' competences on STEM activity implementation supported by technology (Akaygun, & Aslan-Tutak, 2016). In particular, pedagogical strategies which enabled STEM implementation in a more theoretical way were neglected. Moreover, there were more foci on developing web-based STEM resources and less emphasis on developing an interactive and seamless learning system facilitating teachers' teaching and students' learning of STEM activities in and out of classroom. To address these, we design and develop a learning management system named: IN-STEM. IN-STEM can be the acronym of both INquiry STEM learning environment and INtegrated STEM learning environment. The system will facilitate teachers to design and implement inquiry-based STEM activities and engage students in collaborative problem solving processes. The research will lay a pedagogical foundation for STEM education supported by technology. It will inform STEM teacher education, STEM curriculum design, development, and implementation.

2. Theoretical Foundation

CSCL supported CPS is particularly suitable for solving complex problems in the STEM-based learning context. CPS is the capacity of an individual to effectively engage in a process whereby two or more agents attempt to solve a problem by sharing the understanding and effort required to come to a solution and pooling their knowledge, skills and effort to reach that solution (PISA, 2015). The definition combines the key components of collaborative learning (Dillenbourg, 1999) and problem solving (Mayer, 1990). Participating in the CPS-based learning activities will involve students in the problem solving process as well as interactive learning process. Further, inquiry learning often incorporates an element of collaboration, which means the engagement of participants in a common endeavor (Dillenbourg, 1999; Linn, 2003). Apparently, once CPS is located in the inquiry phases, there will be more potential for new findings on the mechanism of cognition and skill development which are under exploration.

According to Dugger (2010), STEM highlights integration of the mentioned subject areas as a new cross-disciplinary subject in schools. Although it is not mandated to integrate disciplines for STEM education, and it is also not necessary to blur the lines between disciplines, most of the work is oriented to STEM integration (Asghar, et al. 2012). We must confess that when studying STEM education, the STEM integration is unavoidable. Understanding STEM integration will help the teachers to better understand STEM teaching and make them more awareness of how and why we implement STEM education. Theoretically, STEM integration is a type of curriculum integration (Beane, 1997; Wang, et al., 2011), which offers learners coherent education, allowing connections to be made within and across subjects. Borrowing the ideas from the theory of curriculum integration (Aikenhead, 1992; Drake, 1998; Jacobs, 1989), and building on Blum's dimensions of integration in the integrated science (Blum, 1973), "scope" and "intensity" are the two dimensions used for assessing the integration degree of STEM-based activity.

Regarding STEM integration, the scope refers to the content knowledge within STEM disciplines and skills within or beyond STEM areas. For example, the STEM topic robotics includes knowledge of mathematics, science, engineering and relevant skills such as spatial skills, interpreting and picture sequencing skills. Identifying the scope of STEM activity will help the teachers to better facilitate students' understanding of content knowledge of different disciplines, to better link concepts and skills from two or more than two disciplines. Identifying the skills applied in STEM problem solving will enable teachers to design activities for meeting the needs of future society. Referring to the intensity, it is the degree to which the subject matter has been truly integrated (Blum, 1973), it is divided into three levels where amalgamation is the most fully integrated level. Amalgamation occurs when an interdisciplinary topic forms the unifying principle. The combined level of integration occurs when an activity is organized around headers from the different disciplines and with separate subjects but where the seams between them have disappeared. Coordination is the least integrated level. Coordination exists when independent subjects are taught simultaneously, in which some of the science subjects are woven together. (Blum, 1994; Sun, et al., 2013; Rennie, et al, 2014). Thus, these will support use to design and develop a visualization tool with identification of STEM integration scope and levels in the system.

3. The Key Features of IN-STEM Leaning Environment

IN-STEM incorporates CSCL design features into inquiry learning activities. Recently, few CSCL studies have explored students' learning performance when they are involved inquiry activities in a collaborative way. In particular, exploring students' performance in each inquiry phase is under researched. The topic has attracted scholars in the field of learning sciences (Ludvigsen, et al., 2016; Song & Looi, 2012; Sun & Looi, 2013, 2016; Tissenbaum & Slotta, 2012). As a learning management system (LMS), IN-STEM learning environment consists of two modules: teacher module and student module. The teacher module has three functional sections (Figure 1). 1) Profile allows teachers to input personal information: username, school, grade level, and class list. 2) Project manage is the key section for teachers to create inquiry-based STEM activities. The teacher provides basic information of the project via editing Project Detail. Project Content is used to design activities at four inquiry phases we proposed: Questions and Predication, Exploration, Explanation and Reflection. The teacher focuses on writing instructions for each phase. Uniquely, there is another section, namely Project Profile for teachers to input the scope and intensity of STEM activities (Figure 3) before implementation. In the system, each STEM activity will receive an integration score (i.e. Integration scope & intensity score) based on the STEM integration levels. Additionally, according to the skills of STEM activities (i.e. inquiry skills, collaborative learning skills, etc.), additional scores will be given. Finally, each STEM activity will have a STEM integration score for representing the integration degree. Teacher allows grading and commenting on students' responses in each inquiry phase.

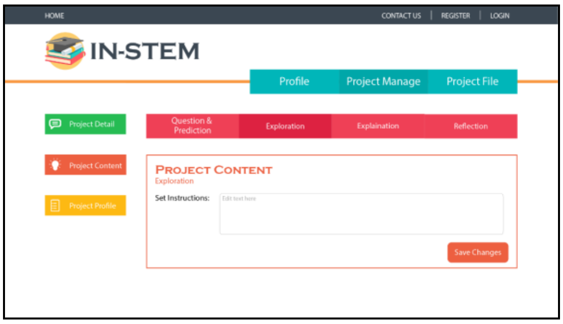

Figure 1. Interface of Teacher Module

There are two sections in student module: student profile and STEM project. After logging the system, students join the inquiry-based STEM activity the teacher has created, with a response to each task in the inquiry phase. They will either do group work or individual work or both in Questions and Predication, and Explanation stages. They will do collaborative inquiry at the Exploration stage and self-reflection at the Reflection stage. Figure 2 is the interface of STEM activity (i.e. Exploration). Students will be required to submit their plan, procedures and evidences during Exploration phase.

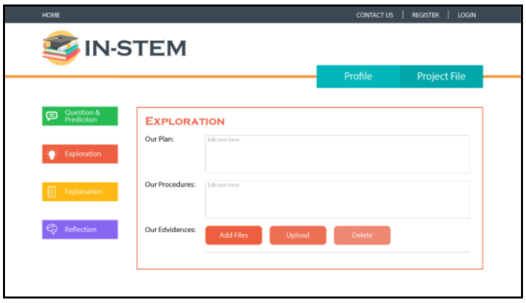

Figure 2. Interface of Student Module

To better support students at lower levels to engage in STEM learning, the system provides a visualization tool for teachers to identify the knowledge and skills involved in the activity (Figure 3). It is convenient for them to provide appropriate and in-time scaffoldings for the students in and out of class (Baran, et al., 2016).

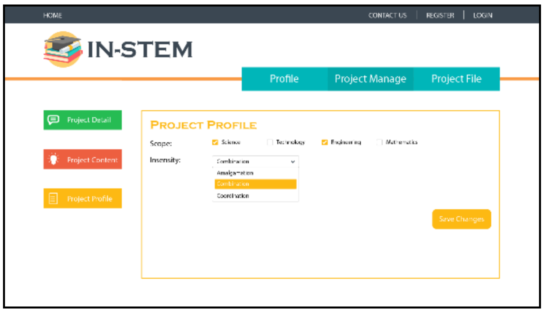

Figure 3. The STEM integration level

Table 1 is used to better understand the nature of STEM integration and guide the teacher to design and implement STEM learning in more principled and structural ways. We list four STEM disciplines as the scopes of STEM integration horizontally, and three levels of intensity are listed vertically. We assign a number for representing the degree of STEM integration. For example, if the activity requires students to apply knowledge from one subject (i.e. science), the integration degree will be 1 (for this case, the intensity can be neglected as only one subject is involved, and the teacher need to prepare content knowledge and skills of this subject). The number will decrease along with the decrement of intensity. We will integrate this coding method in the system for design and development of the visualization tool for representing the STEM integration.

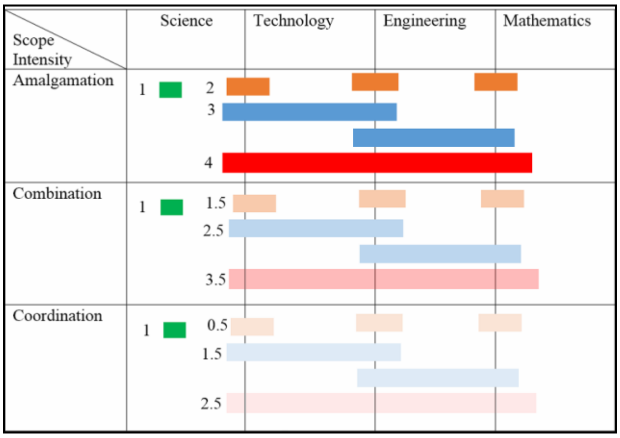

Table 2. The STEM integration matrix

Based on students' performance, teachers can adjust the design of activities to a level suitable for students. In brief, the combination of CSCL, inquiry-based learning and STEM are rarely investigated. We expect there will be more potential and valuable findings through an in-depth investigation. Finally, with such a STEM LMS, teachers' sharing and discussion of STEM resources will be an effective way for them to improve professional development in STEM education.

4. Methods of System Design and Development

The IN-STEM system is built on the WISE system via customizing functions and swapping out unnecessary functions in the WISE system. WISE is a comprehensive web-based learning platform which provides teachers with a powerful authoring tool to design guided inquiry activities and various learning tools for the students to complete the inquiry-based learning activities (Linn & Eylon, 2011). Meanwhile, to facilitate students' seamless learning in and out of classroom, the mobile version will be developed as well. The WISE code can be accessed from GitHub, it can be customized and installed on projects' own server. (Please see https://github.com/WISE-Community/WISE). Therefore, we will translate appropriate functions of the WISE system into the IN-STEM system, meanwhile, the new functional feature of identifying integration degree and CSCL design features will be embedded. Specifically, the STEM integration visualization tool will be developed and integrated into the IN-STEM system.

Along with an in-depth literature review for consolidating the theoretical foundation of the project, and following the common strategies of system design and development, an iterative cycle of design → discuss and modify the design→ develop key features → evaluate→ redesign and improve based on design-based research (DBR) (Fishman, et al., 2004; Revve, 2000) will be employed for consolidating the features of the IN-STEM system. There will be five short cycles in the development process. The key features of Teacher Module and Student Module has been firstly developed and usability tested. Then the simplified version will be established and tested with the embedded STEM integration tool.

5. Conclusion and Implication

In this paper, we propose the idea of designing and developing an innovative and seamless STEM learning environment. The system integrates the design features for facilitating teachers to design inquiry-based STEM learning in collaborative learning context. The design and development will contribute the field of technology supported STEM education, and with the going on of the project, a part of data will be released for further verifying the learning efficacy of the IN-STEM learning environment. We hope there will be an online community based on IN-STEM system which attracts more experienced teachers to share their STEM projects and learning activities with identifying STEM integration scope and levels. This will further guide the development of STEM curriculum and contribute the teacher professional development in STEM education.

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