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THE EFFECT OF A BLENDED COLLABORATIVE LEARNING ENVIRONMENT IN A SMALL PRIVATE ONLINE COURSE (SPOC): A COMPARISON WITH A LECTURE COURSE

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Abstract. *This study explored the effect of blended learning in terms of model-based collaborative learning in a small private online course (SPOC) environment on 10th graders' achievements in stoichiometry through a quasi-experimental design. The participants included 140 tenth graders assigned to two groups: (a) the experimental group, which studied in a blended environment (N = 69) and (b) the control group, which studied in a conventional lecture-based environment (N = 71). The results revealed that the experimental group exhibited significantly superior performance than the control group after the intervention and that the key factor in enhancing students learning is the teacher's facilitation. These findings implied that the blended model-based collaborative learning in a SPOC environment with proper design, facilitation, and face-to-face interaction groups provided students with opportunities to engage in learning to improve their achievements.*

Key words: *collaborative learning, interactive learning environments, model-based Instruction, small private online course, stoichiometry.*

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Introduction

Massive open online courses (MOOCs) greatly influence conventional classroom learning. They provide another learning system, through which students can repeatedly watch online videos. The benefits of students' learning are re-enlightened by shifting the focus of the teaching methods from teacher-centered to student-centered to widen in-depth discussion in class. In practice, it is difficult to ask students to preview videos for all subjects (Breslow, Pritchard, DeBoer, Stump, Ho, & Seaton, 2013; Yuan & Powell, 2013). In addition, because students may have questions about videos, they cannot solve problems and, therefore, do not receive timely feedback. Owing to the limitations of direct alignment with course guidelines for high school courses, most studies show the effectiveness of MOOCs for university students or upper age groups (Alraimi, Zo, & Ciganek, 2015; Imlawi, Gregg, & Karimi, 2015). Teaching high school students, who require much more specific instructional support, is entirely different from teaching either university students or lifelong learners. Selecting suitable videos and affordances for students is a crucial component toward learning online in class. Small private online courses (SPOCs), referring to a version of a MOOC used locally with on-campus students, provide a solution for high school students' learning online in class. Teachers select specific videos for their students to preview or watch in class rather than at home and act as facilitators providing opportunities to engage students in learning. However, studies on the implementation and effectiveness of SPOCs in science learning remain scant. This study *explored* the design of a SPOC for chemistry beginners and their performance after completing the course.

From MOOCs to SPOCs

MOOCs provide an opportunity to elevate the quality of existing residential courses in higher education (Jordan, 2014; Voss, 2013). Students can enroll in related courses, which they select at their universities, to widen their scopes. However, the low completion rates of these courses demonstrates that providing some scaffolding to engage students in learning through online lecture videos is required (Alraimi et al., 2015; Piccioni, Estler, & Meyer, 2014). Some studies have reported a slight change from MOOCs to SPOCs, which is a facilitator being assigned to lead learning activities, assess student achievements, and provide timely feedback (Fox, 2013; Piccioni et al., 2014). In class, a SPOC uses materials from free online learning platforms and provides students with additional practical activities to promote further learning. It has been suggested that MOOCs materials can be used in a blended setting to supplement students' learning experience in real classrooms (Bos, Groeneveld, van Bruggen, & Brand-Gruwel, in press; Fox, Patterson, Ilson, Joseph, Walcott-Justice, & Williams, 2014; Kong, 2014). Rather than watching videos, materials need to be reorganized using suitable learning modules according to different classroom scenarios to improve the time devoted to learning per period.

Collaborative Learning

Collaborative learning is a pedagogical approach wherein learning takes place via social interaction by the sharing and construction of knowledge among participants. Different from cooperative learning highlighting the effects of group interaction on individual learning, collaborative learning more focuses on cognitive processes of learners. Studies with technology in support of collaborative learning explore what affordances with new technology enhance deep understanding (Resta & Laferrière, 2007). It is needed for all participants to organize collaborative learning communities facilitating learners to complete the courses. The literature shows that well-designed practical strategies including classroom management and instructional design can contribute to students' engagement and involvement (Chen & Chen, 2015; Gettinger & Ball, 2007; Tekbiyik, 2015). Interactive teaching, such as discussion, review, or reflection, involves a high level of student–teacher interaction, which provides a strong academic focus. However, only a few studies have demonstrated how to engage students in SPOCs during student–teacher interactions.

Model-Based Instruction

Scientists work with various types of models to generate, validate, and predict patterns or mechanisms underlying specific phenomena (Giere, 1988; Halloun, 2004). Model-based instruction is a method that instructs students about how scientists use models and develop students' own competencies for using models in science learning. The literature indicates that model-based instruction facilitates students' performance (Jong, Chiu, & Chung, 2015; Halloun, 1996; Schwarz et al., 2009). Jong and his colleagues create novel model-based text to provide students with reflection on what they read to develop their modeling competencies. Through such activities, students gained experience regarding how scientists generate, test, validate, and modify scientific models. Based on constructionism and constructivism, model-based instructions not only focus on individual construction learning, but also on collaborative learning. It is argued that integrating model-based instruction and collaborative learning, particularly in SPOC environments, can focus on subjects taught by teachers and students' involvement in learning.

Stoichiometry

Stoichiometry is the main topic of high school chemistry. Stoichiometry is related to balancing a reaction formula, moles, and Avogadro's constant. Studies have shown that stoichiometry is difficult to learn for many students in secondary school chemistry courses (Gabel & Bunce, 1994; Krishnan & Howe, 1994; Pyatt & Sims, 2012; Schmidt, 1990, 1994). Students tend to lack mathematical reasoning and conceptual understanding of stoichiometry when solving quantitative problems. Helping students to construct conceptual structures for various problems, when applying similar or different contexts, is crucial in overcoming their obstacles. Dori and Hameiri (2003) describe a multidimensional analysis system, which is a framework for composing and classifying mole-related quantitative chemistry problems. They observe that students exhibited superior performance in solving these difficult problems after intervention; however, they ignore that mental models correspond to the problems, which consist of objects and their relationships that the students construct, revise, and reconstruct. In classroom practice, teaching modules are investigated for simplifying this difficult part for the teacher.

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Framework for Integrating Model-based Instruction and Collaborative Learning in a SPOC Environment

This study first explored the effects of blended model-based collaborative learning in a SPOC environment on students' performance regarding stoichiometry. A teacher adopted the blended method to integrate online video watching and face-to-face discussion in the classroom. First, mental models were generated through video watching; then the teacher provided students with opportunities to validate and examine their mental models when faced with conflicting or inconsistent results from other students. Therefore, I argued that the generation, revision, and reconstruction of mental models by students through the blended method can act as a channel for teaching students about scientific enterprises. In practice, I adapted and simplified the cooperative process (Johnson & Johnson, 1994) to facilitate generation, revision, and reconstruction of students' mental models that implicitly provided the stages of the collaborative modeling process. As shown in Figure 1, three recursive and simplified collaborative stages existed; instruction, discussion, and reflection. In the instruction stage, teachers selected suitable materials to help students watch or read in class connected to their prior experiences. The major work of teachers at this stage was to help students generate their mental models. In the discussion stage, intra-group and intergroup discussions were necessary including what open-ended or semi-structured questions could be obtained from peers or teachers to validate and examine students' mental models. The major work of teachers at this stage was to facilitate students in revising and reconstructing their mental models. At the third stage, i.e. reflection, teachers encouraged students to reflect and overcome the barriers in the process, and praised them for their outstanding performance observed through intergroup comparison. At this stage, teachers provided students with opportunities to reflect their learning processes to examine how their models were constructed, revised, and reconstructed.

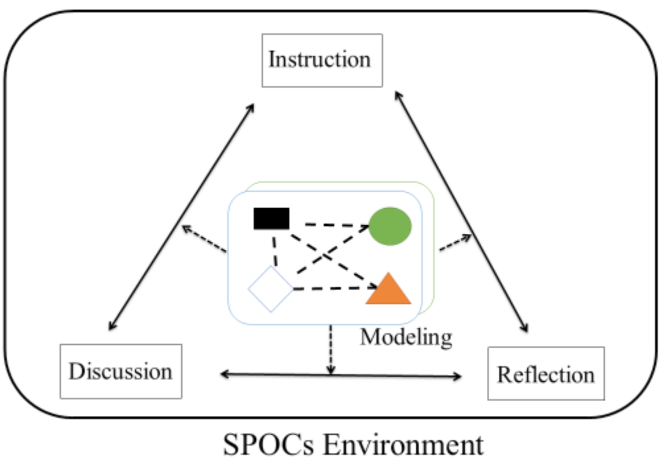

Figure 1: Framework of model-based collaborative learning in SPOC environments.

The hypothesis of this study is that exposure to the blended-model-based collaborative learning in a SPOC environment results in students exhibiting superior performance. Two questions are addressed as follows:

1. What are students' stoichiometry achievements after they are exposed to the blended teaching method?
2. How can the teacher facilitate students' deep understanding with the blended teaching method?

In this study, a model was defined as comprising multiple components and the relationships between them. Therefore, the mental models were based on students' cognitive structure of stoichiometry, including balancing the reaction formula, use of mole, Avogadro's constant, and yield of products. Scientific models referred to the correct contents provided by chemists or textbooks.

Methodology of Research

The context and participants were first described, followed by the materials and assessments used for this study. Then, the research procedure which involves the educational intervention, data collection, and data analysis were presented.

Participants

This study was conducted during the spring semester of 2015, and participants were 140 tenth grade students (aged 15–16 years) from a high school in New Taipei City, Taiwan. All the participants were from middle-class families. None of the participants had any previous experience in model-based and SPOC-related learning activities. Participants were selected from four classes through purposive sampling and were taught by the same chemistry teacher. The four selected classes were randomly assigned to an experimental group (two classes, $N = 69$) or a control group (two classes, $N = 71$). The chemistry achievement test during the autumn semester of 2014 (experimental group = 48.23, standard deviation (SD) = 13.54; control group = 47.07, $SD = 16.55$, $t = .454$, $p = .651 > .05$) and pretest of a concept test (experimental group = 23.55%, $SD = .12$; control group = 26.83%, $SD = .14$, $t = 1.466$, $p = .145 > .05$) showed that the differences between the experiment and control groups were not significant, which indicated that the students in these two groups had approximately the same levels of conceptual knowledge of chemistry.

Materials

A locally published high school textbook was used for both groups in this study. The video-materials used in the experimental group were obtained from the Junyi Academy platform, an e-learning platform in Taiwan, which was similar to Kahn Academy. Junyi Academy provided over 300 exercises and videos for all science subjects of high school. Balancing reaction equations, ideal stoichiometry, limiting reagent of stoichiometry, and yield of products were included. Instead of video-watching, the teacher gave the control group lectures which were the same content with the experimental group. Since the experimental group contained more discussions and reflections, students in the control group were asked to practice more exercises in order to equalize the time students in both groups spent in class.

Concept Assessments

Fifteen multiple-choice and five closed-ended questions were used to assess students' acquisition of the main concepts (Appendix A). Table 1 presented the propositional descriptions. The students could complete the assessment within 40–50 minutes. The concept assessments were finalized and face validity of the assessments was verified by two science educators who each had at least 3 years of experience in the field of scientific modeling and two chemistry teachers who each had 5 years of experience; revisions were made according to comments from the reviewers. The assessment's Cronbach α was .83. The concept assessments were conducted during the pretest and posttest.

Table 1. Main concepts and propositional descriptions in the stoichiometry concepts assessment.

Main concept	Propositional description	Number of items
Balancing reaction equations	Based on the law of conservation of mass, differences kinds of atoms in reactants is equal to products	4
Ideal stoichiometry	Determine the amount of a product from a given amount of one reactant.	4
Limiting reagent stoichiometry	Determine the amount of a product from given amounts of two reactants, one of which is limiting.	9
Yield	The percentage yield is calculated by dividing the amount of the actual and theoretical product.	3
Total items		20

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Research Procedure

This study used a field quasi-experimental design. The course for both groups, which lasted 12 periods for 6 weeks, was divided into four units: balancing reactions, ideal stoichiometry, limiting reagent stoichiometry, and yield of product. Before the first period of balancing the reaction, students from the two groups were asked to complete the pretest. During the experimental phases, the experimental group adopted the blended method for model-based collaborative learning in a SPOC environment, while, the control group adopted the lecture-based method without any discussion in class. In the experimental group, for example, considering a period (50 min per period) of limited reactant stoichiometry, the teacher provided web addresses of videos (approximately 10–15 min long) to students who were provided with iPads for viewing through self-paced learning. After watching the videos, students were asked to discuss face-to-face what the videos demonstrated to validate their mental models (approximately 5 min). Then, similar contexts of practices were assigned to each group to examine the transfer of their mental models (approximately 5 min). The teacher acted as a facilitator to provide hints for group discussions (approximately 10 min). Moreover, students who were volunteers or assigned were asked to solve the problems and were scored based on their explanations for solving the problems (approximately 5–10 min). Finally, the teacher asked students to reconsider how they learned in this period and how they generated, revised, and reconstructed their mental models, while also praising hardworking groups (approximately 5 min). By contrast, in the control group, the teacher adopted the lecture-based method to show the students how to solve the problems (approximately 30–40 min) and asked students to practice (approximately 10–20 min) without emphasizing the process of revision and reconstruction of their mental models. Few interactions among students or between students and the teacher were observed. After the experimental phase, that is, 6 weeks later, the concept assessments were used for the posttest.

Data Collection

A mixed-method was adapted in this study. Quantitative data were collected from the results of the stoichiometry concept assessments in the pretest and posttest. The teacher's lectures and dialogues in class were collected using a video recorder and transcribed into verbatim.

Data Analysis

Data analysis involved both quantitative and qualitative methods. One-way analysis of covariance (ANCOVA) was used for comparing the posttest scores of the concept assessments. The students' scores in the corresponding pretests were used as the covariate. SPSS 19.0 was used for statistical analysis. In addition, the effect sizes (Cohen's f), small (.10), medium (.25), and large (.40), were reported (Cohen, 1988). The qualitative analysis included identifying a series of dialogues among the teacher and students.

Results of Research

Finding 1: Effect of the Blended Teaching Method on Students' Understanding of Stoichiometry

ANCOVA was applied to analyze correct responses. The independent variable was the score given to the teaching method. The dependent variable was the posttest score of students' concept assessments. The covariate variable was the pretest score of students' concept assessments. A preliminary analysis, evaluating the homogeneity-of-slopes assumption, was conducted before ANCOVA obtained the following results: balancing reaction equations, $F_{(1, 138)}$ = .10 (p = .756 > .05)); ideal stoichiometry, $F_{(1, 138)}$ = 1.42 (p = .236 > .05); limiting reagent stoichiometry, $F_{(1, 138)}$ = 1.50 (p = .224 > .05); yield, $F_{(1, 138)}$ =.96 (p = .330 > .05); and overall score, $F_{(1, 138)}$ = .56 (p = .813 > .05). These results, in which no test attained significance, matched the basic assumptions of regression analyses.

ANCOVA results on acquisition of various main concepts are presented in Table 2. For balancing reaction equations, the posttest difference in means between the two groups achieve significance ($F_{(1, 138)}$ = 12.71, p = .001 < .05) with an effect size of .31. The comparison shows an adjusted mean of the number of correct responses in the posttest (59%, SE = .03) for the experimental group, which is higher than the mean of 44% (SE = .03) obtained for the control group. This shows that the experimental treatment has a considerable effect on the construct of balancing reaction equations. For ideal stoichiometry, the posttest difference between the two groups achieve significance ($F_{(1, 138)}$ = 6.18, p = .014 < .05) with an effect size of .21. This shows that the experimental treatment has a low to medium effect on the construct of ideal stoichiometry. The comparison shows the adjusted mean posttest score of 75.2% (SE = .03) for the experimental group, which is higher than the mean posttest score of 64.2% (SE = .03) obtained for the control group. For limiting reagent stoichiometry, the posttest difference between the two groups achieve significance ($F_{(1, 138)}$ = 7.02, p = .009 < .05) with an effect size of .23. This shows that the experimental treatment has a low to medium effect on the construct of limiting reagent stoichiometry. The comparison shows the adjusted mean posttest score of 53.8% (SE = .03) for the experimental group, which is higher than the mean posttest score of 42.7% (SE = .03) obtained for the control group. For yield, the posttest difference between the two groups does not achieve significance ($F_{(1, 138)}$ = 3.26, p = .073 > .05) with a small effect size of .15. The adjusted mean posttest score of the experimental group is 48.7% (SE = .04), compared with the mean posttest score of 39.6% (SE = .04) of the control group. Finally for overall score, the posttest difference between the two groups achieve significance ($F_{(1, 138)}$ = 15.39, p = .000 < .01) with an effect size of .34. This shows that the experimental treatment has a medium effect on the stoichiometry overall. The comparison shows an adjusted mean posttest score of 59.2% (SE = .02) for the experimental group, which is higher than the mean posttest score of 46.1% (SE = .02) obtained for the control group.

Table 2. The ANCOVA of main concept.

Concept	Group	Pretest mean(%) (SD)	Posttest mean(%) (SD)	Posttest adjusted mean(%) (SE)	F	η2	f
Balancing reaction equations	Control	24.65 (23.34)	44.01 (27.21)	44.2 (3.2)	12.707***	0.085	0.305
	Experiment	25.36 (20.78)	59.42 (27.15)	59.4 (3.3)			
Ideal stoichiometry	Control	21.13 (18.25)	64.08 (29.50)	64.2 (3.5)	6.178*	0.043	0.212
	Experiment	22.10 (21.66)	75.36 (23.28)	75.2 (2.8)			
Limiting reagent stoichiometry	Control	32.55 (17.65)	44.13 (24.99)	42.7 (3.0)	7.018**	0.049	0.227
	Experiment	27.70 (16.13)	52.33 (27.95)	53.8 (3.4)			
Yield	Control	20.19 (24.34)	40.38 (27.55)	39.6 (3.3)	3.263	0.023	0.153
	Experiment	10.63 (21.76)	47.83 (31.04)	48.7 (3.7)			
Overall	Control	26.83 (13.96)	47.54 (22.60)	46.1 (2.7)	15.391***	0.101	0.335
	Experiment	23.55 (12.40)	57.68 (23.26)	59.2 (2.8)			

*Note: SD, standard deviation; SE standard error; f, Cohen's $f^2 = \eta^2/(1-\eta^2)$; *P < .05; **P < .01; ***P < .001*

Finding 2: Description of the Teacher's Role in Facilitating Students' Engagement and Reflections

In this part, the results were examined how the teacher enhanced students' conceptual understanding in class. The following example with the teacher illustrated the differences between the two groups to explain the changes facilitating students' engagement and reflections. Within the experimental group classroom in the unit of limiting reagent stoichiometry, the teacher provided web addresses of videos which students were asked to view in the periods. The teacher said "you need to watch the videos as follows in this period," and "if you have any questions about the videos, you can repeat the videos or raise your hand for help." Students followed instructions to watch the assigned videos and completed the exercises when finishing the videos. While students watched the videos, the teacher walked around the classroom to monitor students' self-paced learning. Once students finished

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the videos and exercises, the teacher confirmed and validated their constructed model. The teacher said "please tell your partner or group leader what limiting reagent stoichiometry is and how to solve the problem." Students shared their conceptual knowledge of limiting reagent stoichiometry and shared their experiences of the way in which they solved the problems in these exercises. The teacher quickly knew who needed help via classroom management. The teacher said "Stand up, please, if you can explain a limiting reagent and how you judge it. Then you may sit down." Students who could not explain and reason received the help from group members or the teacher to enhance conceptual understanding. Then the teacher asked misconceptions about limiting reagent to test the reasonableness of their mental models. The teacher said "Someone told me we can treat oxygen gas as the limiting reagent because there is more mass of oxygen than others. Is that right? Stand up, please, if you can explain why this is wrong and what the correct answer should be. You may sit down." Then, students were asked to solve similar problems independently and selected students were asked to present their reasoning in front of others. The teacher drew lots and said "John (not real name)! You are the first! Next is …Mary (not real name)." The teacher evaluated the performances of students who were selected on the basis of their presentations. When John and Mary had explained how they did the exercise, the teacher helped students to reflect how the concept was constructed, validated and reconstructed. Finally, the teacher said to all to end up the period. "During this period, you watched the videos to construct your thought about limiting reagent, and undertake exercises to consolidate and modify your thoughts," and "then revised wrong explanations to reconstruct your own thoughts."

Students' responses to the teaching method in the experimental group revealed a positive feedback of their engagement in learning. One high achieving student said "I felt comfortable and perceived more interactions with other students in the class (experimental group-40507)." Another student with middle achievement said "The method of grouping was helpful to me (experimental group-40510)," and another student of low achievement said "I felt more efficient because we discussed doubts immediately (experimental group-40516)." In addition, the method of grouping and discussion solved the problems as soon as they were encountered. One student of high achievement said "I devoted time to watch videos and discussing with others. This method helped me to be involved, because I repeated watching the videos and discussed immediately what I did not understand." Another student with low achievement said "Watching videos was similar to attending lectures; however I repeated watching the videos if I did not understand their content. The learning occurred without my realization."

By contrast, the students in the control group just listened to what the teacher said, and few interactions were observed between the teacher and students. For example, instead of providing contexts testing, validating, and revising the established model and describing the restrictions of the model, the teacher just explained why oxygen was the limiting reagent, and how to calculate the yield of product. Students' responses to the teaching method revealed a general feedback of their engagement in learning. One student of middle achievement said "Sometimes I wasted tremendous amounts of time because I did not understand what the teacher said (control group-40205)." Another student of high achievement said "When I encountered problems, I read the text and attempted to solve them once again (control group-40501)," and another student of low achievement said "I listened to what the teacher said; however I could not determine whether I understood what the teacher said (control-group-40509)." Few interactions were observed among students or between the students and the teacher. Students received little feedback from their classmates or teacher. These results demonstrated that the blended model-based collaborative learning in a SPOC environment with proper design and facilitation provided opportunities to improve students' involvement in learning.

Discussion

Providing a Theoretical Framework for Educators to Design Interactive Teaching Activities in SPOC Environments

The goal of this study is to develop a framework that portrays the integration of model-based instruction and collaborative learning in SPOC environments for science learning. The literature shows that a flipped classroom provides a student-centered teaching method; however, it cannot confirm if all students preview their homework. It is suggested that students should learn in SPOC environments rather than MOOC environments (Fox et al., 2014). However, Fox et al. do not practically implement this in subject learning. This study not only stresses how to integrate model-based instruction and collaborative learning, but also stresses how to facilitate students' learning. The results, similar to those in Strømme and Furberg (2015), show the teacher often acts as an important resource and provides various forms of guidance during students' learning activities. Different from Strømme and Furberg's previous study regarding exploring students' interactions online, students in this study complete the online learning at their own pace in class to generate their initial models, and then via problem-solving to clarify misconceptions to revise their faulty models. The teacher provides interactive activities to emphasize the connections between their thoughts and the scientific models to encourage students to devote themselves to learning.

Blended-Model-Based Collaborative Learning in SPOC Environments Promotes Students' Concept Learning

In this study, blended-model-based collaborative learning activities emphasize students' construction, revision, and reconstruction related to stoichiometry. The experimental group who devoted themselves to learning outperformed the control group who immersed themselves in a lecture-based environment. Students in the experimental group could engage in the modeling process through teaching activities, such as online video learning, to generate an initial mental model of stoichiometry. After that, they revised the faulty mental model through teacher–student or student–student interactions, and reflected on what and how they learned to motivate and consolidated their learning. The differences in concept learning between both groups might drive from students' involvement. As demonstrated in the literature, students were inattentive to what was being said in a lecture for 40% of the time (Meyer & Jones, 1993). However, interactive teaching involving a high level of interactions increased the involvement that students devoted to learning to facilitate their engagement (Baepler, Walker, & Driessen, 2014; Greenwood et al., 1984). Our results differed from those of other studies on MOOCs and collaborative learning (Bos et al., in press; Fox et al., 2014; Kong, 2014; Tekbiyik, 2015); materials from Junyi Academy platform in this study provided a foundation for online learning in class rather than at home. Dori and Hameiri (2003) described a multidimensional analysis system for composing and classifying mole-related quantitative chemistry problems; however, they ignored the problems corresponding to mental models, which consisted of objects and their relationships that the students constructed, revised, and reconstructed. Different from Dori and Hameiri's study focusing on transformations among representations, this study stressed the teaching modules for facilitation conceptual learning in classroom practice. Model-based collaborative learning highlighted the essence of collaborative learning and extended connections between teaching sequences and modeling to focus on the models that students constructed rather than focusing only on a particular teacher–student interaction.

The Role of Teacher in the New Instructional Approach Is to Be a Facilitator

Online free courses provide an innovative self-learning mode; however, low-completion rates, absence of timely feedback, and limitations in aligning course guidelines of K-12 prevent the extension of these courses to a real classroom (Alraimi et al., 2015; Breslow et al., 2013; Imlawi et al., 2015; Yuan & Powell, 2013). Instead of watching videos at home, students in this study are asked to view assigned videos through self-paced learning in class. With the teacher providing scaffolding to engage students in learning, students finish the high school course alignment with guidelines and receive timely feedback. The key of blended-model-based collaborative learning is the role of the teacher. In the control group, the teacher's role is as a lecturer using a teacher-centered method to show students how to solve the problems in the textbook. The teacher lectures based on the same videos and as used in the experimental group, but the interactions among the teacher and students seldom occur in the control group. The control group's scores on the posttest are better than on the pretest, but no better than the experimental group. Different from being a lecturer, the teacher uses a student-centered method in the experimental group. The teacher asks students to reflect on their learning, how they solve the problems and why the problems can be solved. The teacher acts as a facilitator in the experimental group to provide students opportunities to modify and revise their conceptual models into scientific models. The results of this study are similar to those of Chen and Chen (2015), the key factor to promote students' gains is facilitation strategies by the teachers. Chen and Chen hold study group with face-to-face meetings to help the participants reflect upon and share/learn self-regulation strategies with each other in a MOOC environment. Different from MOOCs learning, this study highlights how to facilitate students to finish assigned videos aligning K-12 course guidelines within their self-paced learning in class.

On the basis of the findings, I argue that course-based social interactions provide students with the opportunity to obtain more information about the instructor providing model-based collaborative learning in SPOC environments. The instructor monitors and encourages students to devote more efforts in engaging in learning in class. This method not only enhances students' concept learning in such a blended environment, but also provides students more opportunities to involve themselves in learning compared with a conventional classroom.

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Conclusions

This study provides a more profound understanding of the effect on students' conceptual knowledge and their engagement in SPOC learning environments. The framework in term of model-based collaborative learning focuses on the construction of mental models, which are associated with specific manipulatives, such as instruction, discussion, and reflection. The associated steps require a thorough understanding of the purpose of modeling, which aims to facilitate as well as afford students' construction in SPOC environments.

The major implication of this study is adopting a blended teaching strategy, which uses free online courses in science classrooms in formal education to improve students' engagement and achievements by integrating additional support in model-based collaborative learning. The results show that the blended strategy can help students generate and revise mental models during instruction; students generate an initial model by watching online videos, consolidate or revise their initial through face-to-face student–student and teacher–student interactions, and reflect on what and how they learn to improve their concept learning. Because of the absence of a blended learning strategy for high school courses, the results of this study provide a reference for integrating the relevant online free courses into real classroom instruction.

This study has some limitations. The first limitation is that during sampling, not all threats to validity are eliminated when the study was designed. Students who participate in this study are carefully selected from specific classes and then assigned randomly to the experimental or control group, but our results are limited by the homogeneous nature of the student pool. Another limitation of this study is that it lacks the measurements of formative assessment to detect students' development and transformation of their mental models. Additional studies are required to investigate students' mental models how to develop over time in SPOC environments.

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Appendix A

Selected Items in the Stoichiometry Concept Assessments

Al can reduce oxidized Mn to obtain the metal Mn. The reaction equation is as follows.

$$MnO_{2(s)} + Al_{(s)} \rightarrow Mn_{(s)} + Al_2O_{3(s)}$$

Based on this reaction, answer the following questions:

1. What is the balanced reaction equation for the previous reaction?
2. What is the mass of the product $Mn_{(s)}$, if 800 g of $MnO_{2(s)}$ reacts with 400 g of $Al_{(s)}$ (Mn = 55, Al = 27, and O = 16)?
3. Which reactant molecule acts as the limiting reactant? Give reasons.
4. What is the yield (%) of a product if its mass is 253 g?

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