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Student-centered Development of an e-Learning courseware for Metabolic Pathways

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Abstract

Animated pedagogical agents (APAs) are increasingly developed in the educational field to motivate students' learning and improve learning outcomes. However, dissociation between teachers and the courseware engineers during APA development has been a known limitation. Therefore, a *student-centered approach* by a three-party team model – including a *student designer,* a *teacher*, and an *information technologist* – was adopted for e-Learning courseware development to bridge the gap between teachers and courseware developers. An e-Learning courseware *Metabolism Metro* was subsequently developed with the use of *design thinking* for *Urea Cycle* for metabolic teaching. The subject chosen for courseware development was based on students' comments about difficulties in learning metabolism. The *Urea Cycle* was illustrated as a railway metro line, and the teaching contents were presented as cartoony-styled animations. This project was a case study in which the student designer was also a learner in metabolism, which the student designer was highly motivated to self-learn metabolism to complete the tasks and therefore the student designer's own subject knowledge was reinforced. Students' feedback was collected early within two weeks upon release of the courseware. Positive feedback was received from students, suggesting that involving students in courseware development may facilitate their learning in relevant subjects.

Keywords: Medical education, biochemistry, metabolism, student-centered, online courseware

Introduction

Students' motivation is an essential subject to be investigated in optimizing educational strategies as it facilitates learning by retaining students in an educational interaction (Sormunen M et al., 2022; Gardner, 2007; Rodgers and Withrow-Thorton, 2005; Vallerand et al., 1992). There are various components and media which contribute to modulating students' motivation. One of the media is animated pedagogical agents (APAs), in which virtual characters were involved in engaging students by non-verbal communication cues during the presentation of educational materials (Morey 2012). The major features of APAs involve (1) the use of virtual characters, (2) student-computer educational interactions, and (3) the presentation of teaching contents. APAs are also commonly developed in the tertiary education system to supplement lecture-based teaching and optimize students' exposure to learning materials (Morey 2012). However, the limitations and outcomes of APAs assisted strategies have not been well evaluated.

One of the limitations is the dissociation between teachers and the courseware engineers during an APA development. It was noted that the development of e-Learning courseware required much effort from the information technologists (Virvou and Alepis, 2005; Koehler and Mishra, 2005), and teachers expressed difficulties in illustrating teaching contents digitally (Tsou, Wang and Li, 2002). Most teachers might have limited design/programming skills and technologists were unfamiliar with the teaching contents. Moreover, many of the courseware were designed in teachers' perspectives and might not truly addressing the needs of the students. Therefore, we here propose a *student-centered approach* to courseware development which attempts to bridge the gap between teachers and courseware developers, optimizing the courseware according to the students' needs.

Methods

The Student-centered Approach – A Three-party Team Model

Due to the complexity of metabolic pathways, and teachers frequently received comments from students about difficulties in studying these pathways, the subject "*Metabolism*" was chosen for courseware development. In the past, there have been teaching aids developed to facilitate students learning metabolism (Lee, Ng and Chen, 2019; Teplá and Klímová, 2015; Vega Garzón, Magrini and Galembeck, 2017). Since participatory design provides the opportunity for learners to participate in part of the design process, which fill the gap of the needs of the end-users (Ertmer, Parisio and Wardak, 2013), a three-party team model was adopted to bridge the communication gap between the teachers and the programmers, in which a *student designer* was involved in addition to the original two parties. Thus, a team including *a student designer, a teacher,* and *an information technologist* were involved in this project.

A student designer was recruited according to several selection criteria: (1) The courseware designer should have comprehensive knowledge and a thorough understanding of the relevant course content. (2) The designer should be able to understand the challenges that students face when studying the subject. (3) The designer should have good drawing skills and is willing to learn new software programs.

In this project, the *designer* selected was a student who took the same metabolism course previously. He was responsible for integrating his academic knowledge learnt from the teacher and technical skills taught by the information technologist to design a courseware. During the design and development of the courseware, his reflections on his learning experience in relevant courses were involved so as to best fit the users' needs.

Design Thinking in the Developmental process

Design thinking is a cognitive strategy involved in designing products and was first discussed by H. A. Simon in 1996 (Simon, 1996). *Design thinking* used nowadays involves five steps: empathize, define, ideate, prototype and test. The five steps will be illustrated by our developmental process. The student designer adopted these design thinking strategies during the development of the e-Learning courseware. This courseware was developed for a biochemical course in which metabolic pathways involving the *Urea Cycle* were taught.

Step 1: Empathize

The designer had to empathize with the students' learning experience so as to optimize the design according to the students' needs. There were a few reasons for the development of this courseware:

(1) Students' general impressions regarding metabolism were 'boring', 'tedious' and 'complicated'. There was a need to motivate students learning this subject.
(2) Metabolism is a highly complicated and abstract topic. Students could gain a better understanding if the pathways could be visually presented by animations.
(3) Thorough understanding of this subject requires integrative thinking between all metabolic pathways. However, these pathways were usually taught one by one during class. The complexity of metabolism made cognitive integration of all pathways challenging for students.
(4) This intensive undergraduate course was organized in one semester in which students concurrently were taking other courses with a significant workload. Therefore, limited study time were allocated to each course. A courseware that facilitated the understanding of course content was needed.

Step 2: Define

After reflections, two problems were defined. (1) The course knowledge was presented in a fragmented way without integration. (2) Students had minimal intrinsic motivation to learn the course knowledge.

Step 3: Ideate

Through brainstorming between the teacher and the student designer, an idea of designing a courseware containing multimedia, interactions and games was proposed to assist in teaching the course (Figure. 1). The courseware was designed based on an integrated 'map' of metabolic pathways.

Step 4: Prototype

With the proposal of developing a courseware, a prototype of a courseware *Metabolism Metro* was built with reference to the *Urea Cycle*. The design was based on a role-playing game (RPG) design in which players navigate by walking through a map. The course contents were presented as integrated maps and short animations.

Step 5: Test

The prototype was immediately released after initial optimization for early feedback collection. Most of the users welcomed and were satisfied with the courseware, and they also demanded further development to cover all subtopics in the course. Feedback was collected from students after the launching of the courseware, written comments were reviewed and the courseware was fine-tuned according to the needs of the students.

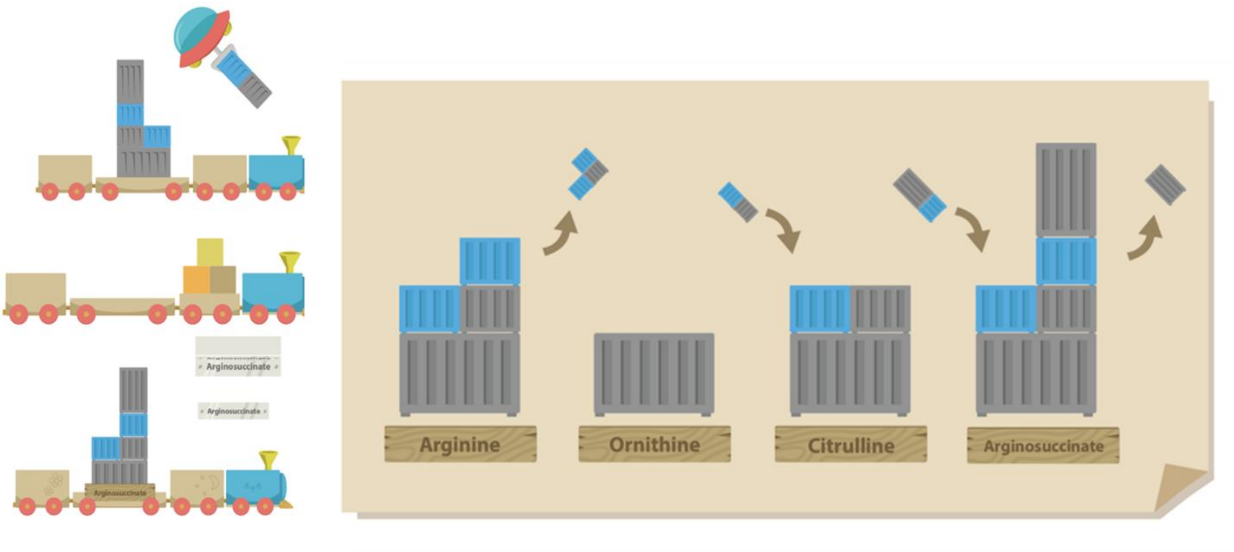

Figure 1. Ideation drafts in *design thinking*. Metabolites to be taught were designed as cargos carried by train (Blue cargos represented amino group, whereas grey cargo represented carbon skeleton). The train is a design medium to complete the idea of the metro. Chemical reactions are indicated by the addition and removal of cargos.

The Courseware Metabolism Metro

As a result, Phase 1 of *Metabolism Metro* was developed with respect to the *Urea Cycle*. The animations can be assessed at https://www.eds.med.cuhk.edu.hk/elearnshowcase/drrebeccalee/mm-legoland-20230321/story.html. The following features were the products of the *design thinking* process.

(1) The *Urea Cycle* was illustrated as a railway metro circular line with the intermediate metabolites presented as 'railway stations' (Figure. 2). In addition, this part of metabolism was further illustrated in the whole 'world railway metro map' to illustrate its relationship with other parts of metabolic pathways. Although the other parts of the world

map were not released in Phase 1, the connections between the *Urea Cycle* and other metabolic pathways were outlined by dimmed grey lines.

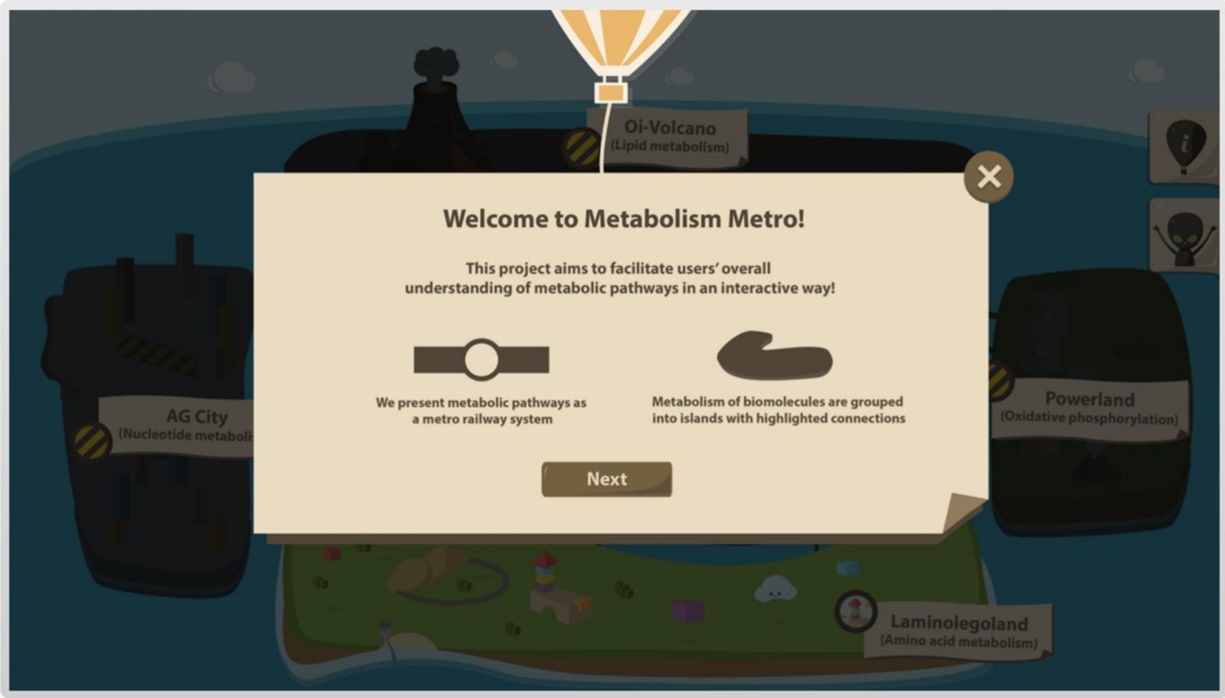

Figure 2. Urea cycle in *Metabolism Metro*. Navigation slide towards educational animations. Urea cycle pathway is presented as metro lines.

(2) The contents of *Urea Cycle* were presented as animations with a cartoony graphical style. The cargos on the train represented simplified chemical structure of the biomolecule. In the animation, blue cargo represented amino group, whereas grey cargo represented carbon skeleton (Figure. 3). By presenting the chemical structure in this way, students could easily recall the number of amino groups in each biomolecule in the urea cycle. This was intended to counteract the negative psychological impacts brought by the tedious metabolic pathways and complicated chemical structures, and thus can enhance motivation towards the learning materials. In the animation, there was a railway line displayed at the top of the screen to orient the users to the current location in the metabolic pathway. Metabolites represented as cargos on a train would be animated to demonstrate reactions occurring on the metabolites. Important enzymes and metabolites were labelled in the animations as animated objects and railway stations respectively (Figure. 4).

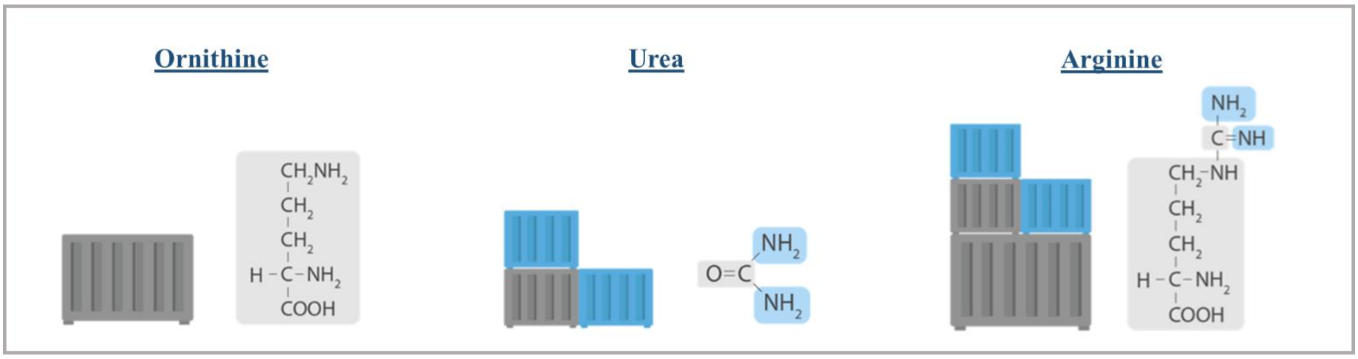

Figure 3. Biomolecules are simplified and presented as cargos for students to visualize the chemical structure (Blue cargos represented amino group, whereas grey cargo represented carbon skeleton).

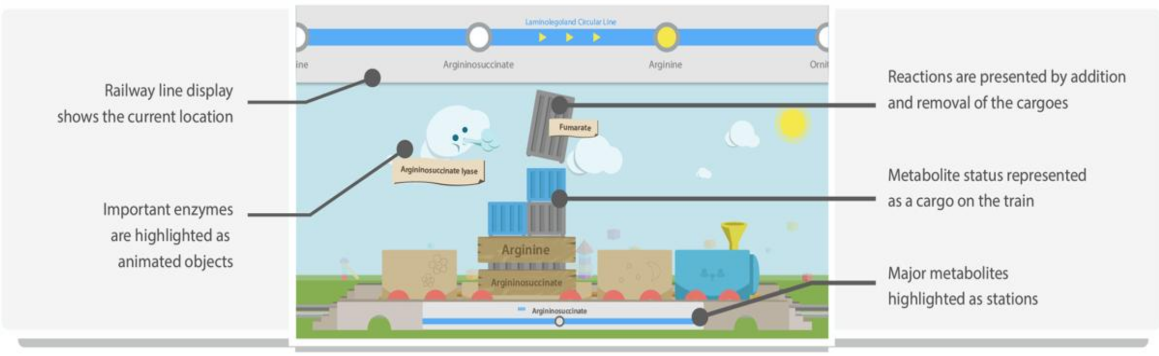

Figure 4. The urea cycle is presented as animations with features labelled.

(3) The design of the user interface (UI) was discussed between the student designer and the information technologist and was reviewed internally within the team several times to optimize the navigations. UI was regarded as an important part of courseware design as students tended to invest minimal time on non-compulsory learning materials and therefore would likely leave the courseware when it did not work smoothly. UI components focused in this phase were the introductory slides and navigation buttons (Figure. 5). Instructions and explanations about the aim of developing the courseware were included in the introductory slides. Clear instructions were needed to guide users' navigations through the courseware. In the courseware, buttons essential to animation navigations, such as "Play", "Pause" and "Skip" were included. Selection menus with "Next", "Exit" or "Replay" options were also embedded at the end of all animations.

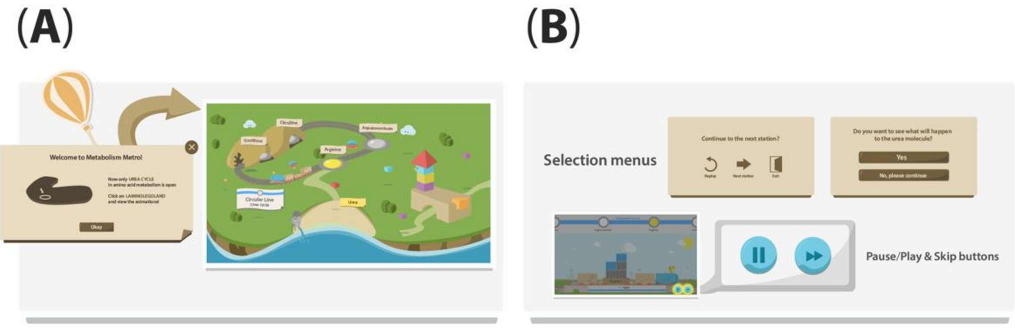

Figure 5. Design of the user interface (UI). (A) Navigation slides with the briefing and instructional messages. (B) Animation navigation buttons.

(4) In comparison with traditional APAs, *Metabolism Metro* had an emphasis on graphical quality and UI design to specifically address students' psycho-educational needs. Biomolecules were labelled as metro "stations" and a simple circular line was used to represent the urea cycle (Figure. 6).

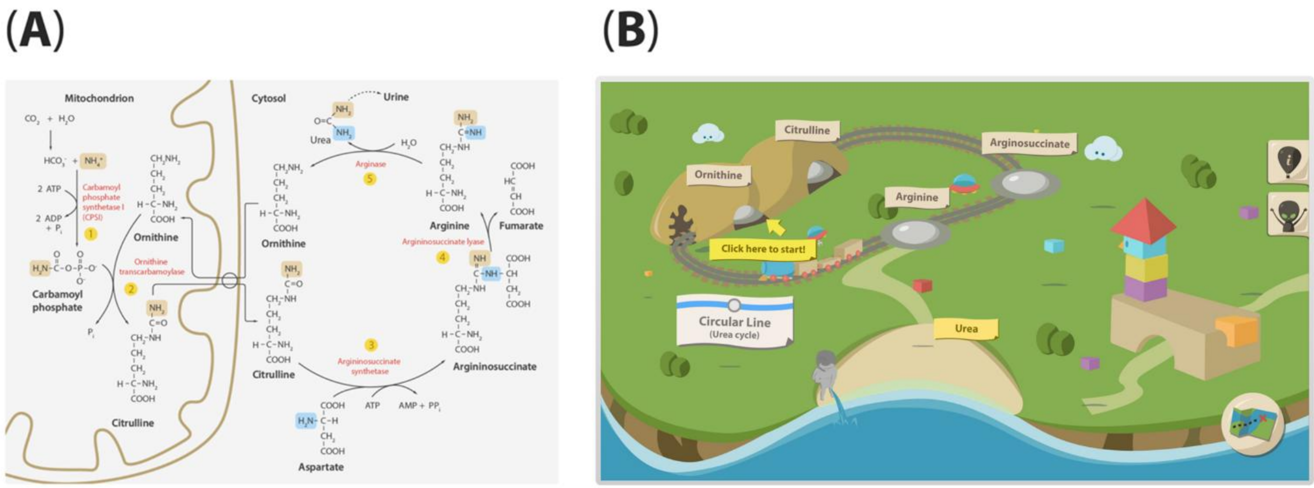

Figure 6. Comparison between a textbook figure and a designed figure of Urea cycle. (A) Replica of a textbook figure. (B) A simple circular line was used to represent the urea cycle. Biomolecules were labelled as metro stations.

Results and Discussion

Students' Feedback

Preliminary evaluations were conducted online within two weeks upon release of Phase 1

Metabolism Metro to collect feedback from students. The online questionnaire consisted of 10 questions by which we evaluated if the courseware had been positively affecting students' motivation and learning outcomes.

The 10 questions are charted below. Students would respond by rating on a scale from strongly agree, agree, neutral, disagree to strongly disagree.

(1) Have you ever used the courseware?
(2) How often did you use the courseware during the course?
(3) The courseware motivated me to learn by arousing my interest and curiosity about the subject.
(4) The courseware helped to improve my understanding of difficult concepts.
(5) The courseware allowed me to learn at my own pace.
(6) The courseware helped me understand the course content better.
(7) The courseware can highlight important concepts.
(8) The courseware is easy to use.
(9) The courseware is attractive.
(10) In general, I am satisfied with the courseware.

27 students responded to the online questionnaire, and 26 of them had used the courseware (96.3%). Among the 26 students, 53.8% of them used the courseware once, and the rest (46.2%) used it 2 to 5 times. 84.6% of the students strongly agreed/agreed that the courseware had motivated their learning by arousing interest and curiosity towards the subject. 96.2% of the students strongly agreed/agreed that the courseware had helped improve their understanding of difficult concepts. 84.6% of the students strongly agreed/agreed that the courseware had allowed learning at their own paces. 92.3% of the students strongly agreed/agreed that the courseware had helped them understand the course contents better. 92.3% of the students strongly agreed/agreed that the courseware could highlight important concepts. 88.5% of the students strongly agreed/agreed that the courseware was easy to use. 92.3% of the students strongly agreed/agreed that the courseware was attractive. 96.2% of the students strongly agreed/agreed that they were satisfied with the courseware in general.

There were two open questions for the collection of positive comments and recommendations on the courseware. The questions were (1) 'What did you like most in the courseware?' and (2)

‘What could be improved in the courseware?’. The following are highlights of the students’ feedback:

“I liked the graphics and animations a lot! They looked very cute and very different from boring lecture notes, but they still presented the main points of the urea cycle rather well.”

“The presentation of chemical structure as cargoes helped me visualize the exchange of functional groups/carbon skeletons that is brought in and out of the cycle by different molecules. Highlighting the nitrogen-containing portions also helped.”

“I like the way that the biochemistry pathways, enzymes and biomolecules involved are presented as attractive animation, so learning becomes more fun.”

The following are some of the recommendations suggested by students:

“Maybe a speed-up button can be added? This courseware is very good in general and I hope we can soon access animations about other metabolic pathways, especially the nucleotide metabolism pathways.”

“The speed of the animation can be faster (e.g. can include x1.5 speed), so learning with the courseware can be more efficient.”

“It might be better if we can control the pace by ourselves like in EchoCenter. Also, if quizzes are also provided as challenges, the courseware will be more interesting. It is nonetheless a surprising courseware!”

Learning by Designing

This project was a case study in which the student designer was also a learner in metabolism. The student designer reflected on the experiences of designing and evaluated the learning outcomes after making the courseware. Benefits for the student helper to learn through designing this courseware include:

(1) Became highly motivated to perform task-based problem solving which would make self-directed learning inevitable;
(2) Learnt how to integrate academic knowledge, needs of end-users, and design/programming skills for the design of a courseware that best-fit the students;
(3) Learnt how to present abstract and complicated concepts in an easy-to-understand manner; and
(4) further deepened the student designer's understanding in the relevant subject knowledge aspect. In another words, his own subject knowledge was being reinforced by performing the design work.

Therefore, involving students in courseware development could be a way to facilitate self-directed learning to optimize the learning experience.

This case study serves as an empirical trial of a new team model and developmental approach to e-Learning. Further studies and statistical evidence are required to demonstrate the outcomes of the proposed model, which will require randomized groups with pre- and post-courseware use assessment of the subject knowledge.

The students' feedback comments, especially those related to animation speed and user interface (UI) design, were reviewed for the next phase of development, in which the whole *design thinking* process was repeated. As demanded by the students that they would like to learn metabolic pathways through animations, a new phase will be launched for carbohydrate metabolism. New features will be added, and the current phase will be fine-tuned with respect to students' comments, including with a faster playing speed, addition of subtitles for the animations, and a map button which links to the pathway map of metabolism.

The proposed student-centered model can be applied in contexts other than biochemical teaching, including teaching in other subjects in tertiary education and also primary/secondary education contexts. Ertmer, Parisio and Wardak (2013) suggested that cultural discrepancy between the users and the designer can potentially lead to the use of offensive symbols in the designed product. Hence participatory design was suggested in the general context of educational technology to facilitate learning outcomes, where the designer is a member from the learners' population. Therefore, in all settings mentioned above, namely primary, secondary and tertiary education contexts, recruitment of students to participate directly in the design process is highly encouraged to improve the learning outcomes derived from the designed product.

Conclusions

An ideal student-centered development of a courseware should involve, in addition to teachers and IT technologists, a student designer who has relevant academic knowledge and skills to work on the project directly. The preliminary study showed that this approach could result in positive feedback from students on the courseware in both aspects of motivation and learning outcomes. The student involved in the development could also benefit significantly from working on the project as well. This implies that involving students directly in real-world task-based problem solving could optimize the students' learning outcomes.

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