Instructional Design & Development for Computer Aided Design Programming through Problem-Based Learning

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ABSTRACT: Computer-aided design (CAD) is an indispensable part in modern design and manufacturing. With the advent of optimization-based generative design, CAD programming skills is increasingly necessary. From the educational aspects, teaching 3D CAD modeling often involves costly expenditure in software licensing and purpose-built computing hardware, which is not always affordable. In this study, a problem-based learning (PBL) instructional module is developed to teach 3D modeling using programming approach. Accompanying an open-source 3D modeling software, the developed module is deemed suitable as an instructional material after the evaluation by three experts.

Keywords: *Computer-Aided Design, Programming, Problem Based Learning, Instructional Design*

1. Introduction

Computer-Aided Design (CAD) is a widely and commonly applied computer software application in the design and manufacturing industries nowadays, and is an essential part of an integrated manufacturing system. The basic building blocks of 3D modeling, such as boundary representation and constructive solid geometry, are the basic essential skills in CAD. While the modeling is achieved through visual approach in CAD systems, programming or scripting in CAD is an increasingly important skills in modern generative CAD design systems [1]. Most of the CAD systems contain certain programming or scripting features, with customizable applications on design automation or even robot kinetic simulation [2]. However, in the perspective of educational implementation, cost of ownership for both CAD hardware and software is usually less affordable for students. Besides, students also lack the required programming skill training to explore the advanced topics of generative CAD programming. Therefore, a cost effective solution is required in order to solve this challenge. This study explores a problem-based learning (PBL) approach towards teaching 3D CAD modeling through programming. An free open-source 3D modeling software named OpenSCAD[1] is suggested, with an instructional or teaching module that is PBL-oriented is proposed for this purpose. We shall detail the design and development of this teaching module in the following sections.

[1] https://openscad.org

2. A Problem-Based Learning Approach to CAD Programming

In this study, the process of designing and developing the PBL instructional module can be divided into a few phases as explained in the following sections.

2.1 Analysis Phase

The first phase of the software development phase is to perform requirement analysis, e.g. to understand the explicit needs and justification of this study. An initial interview is carried out with an experienced CAD instructor, in order to find out what are the specific issues with teaching CAD modeling. In summary, the outcome of the interview indicates that there are many challenges in teaching 3D modeling, which includes: complicated visual approach of building 3D models in software such as AutoCAD, the availability of commercial software to support students learning, and computational intensive hardware requirements, to name a few. In view of the increasing importance of coding skills, the interviewee agreed that OpenSCAD is a good alternative for students learning, where programming thinking skills can be embedded. Problem-based learning is also a recommended approach to train thinking skills. As such, a good teaching module is required for instructors to teach the idea to students.

2.2 Design and Development Phase

Based on the feedback and expectations from the preliminary interview, design phase proposes practical teaching design for the instructional module. The module is aimed to allow 3D CAD modeling to be performed by using the scripting language of OpenSCAD, with targeted exercises and problems described using the PBL approach. The targeted users of this module are lecturers from vocational colleges (VC). Firstly, the outcome-based education (OBE) syllabus for CAD subject that is applied nationwide in VCs was obtained with topics related to 3D modeling were identified. The required skills in syllabus for 3D modeling were determined, and suitable tutorial content adaptation of performing the required modeling using OpenSCAD is derived. Figure 1 shows an example of a CAD programming tutorial example with complete explanation.

Next, tutorial exercise and PBL problems were designed based on the authentic PBL (APBL) methodology by Wee et al. [3-4]. The scope of the

tutorial exercise is in accordance to the syllabus coverage in VCs with answers. Similar approach is also taken for PBL problem, where it is posed as a more open-ended problem with some triggers or clues to help jumpstart the PBL process. Figure 2 shows an example of the PBL problem with detailed instructions and clues indicative of learning objectives. The PBL problem is done in a group assignment setting where students are able to explore the answers together under the facilitation of the instructor. In relation to the problem, model answers were also developed to guide the facilitation process. Figure 3 shows partially the corresponding model answers, in the form of facts, ideas, learning issues and action plan (FILA) table.

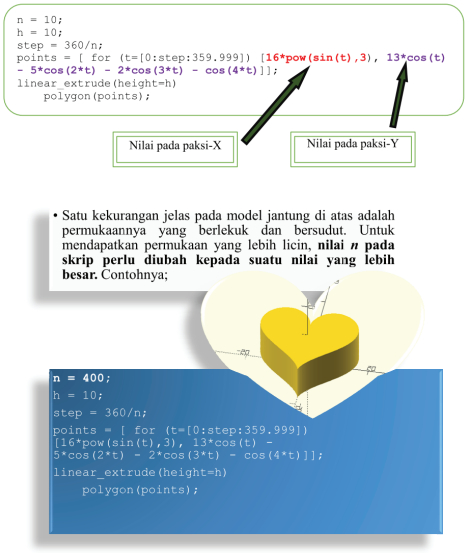

Figure 1 CAD Programming Tutorial Example

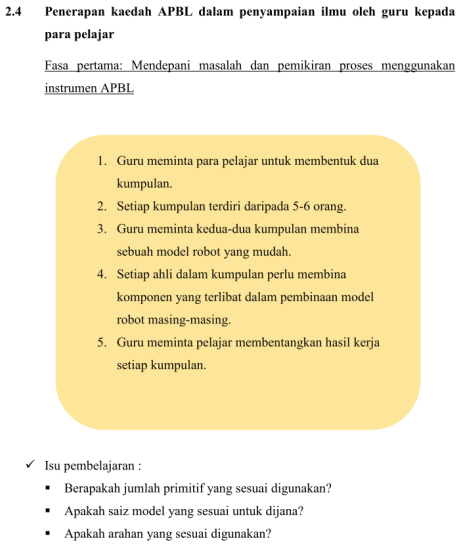

Figure 2 CAD Programming PBL Problem

2.3 Evaluation Phase

After the instructional module is developed, it undergo the expert evaluation or review process where three experienced CAD instructors from a VC is involved. The review process is performed using a questionnaire based on three parts of the module:

A. Design aspects (on formating and content design) with 11 items,
B. Module assessment aspects (on suitability of exercise and problems given) with 5 items, and
C. Perception aspects (on suitability and functionality of module in actual teaching) with 11 items.

Each item in the questionnaire contains a agree/disagree response with optional comments section. The results from the questionnaire is analyzed using descriptive statistics where the percentage of total agreement is studied. From the outcome of the results, the total response of agreement towards items in Part A, B and C is 87.9%, 100% and 84.8% respectively. These indicates high level of agreement among experts. Comment wise, suggestions in terms of minor content adjustment in early stages of coding tutorial using OpenSCAD are also provided for further improvement. Nonetheless, all experts agree that the module is suitable for teaching 3D CAD modeling in VCs.

Facts **(Fakta)**	***Ideas*** **(Idea)**	***Learning Issues*** **(Isu Pembelajaran)**	***Action Plan*** **(Rancangan tindakan)**
Model sebuah robot	Menggabungkan primitif-primitif. Memggunakan teknik *extrusion* dan *twist* dalam penjanaan model.	❖ Berapakah jumlah primitif yang sesuai digunakan? ❖ Apakah saiz model yang sesuai untuk dijana? ❖ Apakah arahan yang sesuai digunakan?	❖ Perbincangan secara berkumpulan. ❖ Merujuk kepada guru bagi mendapatkan klu dan bimbingan.

Figure 3 PBL FILA Descriptions

3. CONCLUSION

This study has successfully design and developed an instructional module to teach 3D modeling skills though CAD programming that is PBL focused. In an overview, the evaluation of the developed module has received positive feedback. Next, we wish to see how the developed module can truly train the competency of VC students in performing 3D modeling using their coding skills. We shall further report the outcome when it is ready for face-to-face implementation.

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