Work in Progress: The Effects of Computer Simulation and Animation on Student Metacognition During Engineering Dynamics Learning

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Abstract

Research on metacognition (i.e., the awareness and management of one's own thought) has long been conducted in the conventional learning environment, such as "chalk and talk" classroom lectures. This work-in-progress study investigates how computer simulation and animation (CSA) affects student metacognition during the process of learning engineering dynamics, a foundational course that students in many engineering programs are required to take. The results show that when learning with CSA, student metacognition primarily focuses on four activities: clarifying understanding by interfering or questioning; paraphrasing, scanning, skimming the problem; demonstrating confidence, and deciding to focus on the mathematical representation.

Keywords

Computer simulation and animation, metacognition, learning, engineering dynamics.

Introduction

The process of learning is complex and influenced by many factors. One factor that has received increasing attention in recent years is metacognition, which means "awareness and management of one's own thought" [1] or "thinking about one's own thinking" [2]. For example, when a learner is learning a new concept or a new problem-solving procedure, he or she may talk to himself or herself, consciously or unconsciously, "It is difficult for me to understand this problem," or "I do not think the solution is correct. I need to check it with my professor." A significant amount of evidence has shown that deep learning is often accompanied with intense metacognitive activities, and that student learning outcomes can be improved by strengthening metacognitive processes and adopting proper metacognitive strategies during the learning process [3].

Research on metacognition has long been conducted in the traditional learning environment where an instructor delivers a "chalk and talk" lecture or a powerpoint presentation in the classroom [4, 5]. However, the way in which students learn has changed in recent years as computer and Internet techniques develop rapidly. For example, computer simulation and animation (CSA) provides students with a visual tool for active learning and is often employed inside and outside the engineering classroom [6]. How CSA affects student metacognition remains unknown in the engineering education community. It is important to answer this question in order to develop a better understanding of how students learn and to design effective CSA software programs and learning modules.

This work-in-progress study fills the research gap by performing a case study in engineering dynamics. Engineering dynamics is a sophomore year, foundational course that students in many engineering programs, such as mechanical, aerospace, civil, and environmental engineering, are required to take. The course has traditionally been regarded as one of the most difficult courses in undergraduate study because of numerous fundamental concepts and problem-solving procedures. In this work-in-progress paper, a CSA learning module is described. A qualitative research method is introduced, followed by the description of preliminary results. Concluding remarks are made at the end of this paper.

Development of a computer simulation and animation (CSA) learning module

The Principle of Angular Impulse and Momentum is one of the most difficult concepts in engineering dynamics [7]. To apply this Principle for problem solving, students must not only have a solid conceptual understanding of angular impulse and angular momentum, but also be able to set up the correct math equations to determine the quantitative relationship between angular impulse and angular momentum. We designed the following Dynamics problem for this research that involves the application of the Principle of Angular Impulse and Momentum.

> A varying moment of $M = (200\text{-}50t)$ lb·ft, where t is time, is applied to rotate a telescopic arm of a horizontal crane, as shown in Figure 1. A crate of 2,500 lb is attached to the tip of the telescopic arm. While rotating, the arm simultaneously shortens its length. The total weight of the arm is 200 lb and its center of mass is assumed to be at the midpoint of the arm all the time. The initial length of the arm is $R_1 = 8$ ft. The initial speed of the arm tip is $v_{arm1} = 1.5$ ft/s. As the telescopic arm rotates, its length is shortened at a rate of 0.5 ft/s. Determine the speed v_{arm2} of the arm tip when the arm length is reduced to $R_2 = 3$ ft.

Based on the above problem, we developed a CSA learning module using Adobe Flash. The module contains a step-by-step solution to the above problem. Through the interactive computer graphic user interfaces of the module, students can observe how the crate-telescopic arm system moves. Hints are also provided throughout the module to facilitate student learning. Figure 2 shows a representative computer graphical user interface in the module.

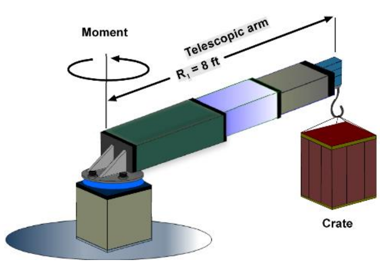

Figure 1. A Dynamics problem particularly designed for this research

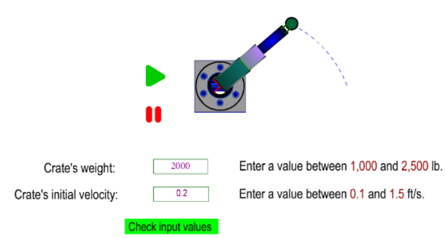

Figure 2. A representative computer graphical user interface in the CSA learning module

Qualitative research method

Six undergraduate engineering students were recruited to participate in this qualitative research. These students had learned the Principle of Angular Impulse and Momentum in an engineering dynamics course before they participated in this research. The CSA module provided an additional opportunity for these students to learn this Principle in a new way (i.e., CSA). Data were collected through a think-aloud approach [8], where students spoke out loudly whatever came to their mind while learning with the module. Video and audio recordings were made to record students' think-aloud process. Audio recordings were subsequently transcribed and then coded to determine how metacognition affects student learning with CSA. The coding table that guided the coding process was developed based on relevant literature as well as our own observations and discussions on the transcripts generated from this research. For each transcript, two coders were involved to ensure the inter-rater reliability of coding.

Results

Table 1 summarizes the preliminary results. Students' metacognitive activities are grouped into three categories: orientating, planning, and monitoring. Each category includes a set of sub-categories. We proposed a frequency index to represent the overall popularity of a particular activity performed by all student participants involved. A frequency index is the product of the total number of students who conducted the same activity (in the sub-category) and the total number of times that the same activity appeared in all transcripts. The higher a frequency index, the more popular (or common) the corresponding activity is among all students.

Table 1. Summarization of students' metacognitive activities

Category	**Sub-category**	**Number of students**	**Number of times**	**Frequency index**
Orientating	Paraphrasing, scanning, and skimming the problem	**5**	**5**	**25**
	Recognizing ability to remember or active prior knowledge	1	1	1
	Demonstrating confidence during learning	**4**	**4**	**16**
	Remembering principle, equation or concept	1	1	1
Planning	Deciding to focus on the mathematical representation	**3**	**3**	**9**
Monitoring	Clarifying understanding by interfering or questioning	**5**	**9**	**45**
	Recognizing confusion or inconsistency	2	3	6
	Summarizing solution strategy	2	3	6
	Claiming progress in understanding	2	2	4

It is clear from Table 1 that in terms of frequency index, top four metacognitive activities students conducted while learning with CSA were: 1) clarifying understanding by interfering or questioning, 2) paraphrasing, scanning, and skimming the problem, 3) demonstrating confidence, and 4) deciding to focus on the mathematical representation. A close examination of student behavior during problem solving also showed that students frequently used CSA to clarify their understanding of the problem, which played a critical role in problem solving.

Concluding remarks and future work

In this work-in-progress study, we have investigated how computer simulation and animation affects student metacognition in learning engineering dynamics, and have identified four primary metacognitive activities. More CSA modules will be involved in the future work.

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