AC 2011-521: A PRELIMINARY STUDY OF CONDUCTING SEMI-STRUCTURED INTERVIEW AS METACOGNITIVE ASSESSMENT IN ENGINEERING DESIGN: ISSUES AND CHALLENGES

Harry B. Santoso, Utah State University

Harry B. Santoso received a BS and MS from Universitas Indonesia (UI) in Computer Science. Before pursuing his PhD program majoring Engineering Education at Department of Engineering and Technology Education, Utah State University, he taught some courses at UI (e.g., computer-assisted instruction and multimedia technique). He has been an administrator of e-Learning system for several years in his department and university. He is also a member of E-School for Indonesia (Esfindo) research group that has main objective to promote a wide-access Internet-based e-Infrastructure for K-12 education. His research interest includes learning personalization, cognition and metacognition, multimedia content, e-Learning standardization, and distance learning.

Raymond E. Boyles, Utah State University

Raymond Boyles attended California University of Pa. where he received two degrees; BA in Information Science: and a MS in Technology Education. He also attended Pittsburgh Institute of Aeronautics where he received an Associate degree in Avionics. He has professional experience as an engineering assistant, computer programmer, and a Robotics instructor, as well as volunteer experience as a teacher, advisor, peer counselor, and a special needs coordinator. He has been involved in the International Technology Education Association and T.E.A.C. His current interest involves robotics, education and student motivation with curriculum development. His goal is to design a robotics based system that allows all to achieve their educational goals with enjoyment.

Oenardi Lawanto, Utah State University

Oenardi Lawanto received his B.S.E.E. from Iowa State University, M.S.E.E. from the University of Dayton, and Ph.D. from the University of Illinois at Urbana-Champaign. Currently, he is an assistant professor in the Department of Engineering and Technology Education at Utah State University. Before coming to Utah State, Dr. Lawanto taught and held several administrative positions at one large private university in Indonesia. In his years of teaching experiences in the area of electrical engineering, he has gained new perspectives on teaching and learning. He has developed and delivered numerous workshops on student-centered learning and online-learning-related topics during his service in Indonesia. Dr. Lawanto’s research interests include cognition, learning, and instruction, and online learning.

Wade H Goodridge, Utah State University

Dr. Wade Goodridge, Principal Lecturer in the Department of Engineering and Technology Education at Utah State University instructs Solid Modeling, CAD, Introductory Electronics, Surveying, and Introductory Engineering courses at the Brigham City Regional Campus. Wade has has been teaching for the Utah State college of Engineering for over 8 years. He holds duel B.S degrees in Industrial Technology Education and Civil Engineering from Utah State University, as well as an M.S. and Ph.D. in Civil Engineering from Utah State University. His research interests include metacognitive processes and strategies involved in engineering design using Solid Modeling, learning style impacts upon hybrid synchronous broadcast engineering education, and team teaching in broadcast environments.

©American Society for Engineering Education, 2011
A Preliminary Study of Conducting Semi-Structured Interview as Metacognitive Assessment in Engineering Design: Issues and Challenges

Abstract

Exploring metacognitive skills in students' engineering design activities has merit for better understanding how the students deal with problem solving. This understanding will benefit the students, engineering educators, and curriculum developers. Researchers realize that metacognitive assessment is a complex endeavor that suggests the need of using data triangulation protocols. A mixed-methods approach to research is also needed to gather comprehensive and valid information about student metacognition. Among many other data collection methods, the semi-structured interview is a widely used method. The semi-structured method offers high flexibility and interaction with the students while providing a consistent framework for interviews. The objectives of this preliminary study were to investigate students' activities that reflect their metacognition, and to suggest what preparation should be undertaken during a semi-structured interview.

Engineering graphics (MAE 1200) students (n=4) in the College of Engineering, at Utah State University (USU), participated in this preliminary study. Butler and Cartier's Self-Regulated Learning model was used to frame interview questions. Two graduate students in the Department of Engineering and Technology Education (ETE) conducted interview sessions to assess the participants’ task interpretations, strategies, monitoring activities, and judgments about their design at the early and final stages of a design project. Participant responses were categorized and tabulated according to interview questions. The results suggest that there was a change in both task interpretation and strategy during the engineering design activity. Additionally, time constraints and skill level with the software affected student monitoring strategies in completing the design task. Most participants were satisfied with their design result. In addition, issues and challenges, as well as suggestions for conducting the semi-structured interview, are discussed in the paper.

Keywords: Engineering Design, Metacognition, Semi-Structured Interview, Self-Report Assessment

1. Introduction

Design is an important part of engineering education. As Dym¹ said, “Design should be the backbone of engineering curricula.” Design is also a complex process and available primarily in ill-defined forms. In addition, engineering design process, as noted by Sheppard and colleagues², “is not linear: at any phase of the process, the engineer may need to identify and define sub-
problems, then generate and evaluate solutions to the sub-problems to integrate back into the overall process” (p. 104). Design is generally characterized as a complex and nonlinear activity. Engineering students particularly need to maximize their strategy and evaluation process to solve engineering design problems, thinking about the overall process of their design activities rather than just working on their design project. Flavell\textsuperscript{3,4} defined this “thinking about thinking” process during learning as metacognition.

A quote by Russel Baker\textsuperscript{5} states that “A solved problem creates two new problems, and the best prescription for happy living is not to solve any more problems than you have to.” Never is the truth of his statement more evident than when observing college students attempting to solve engineering design problems. An understanding of metacognition in design activities can expose deficiencies in a student’s training and/or education. This exposure provides the instructor with valuable feedback to alleviate confusion and many other agonizing obstacles that students experience during their engineering education. This understanding will benefit not only the students and educators, but also curriculum developers.

In an effort to identify the obstacles implied by the students’ metacognition, data triangulation protocols were utilized to illustrate a correlation of the student’s problem solving methods. A mixed-methods approach was also used to gather comprehensive and valid information about the students’ metacognition. From the many possible data collection methods, the semi-structured interview was selected specifically for this study and will be the focus of the authors’ poster presentation. The semi-structured method was chosen for its flexibility and potential for interaction; and also to provide a more consistent framework for interviewers. This preliminary study aims to identify what kind of preparation should be undertaken during a semi-structured interview, focusing on the authors’ experiences while conducting a semi-structured interview during engineering design activities. The authors describe the lessons learned from this preliminary study, and offer recommendations that may be valuable for conducting future studies.

2. Background of the Study

2.1 Interview in Engineering Education Research
Metacognition is a conscious activity, dealing with human internal mental processes that are hard to observe compared to physical activity. In addition, engineering design activity is a complex and methodology-based task which requires the student to follow specified processes and use strategies. Consequently, research on metacognition in engineering design activity tends to apply a mixed-methods approach because of the complex nature of the field.

Interviews, most often used in qualitative-based research, are also valuable in a mixed-method study. Interviews provide researchers an opportunity to confirm collected data from other data-collection techniques with the study participants. Table 1 below shows the sample distribution of
engineering design studies in the *Journal of Engineering Education* that used interview as a single or complementary method.

<table>
<thead>
<tr>
<th>Paper title</th>
<th>Year</th>
<th>Method(s) involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Why Do Students Choose Engineering? A Qualitative, Longitudinal Investigation of Students’ Motivational Values</td>
<td>2010</td>
<td>semi-structured interview and informal conversation</td>
</tr>
<tr>
<td>Students’ Conceptions of Tutor and Automated Feedback in Professional Writing</td>
<td>2010</td>
<td>in-depth interview (semi-structured interview)</td>
</tr>
<tr>
<td>Investigating the Teaching Concerns of Engineering Educators</td>
<td>2007</td>
<td>formal open-ended interview</td>
</tr>
<tr>
<td>Considering Context: A Study of First-Year Engineering Students</td>
<td>2007</td>
<td>structured and unstructured interview</td>
</tr>
<tr>
<td>A Qualitative Study of a Course Trilogy in Biosystems Engineering Design</td>
<td>2005</td>
<td>focus group interviews with students and one-on-one interviews with instructors</td>
</tr>
<tr>
<td>Spotlighting: Emergent Gender Bias in Undergraduate Engineering Education</td>
<td>2005</td>
<td>semi-structured interview</td>
</tr>
</tbody>
</table>

2.2 Semi-Structured Interview

Interview techniques can be divided into three categories based upon the form of the questions used: unstructured, semi-structured, and structured interview. According to Gall, Gall, and Borg, semi-structured interview “involves asking a series of structured questions and then probing more deeply with open-form questions to obtain additional information (p. 246).” Compared to the other two techniques, semi-structured interview has advantage because it offers high flexibility for interviewers to investigate unanswered questions or enrich the gained information based on interviewee’s response. The semi-structured interview technique is suitable for a dynamic context such as metacognitive assessment in engineering design activity.

2.3 Design Task Information

The objective of this design project was to allow students to demonstrate their acquisition of design skills, mechanical knowledge, and software mastery in the development and modeling of a robotic gripper. The gripper was designed, modeled, and prototyped using a parametric solid modeling software package called “Solid Edge”. The student was placed in a theoretical role as a mechanical engineer hired to design and develop a gripper and associated attachments for a robotic arm to be used on an assembly line. To add to the complexity of a successful design, the robotic arm must process both golf balls and pencils with the same gripping mechanism. The student was provided with sources for pneumatic actuating cylinders, and the final design was expected to implement them as the actuating components.

Students were provided with specific requirements that needed to be incorporated into their design. The design process must demonstrate the following: a clear understanding of the grippers successful design criteria found in the solution; obvious mastery of the software utilizing...
commands and functions to arrive at the design solution; successful gripper operation based on the six requirements given in gripper section of the design brief; evident consistent work throughout the six weeks allocated for project completion; and use and creation of assigned components designated in the design brief, i.e. the pneumatic cylinders.

3. The Study

3.1 Participants
Freshman level engineering students in the undergraduate mechanical engineering program at the College of Engineering, Utah State University, participated in this study. These students attended the Engineering Graphics (MAE 1200) class. Forty five students attended the class, but only four students accepted an invitation to be involved in interview sessions. At the end of the second interview, these students received gift cards.

3.2 Procedures

- Preparation
  - Prepare the questions
    The researchers developed questions to gather information which reflect students’ self-regulated learning (SRL), including metacognition. Specific core questions were prepared to be asked at the beginning and the end of the design project. Table 2 lists the interview questions that were used to capture students’ metacognition for this design project.

  - Prepare the participant and schedule
    After receiving confirmation of voluntary participation from four students, all of whom happened to be male, two graduate students from the Department of Engineering and Technology Education (ETE) at Utah State University (notated ETE USU) prepared the schedule of the interview sessions. The graduate students and participants mutually agreed to a time and place for the interviews. It was determined that the interview sessions should last approximately 50 minutes. Three students agreed to be interviewed at ETE USU and one student agreed to be interviewed at the USU Regional Campus in Brigham City, UT, 17 miles south of the main campus in Logan.

  - Prepare how to conduct the interview
    The researchers discussed a variety of methods to obtain appropriate information from the participants before conducting the interview sessions. The discussion covered: (1) primary and confirmatory questions to ask; (2) optimal arrangement for the room and recording tools; and (3) seating arrangement for the interviewer and interviewee. Figure 1 illustrates the interview environment. The intent of the layout was to provide a relaxed and comfortable atmosphere for the interviewee. After
explaining the purpose of this study, the two graduate students interviewed each participant twice: first at the beginning of the design phase (week 1), and then at the final stage of the design phase (week 6).

**Table 2. Example of Interview Questions**

<table>
<thead>
<tr>
<th>Questions at the early phase</th>
<th>Questions at the final phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core questions that will be asked at the beginning of the design project:</td>
<td>Core questions that will be asked at the end of the design project:</td>
</tr>
<tr>
<td>1. Have you had a similar design experience before? Could you please share it with us?</td>
<td>1. How did you actually approach your design task (strategies used to solve your design problem)? I would appreciate if you could share them with me in as much detail as possible.</td>
</tr>
<tr>
<td>2. What is the advantage for you in completing this design task outside the scope of the course objectives?</td>
<td>2. What do you like the most and the least about both your design task and design process that you have completed? Why? How did it impact your design strategy?</td>
</tr>
<tr>
<td>3. What is your understanding about this design task?</td>
<td>3. During these past six weeks, has your understanding about your design task ever changed? Please share with us how that has (has not) changed.</td>
</tr>
<tr>
<td>4. Based upon your current understanding of the design task, what challenges do you foresee? How will you resolve the situation?</td>
<td>4. Having completed the design task, what do you perceive the level of difficulty of your design task to be?</td>
</tr>
</tbody>
</table>

- **Conduct the interview**
  Two graduate students were involved in this study as interviewers. They both attended all interview sessions. One graduate student was responsible to ask the written (prepared) questions, and both of them were free to ask confirmatory questions. Interview sessions averaged from 50 to 60 minutes, during which the interviewers both took notes. At the final phase of the design task, the participants were asked again how they approached their design. The same SRL components were asked using slightly different wording.
Transcribe the interview

The interviewers videotaped and transcribed all interviews. Once the data collection process was complete, the data were coded into themes. Using Butler and Cartier’s SRL model to understand students’ self-regulated learning aspects with emphasis on metacognition, the findings were determined and examined. Each interview contains approximately 2,000 words of data.

4. Findings and Lessons Learned

The findings may explain aspects of the interview process that need to be considered for conducting the semi-structured interview in engineering design activity. Participants’ responses were categorized and tabulated according to interview questions. To maintain autonomy of the participants while presenting the data analysis, the researchers assigned the participants the fictional names Adam, Thomas, Juan, and Cruise. With the exception of Adam, all participants reported to have had some design experiences before. Thomas participated in Project Lead the Way (PLTW) projects in high school, but these projects were not of a similar, open-ended nature as the one he participated in the MAE 1200 course. Juan has experience as an automotive mechanic and believed that he could find a more efficient way to accomplish the design process by modifying the tools he would use in accomplishing the design task. Cruise has high school drafting experience.

Based on their responses during the initial and final interviews, it is clear that there was a change in task interpretation and cognitive strategies during engineering design activity. Most participants (75%) could explain the basic requirements about the design. Only one participant could describe the restriction of the design task. Prior design experiences helped the participant to complete the design task. Adam and Thomas stated that their prior experiences were helpful in generating ideas to solve design task. Specifically, prior experiences with modeling software helped Thomas and Juan. In addition, Cruise stated that his prior experience gave him more confidence to solve the design task. Based upon their current understanding of the design task, Thomas and Cruise saw the software as a challenge in solving the design task. In order to operate the difficult part of the software, they had to ask for help from their classmates.

Furthermore, each participant reported using a different strategy to solve the design task. Adam’s approach was to consider the individual parts and elements involved, perform a few trial-and-error tasks, and systematically evaluate the results. He also requested help from the teaching assistant. His strategy was to break down the design task into parts. Thomas wrote down the instructor’s idea, and then made a list of his own ideas. Generating ideas to solve the problem was the Thomas’ approach to solve the problem. Juan’s approach utilized collaboration with his fellow students while solving the design task, stressing the importance of teamwork. Last, Cruise focused on understanding the design brief, made some notes, and spent some time thinking through his approach prior to taking action.
During the interview session, the interviewers experienced some difficulties in obtaining answers regarding specific questions. This experience was similar to other research conducted by Barribal and While\textsuperscript{13} using a semi-structured interview technique. To begin with, during the past four weeks, almost all the participants stated that their understanding about the design task significantly changed. Unfortunately, the reasons they provided were not clear. Secondly, during the design process, 75\% of participants stated that they changed their initial strategy. Again, the interviewers could not obtain information when that strategy change happened and for what reason. Thirdly, each participant expressed different preferences for both various aspects of the design task and the design process. Adam enjoyed the creativity of it from the beginning, particularly finding different approaches to solve the problem. Thomas preferred using computer application to solve the problem. Juan found the accomplishment of the sub-tasks accomplishment during the design process the most satisfying. Cruise stated that he most enjoyed the challenge of defining the type of design task. At this point in the study the participants have not provided clear answers about how their preferences impact their design strategies.

At the end of the second interview, the interviewers gave each participant an opportunity to express what would they do differently if given the chance to begin the whole design process again. Fifty percent of the participants responded that they would plan their time differently; 25\% would focus on the visualization model; 25\% would work a little bit harder; 25\% would break down the task into parts; and 25\% would focus on the prototype model.

5. Issues, Challenges, and Recommendation

In this section, the authors highlight the issues, challenges, and recommendation that will benefit the further study in metacognitive assessment using a semi-structured interview.

a. A paradox of flexibility exists in the semi-structured interview. For example, we missed or did not ask the same questions to all respondents because questions were often misinterpreted, especially confirmation questions. A recommendation could be (1) to involve students (i.e., non-targeted participants) to review the interview questions, and (2) to pre-interview all students so that we can choose the students that demonstrate good communication skills.

b. In this study, the time frame should not be adjusted. If the study was a longitudinal study, then the frequency should be repeated in the same time intervals.

c. Involving more participants in terms of quantity and variety (i.e., freshman and senior engineering students) would provide more conclusive results. Four students are not enough to capture a clear portrait of students self-reports.

d. Comparing the result with other types of students self-reports (e.g., journal writing, artifact, and questionnaire). A triangulation process will help the authors to examine to what degree a semi-structured interview will benefit data analysis process in metacognitive assessment.
e. Transcription of the interview proved to be very tasking because the interviews proved to be wordy and not specific to the questions asked. Most of the interviewees were attempting to demonstrate their importance rather than address the questions. Recommendations – see point a.

f. Since an anticipation of how students may react can never be complete or accurately forecast, it is recommended that once the interview has started, the interviewer should go with it. In addition, taking notes may help the next phase of the interview.

6. Conclusion

Russel Baker’s quote does not only apply to the students, but also apply to the interviewers. By not pre-screening students for good communication skills and not spending enough efforts for reviewing interview questions, considerable work had to be performed to assess the metacognitive skills. In addition, transcriptions are much easier to perform if the students do not have to elaborate on each interview question with their own analogous misunderstandings. Considering that this was our first professional interview experience, the interviews went well. However, we soon realized that the art of interviewing is not simple, but rather a technique that requires many years of research and practice, and an understanding that there is no such thing as “the perfect interview.” Although the semi-structured interview has some limitations, it provides valuable information for educators and researchers about the roles of students’ metacognition in engineering design activity.

References


