AC 2012-3324: DEVELOPMENT OF THE SCIENCE AND ENGINEERING CLASSROOM LEARNING OBSERVATION PROTOCOL

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Development of the Science and Engineering Classroom Learning Observation Protocol

Abstract
The purpose of this paper is to describe the development of a classroom observation protocol (SEcLO: Science and Engineering Classroom Learning Observation Protocol) that can help identify how STEM learning outcomes are linked to specific classroom practices when teaching engineering, specifically in the setting of K-12 education. The development of the protocol started by reviewing the K-12 STEM standards and NAE reports on K-12 engineering education. We also conducted a content analysis of prominent engineering curricula such as Engineering is Elementary and Project Lead the Way to identify diverse ways engineering is currently being taught in classrooms across the country. In addition, published and validated classroom observation protocols such as Reformed Teaching Observation Protocol (RTOP) are used as models. In its current form, SEcLO is a theory-driven protocol with sufficient content validity. Future research is needed to evaluate inter-rater reliability and establish its concurrent validity by comparing the observation scores and student learning outcomes.

Introduction

Despite the continuous efforts, increasing K-12 students' access to and performance in STEM subjects is still a challenge. K-12 engineering education brings a new perspective to teaching STEM subjects. However, while some research shows engineering education supports student STEM learning outcomes, others suggest lack of significant gains in student learning. One of the challenges is that while there had been studies examining the relationship between curriculum used and student learning outcomes, few studies looked at how these learning outcomes are linked to specific classroom practices. In other words, are there specific types of engineering teaching practices (re-design projects, new design projects, projects with societal connections, projects with competitive aspects, etc.) that result in different types of learning outcomes? Our intended long-term goal is to study the alignment between K-12 engineering curricula, the implementation of these curricula, and the resulting student learning outcomes. However, as a first step, what is needed is a robust and validated classroom observation protocol that can help distinguish differences in instructional approaches and inform the discrepancies in literature on student learning. Hence, the purpose of this paper is to address this need and describe the development of the Science and Engineering Classroom Learning Observation Protocol (SEcLO Protocol).

Literature Review

Efforts by the National Science Foundation to reform math and science classrooms through the Collaborative for Excellence in Teacher Preparation (CETP) propelled the development of several observation protocols used in science classrooms. Similar approaches and observation tools are needed for engineering classrooms as the emphasis on the "E" for engineering in STEM increases throughout the nation. The stated purpose of the CETP program was "to improve significantly the science, mathematics, and technology preparation of future K-12 teachers and their effectiveness as educator in these areas" (Ruskus, Matson, Perakis, & SRI International, 2001, p. 10). A significant outcome of this project was the development of protocols to evaluate the classrooms of the teachers affected, which can be modified for our purposes. A similar approach has been used by Peter Dirr to develop technology classroom observation protocols.

Methods

The development of the protocol started by reviewing the K-12 STEM standards and NAE reports on K-12 engineering education (See Figure 1). We also conducted a content analysis of prominent engineering curricula such as Engineering is Elementary and Project Lead the Way to identify diverse ways engineering is taught in the classroom. In addition, published and validated classroom observation protocols such as Reformed Teaching Observation protocol (RTOP) are used as models. In its current form, SEcLO is a theory-driven protocol with sufficient content and construct validity.

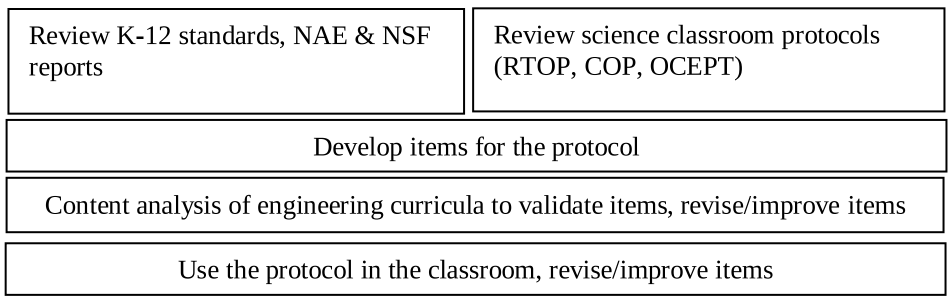

Figure 1. *Protocol development process*

Results

Emergent Themes from Reviewing Standards

A common theme that emerged from all documents was an emphasis on design. While the NAE report include integrating engineering standards into the framework of science standards, these reports focus more on engineering skills (such as systems thinking, optimization, etc.) (NAE, 2009; NRC, 2011) . In 2009, the National Academy of Engineering released a report that included a survey of the current state of K-12 education, which suggested, "K-12 engineering education may improved student learning and achievement in science and mathematics; increase awareness of engineering and the work of engineers; boost youth interest in pursuing engineering as a career; and increase the technological literacy of all students" (NAE, 2009, p. 1). While this report provides guidance for the development of engineering standards, literature on how these standards and their implementation influence student learning is limited and varied. The report calls for increased research on what classroom conditions will allow for students to develop engineering design ideas and understanding, which our SEcLO protocol addresses.

Emergent Themes from Reviewing Published Classroom Protocols

In order to evaluate CETP, NSF developed the CETP Core Evaluation Project to look at individual participating locations (Lawrenz, Huffman, Appeldoorn, & Sun, 2001). Shown in Table 1, this effort resulted in several key classroom observation protocols being developed, validated, and published. Significant items that were reviewed for the purpose of this project include NSF's Classroom Observation Handbook's Classroom Observation Protocol (COP) (Lawrenz et al., 2001), work from the Evaluation Facilitation Group of the Arizona branch of CEPT (ACEPT) (Sawanda, Piburn, Judson, & Turley, 2002), and subsequent work from the

Oregon CETP (OCEPT) (Wainright, Flick, & Morrell, 2003). The trend of these tools' development is that they are based on previously developed protocols and then tailored for the specific study they are being used for. This is the intention of reviewing them for the purpose of our study; they lay a solid base for the protocol we are developing.

The protocols examined contain significant similarity; an outside observer uses them during a period of observation within a classroom. Information is gathered about the background of the observer and teacher as well as classroom demographics and a description of the purpose of the lesson (Lawrenz et al., 2001). Both the COP and OCEPT tools contain indicators for the lesson's ability to accomplish the following: 1) account for students' prior knowledge and preconceptions, 2) foster collaborative learning, promote conceptual understanding, encourage students to generate conjectures and alternative solution strategies, 3) demonstrate teacher knowledge, 4) connect learning to other areas, and 5) promote problem solving. Based on the success of these previous protocols, these same categories are to be included in our SEcLO. However, SEcLO will be designed for use in engineering classrooms.

Table 1. *Math and/or Science Classroom Observation Protocols*

	Categories	Length (# of items) 7 Scale	Sample Item	Authors
COP	Background Information, Classroom Demographics, Classroom Context	31 items (*Five-point scale 1 (not at all) to 5 (to a great extent)* + observation table and 1 open ended question	"This lesson encouraged students to seek and value alternative modes of investigation or of problem solving." "Students were reflective about their learning"	(Lawrenz et al., 2001)
RTOP	Lesson design and implementation, Content, Classroom culture	25 (5-point scale)	"The instructional strategies and activities respected students' prior knowledge and the preconceptions inherent therein." "The lesson was designed to engage students as members of a learning community."	(Sawanda, Piburn, Judson, & Turley, 2002)
O-TOP	Habits of mind, Metacognition, Student discourse & collaboration, Rigorously challenged ideas, Conceptual & Divergent thinking, Interdisciplinary connections, Pedagogical content knowledge, Multiple representations.	10 (0-4 scale)	"This lesson encouraged students to seek and value various modes of investigation or problem solving.' "Teacher encouraged students to be reflective about their learning."	(Wainright, Flick, & Morrell, 2003)

Piloting an Early Version of the SEcLO Protocol

The pilot version of the SEcLO protocol was six pages and included sections focusing on the engineering design process, engineering content, gender differences, science content, reflective and active learning, students' level of frustration, and the amount of direct support from the teacher (see Table 2) for sample items.

Table 2. *Sample Items from SEcLO (Pilot Version)*

Category	**Sample Items**
1) Engineering design process	a) Students identified a problem b) Students shared and developed a plan c) Students created and tested their chosen design d) Students communicated results of their design and testing e) Students improved their design f) Students retested their design
2) Engineering content	a) Students identified the role of clients/users b) Students identified criteria/constraints c) Students modeled their solution(s) prior to creating their final prototype d) Students identified connections between engineering and society e) Students utilized peer and teacher feedback to make decisions about redesign f) students utilized data acquired through testing when making decision about redesign
3) Gender differences	a) Were girls *more*, *equally*, or *less* actively engaged (answer for each stage of the engineering design process) b) Did girls exhibit *more*, *equal*, or *less* leadership (answer for each stage of the engineering design process)
4) Science content	a) Overall use of scientific vocabulary b) Overall quality of scientific vocabulary c) Students discussed scientific concepts in the context of engineering d) Students worked together to develop consensus on meaning of scientific vocabulary e) Students used scientific words to discuss with each other f) Engineering work evokes science questions g) Students apply science concepts and principles in their engineering work h) Students use prior scientific knowledge not identified in the learning standards for the lesson i) Students represented science concepts in invented/informal expressions, diagrams, or pictures j) Students predicted the performance of their design based on scientific knowledge
5) Reflective and active learning activities	a) Students ask for explanation during period b) Students follow teacher's instructions c) Students share information with other students d) Students discuss ideas with other students e) Students collaborate with other students f) Students develop and make graphs/charts g) Students play with/explore objects with hands h) Students use tools for measurement/fabrication i) Students record and analyze observations or data in a design notebook
6) Students' level of frustration	Rate frustration level from 0 (low) to 3 (high) (answer for each stage of engineering design process)
7) Amount of direct support from teacher	Rate amount of direct support received from the teacher from 0 (low) to 3 (high) (answer for each stage of engineering design process)

The pilot version of this protocol had several problems, and was especially difficult for a novice researcher to navigate. The first issue was length, flipping through six pages to make notes during an observation was particularly cumbersome. One of the author notes feeling as if she missed more than she saw trying to make sure that each category and item was considered during the observation period. Second, the protocol used tally marks to keep track of each item, with few exceptions (i.e. Categories 3, 6 and 7 in Table 2). There is no prompt, however, to separate the tally marks by team. Consider the following example. Two students on a team of four use exemplary science vocabulary to describe how their design behaved during testing. Does this count as one tally, or two? Since both students were using exemplary words, let's say two. You move on to observe three more teams and see two more students having a similar conversation, and you make two more tally marks. A week later you review the data from the observation. Did the four tally marks come from one team with four strong members, two teams with two strong members, or four teams with one strong member? As most seasoned researchers know, data from classroom observations can take place several months after the observation takes place, or be analyzed by a different researcher. In either case, the observer's memory should not be relied upon to answer this question.

The number of tallies recorded per team is an important distinction to make, especially if the objective is to get a sense of the classroom as a whole, and thus it should be explicit in the observation protocol. Third, some items are either redundant or ambiguous, particularly within the science content category (Category 4 in Table 2). Consider the same example just discussed. Would the two tally marks for the students using science vocabulary to describe the behavior of their design during testing be placed near Items *A*, *C*, *E*, or *G*, or some combination of these four?

Experience also showed that asking one question to be answered across the entire range of the engineering design process was not applicable (i.e. gender differences, frustration, and direct support from the teacher). Most observation periods ranged from 20 to 50 minutes and specifically focused on one stage of the design process. Reducing these sections would make the length of the document more manageable. There were also some issues with the flow of the protocol. For example, the items included in the engineering content category (Category 2 in Table 2) are also indicators of certain stages in the engineering design process (Category 1 in Table 2). These two categories were on different pages, which made noting connections between the two more cumbersome.

Finally, for the novice researcher, there was very little direction on how to navigate the protocol. The instructions stated "make sure to give attention to all categories and items," but no direction on where to start, how to cycle move around the room focusing on individual teams, but only for a short while, and what can be added at the end for detail, but doesn't need to be written during the observation itself.

The SEcLO Protocol in its Current Form

Based on themes emerging from standards, published protocols, and pilot-testing, several revisions have been made to the current SEcLO protocol. The protocol is now eight pages, but segregated into sections of pre-observation, during observation, and post-observation, all of which should be completed before the researcher leaves the observation site. The pre-observation categories are for information about the classroom and lesson. These items can be completed while the teacher is giving instructions to the students. The during-observation section is now only three pages, and organized such that engineering content, science content, and other observation categories are grouped onto the same page for easy notation. The categories of active observation include:

- Engineering design process vocabulary and behaviors
- Scientific vocabulary and behaviors
- Degree of frustration and understanding
- Gender difference

This section does have designated areas to make notes, but mainly uses a tally-mark system, with instructions to separate tally marks of observed occurrences by team (Figure 2). Another difference is in the examples provided with regard to “exemplary vocabulary” and “exemplary behaviors” to look for (see Figure 2). This is to provide some direction, especially for novice researchers, but there is still space provided to give examples of vocabulary/behavior observed that was not included in the lists provided.

PART THREE: Observation of ENGINEERING DESIGN PROCESS

Exemplary Vocabulary
Criteria/Constraints Client/User Objectives
Materials Ideas/Alternatives Measurement
Prototype/Model Test (try it) Results
Performance Explain Improve/Revise
Optimize Plan Report Reflect

Exemplary Behaviors
Touching Manipulating
Sketching Predicting
Comparing Discussing
Observing Testing
Recoding Organizing

Number of teams: ___________ Number of students per team: ___________

Make a tally-mark for occurrences of ***Engineering Process vocabulary*** in the boxes below (use a different box for each team):

Make a tally-mark for occurrences of ***Engineering Process behaviors*** in the boxes below:

Figure 2. *Clip of Current SEcLO Protocol*

The final post-observation sections are summaries that should be completed immediately after the observation period. The purpose of these sections are to quickly summarize the information ,but also to provide additional details of students’ language or behaviors, teacher interactions that may have influenced results, and/or other relevant contextual descriptions that were too lengthy to write out during the observation period.

Conclusions

We have developed a classroom observation protocol specifically designed for use in engineering classrooms. Future research is needed to establish its concurrent validity by comparing the observation scores and student learning outcomes. An issue that is common to similar classroom observation tools is the complexity of the protocol. This requires observer training, which can be cumbersome. Future efforts will focus on simplifying the protocol while maintaining its validity and gathering data on inter-rater reliability.

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