Assessment of Progressive Learning of Ethics in Engineering Students Based on the Model of Domain Learning

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Abstract

This work presents the results of an assessment instrument designed to assess the progressive learning of ethics in the engineering curriculum at different stages known as acclimation, competency, and proficiency, and to determine the relation of the development stages with three components that contribute to learning: interest, knowledge and strategic processing. The questions in the instrument were defined following the Model of Domain Learning (MDL) to capture the level of ethics skill development. The questionnaire was administered to engineering students of increasing class standing (i.e., freshmen to senior). The results show that the instrument successfully captures the ethics skill development in engineering education taking into consideration the components and stages of learning described by the MDL framework.

Keywords

Ethics, assessment, engineering education, model of domain learning.

Introduction

Ethics is a skill that every professional should have and apply. As any other skill, it can be taught and learned. Academic institutions have adopted different methods to introduce ethics in the engineering curriculum[1-2]. In terms of coverage, some institutions use standalone courses while others have embedded ethics in different courses through the curriculum. Teaching approaches vary from formal lectures to case studies, the latter being a common practice to foster ethics reasoning and to prepare students for the analysis and solution of ethical dilemmas. However, a salient challenge has been the assessment of this skill's progressive development in higher education settings. Some authors have used the Defining Issues Test (DIT and DIT-2) and the Engineering and Science Issues Test (ESIT)[3-5], to assess moral reasoning. Another instrument is the Study of Engineering Ethical Development (SEED) survey[6] that has been used to assess development in ethics knowledge, reasoning and behavior in curricular and co-curricular activities. Additionally, rubrics for outcome assessment of students' ability to comprehend, analyze, and resolve ethical dilemmas through case studies have been proposed in the context of engineering[7-8]. Finally, Davis and Feinerman[5] proposed a questionnaire to assess ethics based on the content of the material taught, the discipline and students' class standing. However, none of the assessment instruments and approaches described above is able to fully show the progressive development from personal moral values students have when they start their engineering education to the professional ethical behavior required at graduation, and the correlation that exists between the learning stages and the learning components contributing to the development of the ethics skills.

This work presents the results of an assessment tool implementation that enabled assessment of students' development of ethics skills at different learning stages, namely acclimation, competency and proficiency; and their interrelation with interest, knowledge and strategic processing components that contribute to the learning process. The instrument presented in this paper is developed based on the Model of Domain Learning (MDL)[9], which has been shown to appropriately describe the progression of learning across above mentioned stages in different academic disciplines.

MDL Framework

The MDL[10] describes learning as a progressive and incremental process where knowledge, skills and attitudes are developed at different stages. Further research by Alexander et al.[11] describes the interrelation that exists between the development stages known as acclimation, competency and proficiency and the learning components through which learning is gained (interest, knowledge and strategic processing). The interrelation among those learning components provides a more comprehensive perspective of how different individuals engage in their learning. For example, in some cases learner performance has a more significant causal link with the interest in a specific domain than with the learner's ability to gain knowledge from a textbook. Table 1 summarizes the description of the MDL learning development stages and components through which learning is gained[12].

Table 1 Description of the MDL Components and Stages

	Acclimation (A)	Competency (C)	Proficiency (P)
Interest (I)	Situational interest: spontaneous, transitory, and environmentally activated interest that is associated with increased attention when a new topic is introduced.	Increased individual interest due to increased engagement in a domain	Individual interest: long-term, deepening, personal connection to a domain, which in turn inspires further exploration of the domain
Knowledge (K)	Limited and fragmented knowledge	More cohesive domain knowledge principled in structure	Broad and deep knowledge
Strategic Processing (P)	Surface-level strategies: the implicit acceptance of information and memorization as isolated and unlinked facts	A mixture of surface-level and deep processing strategies	Deep processing strategies: applying isolated knowledge in problem solving procedures

Alexander[10] compared the MDL with traditional models of learning (TML) in three dimensions and suggested that the MDL might be more appropriate for academic concepts. Contrary to the TML that focuses on problems outside the academic domain (i.e., dance), the MDL focuses on learning in academic domains (i.e., history, math). While the TML promotes training to duplicate expert performance, the MDL fosters students learning and development. Additionally, the MDL considers the motivation and affection of individual learners whereas the TML ignores them. The MDL also establishes the interrelation between three primary learning components (i.e., knowledge, interest, and strategic processing) and the development stages longitudinally over time, which is topic of interest in this work as we study the progression of learning and the relation with learning components contributing to that progression.

Research Goal

The goal of this study is to determine if the progression of engineering students' ethic learning can be captured using the MDL framework. To reach this goal, a questionnaire is proposed and administered to address the following questions:

- Do MDL-based components of students' ethics learning (ethics knowledge, strategic processing and interest) increase over their engineering program?
- Does students' journey between the stages of learning (acclimation, competency, and proficiency) improve along the engineering curriculum?
- Is there a correlation between the interest and the development of the knowledge and strategic processing components?

Research Methodology

Assessment Instrument

The assessment instrument includes 31 questions that are either in multiple choice or Likert scale form. The first five questions are related to demographic information of the group. This allows characterizing the population based on gender, ethnic background and engineering disciplines. The next 18 questions include ethics concepts and short descriptions of situations involving ethical issues (i.e., very short cases), where students are presented with a set of options to select the appropriate response. The responses of the students to the questions capture the level of awareness and reflection on ethics. The final eight questions are designed to measure the level of interest of engineering students on ethics.

The concept questions were derived from the textbook by Barry and Seebauer[13], and the short cases used in the questionnaire were adapted from a list of cases published by the National Academy of Engineers (NAE) (2014), National Society of Professional Engineers (2014), and the Vanderbilt University Center for Ethics (2014). The questions were reviewed and endorsed by an external subject experts representing industry and academia who served as project consultants.

Participants and Demographics

A total of 1,161 students participated in the ethics survey administered to all degree-seeking Penn State Engineering students at the undergraduate level. After cleaning the data and disregarding incomplete surveys with missing answers, the size of the sample reduced to 951. Of the 951 students, 87% were males (n = 828) with the remaining 13% of respondents as female (n = 123). There was a larger proportion of underclassmen (68%) than upperclassmen (32%) participating in the study. There were a total of 432 Freshmen, 219 Sophomores, 154 Juniors and 146 Seniors represented in this study.

Variables

Variables used in the analysis represent the three MDL components and three stages of learning. For the multiple choice questionnaire items, the questionnaire items were recoded as 0 if the student answered incorrectly, and 1 for correct responses. For Likert scale questionnaire items where there is no "right" or "wrong" answer, students who indicated a low value or interest received a 0 while they received a 1 if they held strong values or interest to the related question. Lastly, each study variable was normalized to range from 0 to 1 for easy interpretation and consistency; this normalization allowed representation of results in percentages (i.e., the measurement of student performance in skill development along the engineering curriculum). The summary of variable descriptive statistics can be seen in Table 2.

Table 2 Summary statistics of learning components (Normalized)

Learning Component	n	Mean	Standard Deviation	Min	Max
Interest	951	0.6059	0.2536	0	1
Knowledge	951	0.5082	0.2249	0	1
Strategic Processing	951	0.6592	0.2227	0	1

Results

To gain better insight about the performance on each variable for the stages of the engineering program, the scores were averaged by groups. Participants were classified into four groups: Freshman (n_{fr} = 432), Sophomore (n_{so} = 219), Junior (n_{jr} = 154), and Senior (n_{sr} = 146). By examining the development level within students' class standing groups (freshman to senior), one can gauge whether students over time perform at higher rates than previous years. Ideally, to test gains across a given span of time, data is collected longitudinally, tracking an individual across their college career. Because we assume that regardless of student ability and demographic background, as whole, students will have higher learning gains as they progress through the engineering program, we assert that by aggregating and averaging out values over different class standing groups can provide insights similar to that of a longitudinal study**.**

Figures 1 and 2, where average scores are examined across learning components and stage levels for different class levels. The results show a general upward trend for both variables: learning components and development stages. This suggests that as a student progresses across the stages of the engineering curriculum, ethics skill learning, as captured by the instrument, improves.

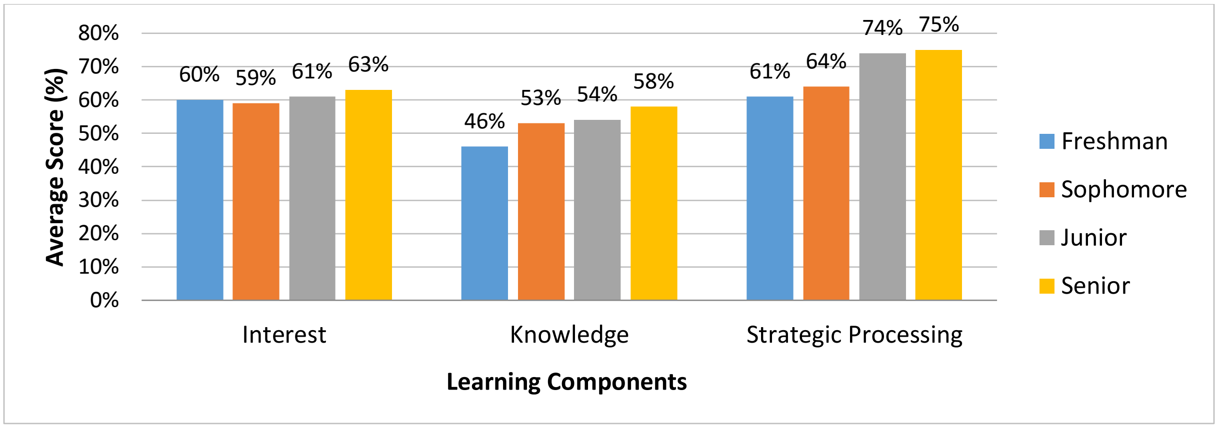

Figure 1: Average Score (%) of Learning Components—Interest, Knowledge, and Strategic Processing (by Student Level)

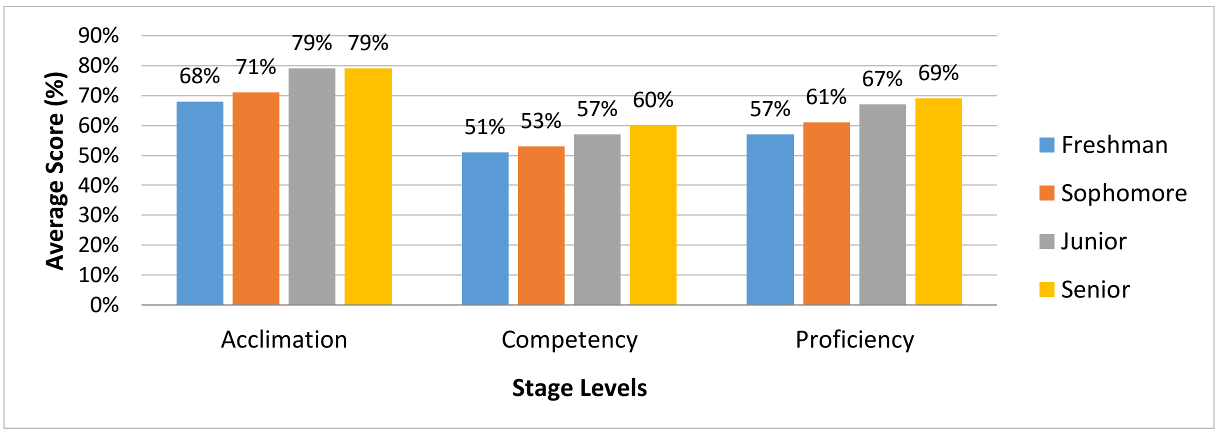

Figure 2: Average Score (%) of Stage Levels—Acclimation, Competency, and Proficiency (by Student Level)

The results constitute the preliminary evidence that the instrument captures the ethics learning development along the engineering curriculum. However, not all the components have the same behavior. In the analysis of the learning components, it is observed that interest plateaus longitudinally (i.e., no significant increase in interest is observed). This can be explained by the nature of ethics and the way it is perceived by engineering students. Knowledge shows a significant increment between freshmen and seniors but not significant differences between sophomore and juniors where a 1% increase is observed. Strategic processing also presents a significant increment between upper level students (juniors and seniors) and lower level students (freshmen and sophomores). A similar behavior is observed for within-stage development levels where increments are observed in all three levels: acclimation, competency and proficiency. This is consistent with the MDL framework in that students initially become familiar (acclimate) and their level of competency increases as they progress in their studies. Finally, a correlation was conducted to test the relationship between the variables, specifically to interest (see Table 3). All relationships were considered statistically significant ($p < 0.05$). Pearson's R results indicate that most relationships suggest a moderate to strong positive correlations with the exception for the relationship between knowledge and interest ($|R| = 0.09$); strategic processing and interest ($|R| = 0.16$); and interest and acclimation ($|R| = 0.25$), which have low positive correlations.

Table 3 Person's R results for the correlation among the six variables

	Interest	Knowledge	Strategic Processing	Acclimation	Competency	Proficiency
Interest	1					
Knowledge	0.0864	1				
Strategic Processing	0.1572	0.3738	1			
Acclimation	0.2546	0.4937	0.7443	1		
Competency	0.4696	0.5102	0.6621	0.4297	1	
Proficiency	0.4663	0.5285	0.7066	0.4985	0.5082	1

Conclusions

This study shows that the MDL can be used to measure the progressive learning of ethics skills in engineering taking into consideration three learning components: interest, knowledge and strategic processing. The results are consistent with the MDL framework; however, the analysis of correlations reveals that the correlation between the interest and the other two learning components is not significant. This contradicts the MDL assumption that higher level of interest will result in an increment in knowledge and strategic processing. The questionnaire does not reveal the causes of the low correlation. It might be the case that students do not perceive ethics as an important competency in engineering so the level of interest remains almost the same as students advance in their studies. Further research is needed to study the effect of interest on the other two learning components in the case of ethics skill development of engineering students.

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