Developing Self-awareness in Learning Practices: Designing and Implementing a Survival Tool for Freshmen in Engineering

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Abstract

Freshman engineering courses are considered to impact students' perception of engineering and university education. In many aspects, the freshman engineering class needs to be one of the most transformative classes on students learning, self awareness, and professional identity. During their freshman year, many students attempt to draw connections between their aspirations and their educational path. While some students get engaged in the pursuit of best grades, many others find engineering courses to be packed with material, information, and tests with taxing "rigor" and an impediment towards pursuing their passion/dreams. This attitude calls for a necessary transformation in both the course delivery and student's outlook towards learning. Thereafter, in the freshmen engineering courses at our institution we have designed our freshman course in Electrical Engineering to allow students to pursue their interests while becoming self-aware of their learning practices, have a smoother transition to university education and hopefully develop some professional identity as students. In this work, students' reflections about learning and critical evaluation of systems will be evaluated. Variations in the texture of the students' reflection over the course of the semester will be described.

Introduction

Developing a sense of purpose, belonging, and a personal identity are all parts of an undergraduate student's college experience [1]. In fact, under many circumstances, students form lifelong connections and with the right teams, many important technological and social developments occur right through one's college years. An integral contributing factor behind these is the environment and the team of learners with whom the student can think, grow, and learn. More importantly, the student's method of learning, awareness of personal practices, and ability to connect different aspects of their knowledge are all essential lifelong learning skills that students can assimilate right from their freshman year [1-6].

While students have pre-existing knowledge and learning methods, it is found that many of these methods aren't appropriate for developing deeper learning and require modifications [7,8]. In these cases, students need a way to revisit, reframe, and redesign their learning approach, quickly become aware of their personal styles, and be open to accept and learn new learning styles. It is also important for them to not learn in isolation or be fixed with a single way of doing things.

1. **Reflective Practices and Inquiry: A motivation**

Since 2006, our team has been involved in technological literacy curriculum working with non-engineering students to develop understanding of Technological and Engineering literacy [9, 10]. Using reflective practice [11,12] in the technological classes enable us to track students' development and cognitive engagement better than regular assignments, quizzes, and tests. Over the year, we have been seeing deeper appreciation and understanding shown by our technological literacy students than in a few of our engineering classes. Starting in 2013, we have started to bring about a similar indepth engagement of reflective practices in our freshman engineering classes. In 2015 we started a more in depth approach to the reflective practice in our Freshman Engineering program. The objective of the project is to see if the engineering students will also develop their deeper learning and cycle of questioning and reflecting. In addition, we would like to know if the process helps them developing self awareness in their learning practices and if this helps them be more successful in their growth as engineers.

As instructors, these bring us new challenges. Generally, students tend to repeat what they mostly did in their classes: memorize and repeat what they know well to achieve good grades. In most classes, tests are also designed around such learning practices. However, there aren't many ways for students to communicate their learning methods, their thoughts, and their reflection on how they approach the material and the subject. Moreover, the students tend to learn by themselves while they do homeworks or labs and may not form a community of learners beyond the classroom.

One way to overcome many of these challenges is the inquiry-based learning approach [13-17]. In this technique the students can pursue their questions and inquiries by building on their pre-existing knowledge. Students are expected to question their learning, formulate and justify their approach, and more importantly, adapt new learning methods that complements their prior knowledge. Students who already learn in this fashion can obtain a deeper perspective in the course and draw connections between what they already know or are learning as a part of the course.

An important aspect of the inquiry-based learning process is the self-driven exploration. While this freedom in learning might be liberating for some, for many others it is a matter of great anxiety. This is primarily because students are unaware of their learning capabilities or are unwilling to share their creative ideas due to fear of grades. Additionally, they feel uninformed about the instructor's expectations from them and tend to share minimal information. From these initial observations, one can easily state that there is a great need for students to be aware of their capabilities, demand of learning, and their personal learning practices. Once they are armed with these personal intuitions, a student can then breakdown any engineering course and enjoy the content without becoming a "slave" to the process of repetitive activities.

Thus, the premise of our work in this paper is to uniquely determine how and when freshman engineers become self-aware of their personal learning practices via inquiry-based methods. Reflective activities will be evaluated to gain insights into the student's development.

2. **Freshmen Students**

The life of freshman engineering students is busy with calculus, physics, chemistry and other classes that are heavy in homework, lab, and tests. One of the major goal of the freshman engineering classes is to help students in engineering (or those who are possibly inclined to be engineering students) make sense of their experiences, understand fundamentals, and the processes of engineering, critical thinking, and problem solving. Consequently, the students needs to develop habits and processes of systematic learning, thinking, and connecting their knowledge.

Freshmen students need to have a greater understanding of who they are and be aware of their likes and dislikes, their strengths and weaknesses, and their way to learn and adapt to new classes, challenges, and communities. In our studies, students who are in technological literacy classes (designed for non engineers) show great interest and knowledge retention, when they get to play, make mistakes, make connections, ask questions, and reflect on their experiences. The key is for them to understand who they are and what they like, and why they need to know something. That way, the students have a set of connections, reasons, and applications that help them understand the process of learning and using the knowledge. In particular, there is evidence that the current students have a more self-focused approach. Consequently, the more they become self aware and engage in personal and group reflections, the more they can develop empathy and understanding of what they want to do and learn.

Research Approach

1. **Dewey's inquiry methods**

One of the most important tool set that students need to have is a dynamic inquiry approach to learning, ideation, critical thinking, and developing systems level perspectives. To facilitate development of such skills, the class and the interactions, reflections, and assignments are based on a Deweyan Inquiry approach together with Habermas and Grundy model [7,8] of cognitive development. This class has very similar elements to other inquiry based classes with the focus on awareness of student cognitive development as they mature in different stages of growth and learning. The class is designed as an active learning environment, in each lecture students discuss and work with other members to develop ideas, and think about an activity (game) and reflect on their learning, challenges, and perspectives. Students do reflections to communicate their ideas, thoughts and challenges.

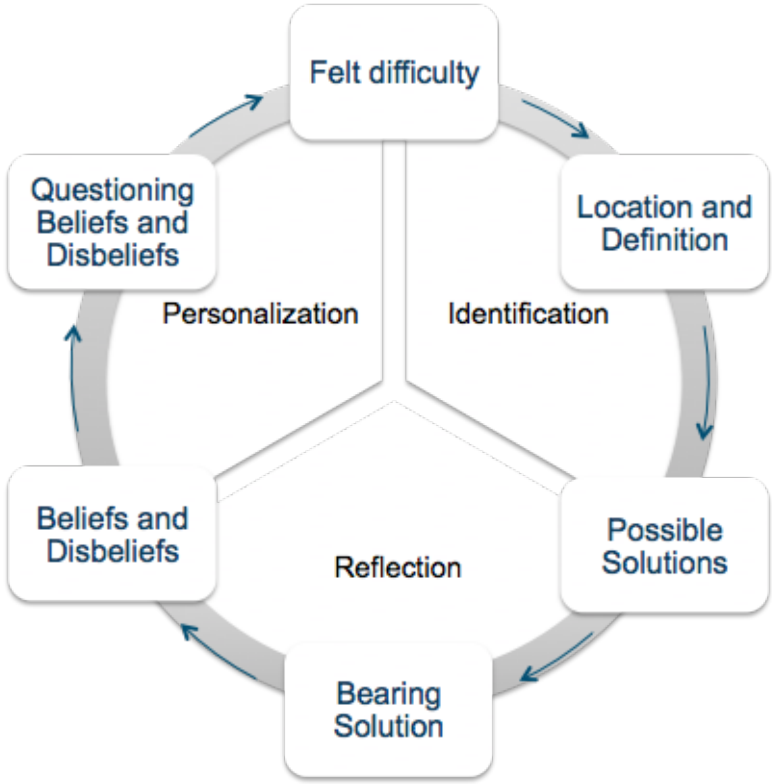
In Fig. 1, we see a representation of Dewey's inquiry cycle adapted for the students in our course. We have further subdivided the inquiry stages into three states that we found the students to be in. These are :

1. **Identification** - This is typically the first four weeks when the students are trying to figure out what the course is all about and how their learning methods can fit in the framework of the course. All students go through this state. They experience a problem and attempt to find a solution. For our work, at this state, students are in difficulty, and repeat and use formulas and definition. They cannot distinguish what is right and why and what is wrong, so they go by others definitions such as formula or repeating facts.

2. **Reflection** - After the initial month in the next two months many students start tracking with the course goals. They are able to reflect and start thinking about possible ways. In this state, students begin to think about the solution they adopted and the potential consequences. This is a n early reflection phase, students are trying things, making mistakes and learning.

3. **Personalization** - This is a phase of metacognitive reflection. Students demonstrate this in action sporadically through the semester. However, a true metacognitive state occurs when the student decides to reflect and think more about their solutions and beliefs, they question their learning and once again enter a deeper cycle of inquiry. In addition, in this stage they make connection, and see that what they know is more than the applications that they are facing, they emancipate and make bigger leaps and connection. Typically deep personalization occurs towards the end of the semester.

Fig.1: A symbolic representation of Dewey's Inquiry Cycle



It is noteworthy that the student advances in learning and thinking stages [18-24] by going through the inquiry cycle multiple times. In every iteration the student grows and internalizes the cycle, creating new ideas and questions leading back to the process of inquiry.

2. Reflective writing and Phenomenography

Perhaps one of the most important places that reflective practice helps the growth of the students is in Freshman Engineering Classes. In our work, the reflections are defined and practiced with very basic definitions such as the ones offered by University of Edinburgh [25].

Since most of the students are not used to reflective practice and active classes that would engage them in doing things in class, and stating their opinions and reflections, they start at a confused state of what it is that they need to do? Is there an answer? Is there always a right and a wrong answer? In this class we do talk about what is reflection, what are the better practices and not so effective ones. We also encourage them to openly state what they think, feel and can and cannot do. The openness and inclusivity of these classes are of essential importance. We would like the students to be open, reflective, and to tell us their difficulties, and the ways that they are successful. The inclusivity, and openness to students' perspective is of essential importance to help student feel belonging and be a part of the process. The goal is to make sure students know we are here for their growth, learning, experimentation, and success. We also encourage them to examine and re-examine their beliefs and discuss that with us and peers in the class.

One of the interesting aspect of this class, is that many students may not openly talk about the importance and the usefulness of the material during the class, and at times they may dismiss the purpose. In their upper level classes they may find the usefulness of the class, the way of thinking, and critical examination of their knowledge. Finally, many of the students come back and let us know that when they were in co-op or internship, the material of this class, especially critical thinking, self learning, and careful examinations of knowledge and doing was of great importance to them.

Our observations show that as students start the process of active learning and doing and reflecting they are unsure and have lots of doubts, fears, and uncertainty about how reflections and in-class active learning may hurt their grades. At the beginning students will be cautious, careful, and not deeply reflective. In order for the process to work, instructors needs to create an open interaction, and inclusive environment for the students to feel safe showing their weakness, questions, and even their answers. Mistakes are inevitable, but is it via taking the chance and writing what they think that mistakes will be revealed to the instruction team. In a reflective environment, if all students show the same lack of understanding and the same mistakes, the instructing team knows that they have been miscommunications and challenges that need be addressed. Consequently, the process of active learning and reflections provide a healthy platform of expression for the students and examination of what is working and what is not by the instruction team.

Our findings shows that as students gain confidence and learn from their work, success and mistakes, the texture and thematic content of their work and reflections changes to a more indepth and advanced language. The instruction team can detect that for each student by being aware of the change in descriptions, discussions, and connections that student make. A phenomenographic analysis approach, primarily based on identifying keywords, phrases and indicators will be used to assess the students' progression [26-28]. In many cases the usage of the words, verbs, and actions follow the progression that are used in Bloom's studies [18]. An important aspect for a successful utilization of reflections is timely and effective feedback to the students from the start of the process.

Research Questions and Findings

Our primary research question is to know if the process of reflection and inquiry helped students become aware of personal learning methods and be better critical thinkers. In view of Dewey's inquiry cycle, we found that most students are willing to identify their problems and find plausible solutions. However, the real transition to a state of metacognition or advanced thinking occurs only when students start to feel the impact of their decisions and re-question their personalized inquiry, thoughts and beliefs.

To assess the students progress two sets of reflective activities have been presented. In the first reflective assessment the students verbalization of personal learning was examined at two different points in the semester. The first assessment was designed to know how the student perceived learning and knowing (earlier in the term) and the second assessment was designed to know if they had changed their ways of learning (a month and a half after the first assessment). The second assessment was designed to know if the student's personal awareness about their learning is reflected in their work. An example of their work related to systematically visualizing an electronic system was similarly assessed at two different points in the semester. Overall, reflective writing of 15 randomly selected students was analyzed from a class of about 100 students. Since not all students were present at all times, the results are based on data from approximately 10-15 students in each study. A summary of the students process of inquiry through these different reflective activities can be seen in the following subsections.

1. Student perspectives on learning

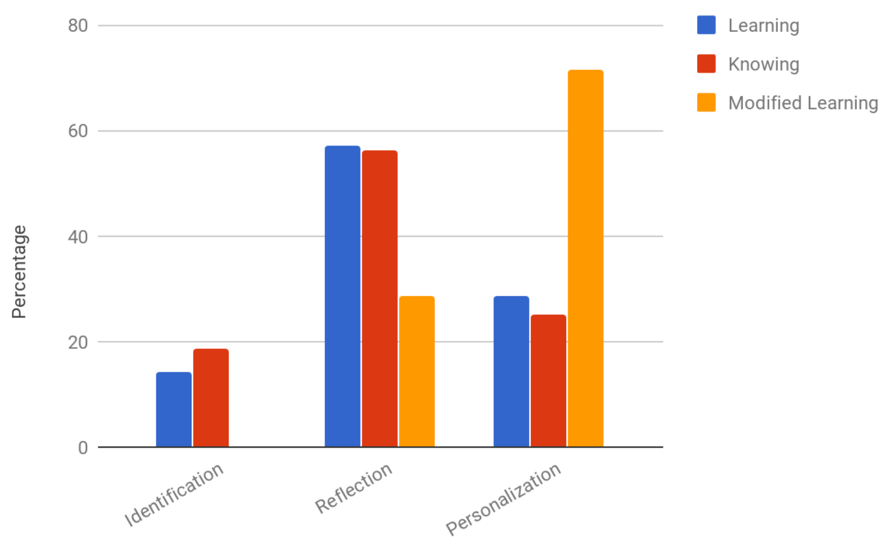
At the outset of the semester, students were asked to describe how they learn or how they know something. The same question was asked at the end of the semester with an additional segment asking them if they had changed their learning methods or style. The progression of the student's approach to learning over the course of the semester are apparent based on the type or responses seen in Table 1.

Table 1: Keywords reflecting student's perception of learning and knowing classified on their growth within the inquiry stages

Inquiry Stage	Initial Keywords: How do you learn	Initial Keywords: How do you know	Final Keywords: Has your learning changed
Identification	Study material, Examples, Memorize	Know what to do	It is same as before (High School)
Reflection	Solve problems, Ask TA, Seek help from peers or those who know	Can explain, Can do tests	Changed or challenged
Personalization	Think, Ask questions, Examine questions	Can explain at all levels, Can talk about it, Can interpret and Can connect	Thinking, questioning, reevaluating, Looking at possible directions, Working in teams, Thinking before asking

Furthermore, classifying the students responses into the different states within the inquiry cycle, we find that (Fig. 1) by the end of semester, almost 70 percent of the students are changing the way they learn and adapting their style to fit university education.

Fig. 2: Percentage of students in different states of inquiry measured through reflections at different points of the semester



These results show that even at an early stage, a majority of the students are reflective and thinking about their personal learning methods. With their awareness, practice and time they slowly start to personalize their style and are able to adapt the process of inquiry in their work.

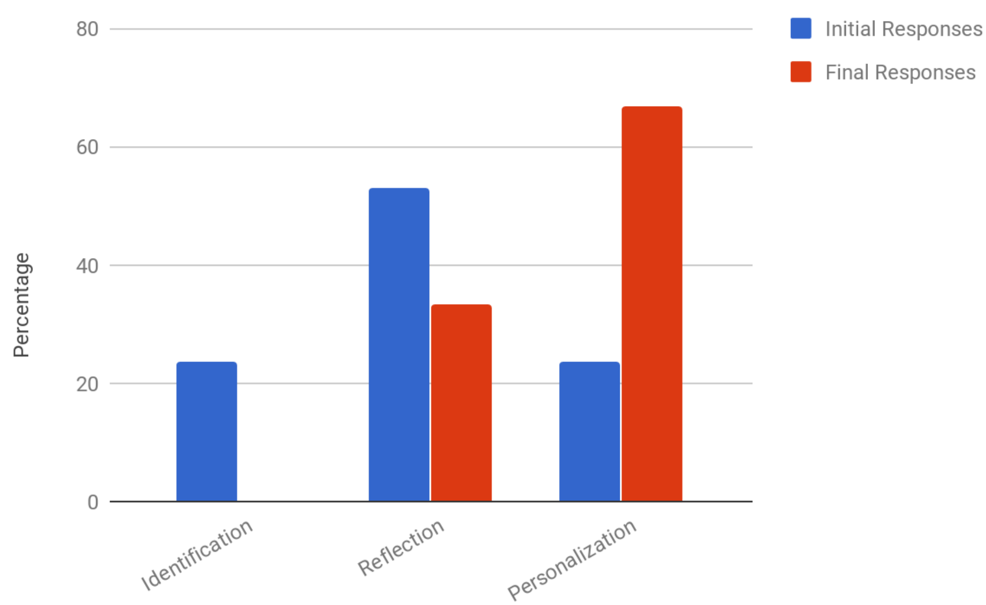
2. Student perspectives on systems level conceptualization

Another valuable reflection which was assessed as a part of our study was the students' reflections on describing any system. The students reflected on two questions. In the initial phase of the course they were asked to describe how they perceived themselves within the university system. The students looked at potential inputs, outputs and feedback between them and their surroundings. Eventually once the students had developed maturity in understanding systems and breaking concepts down to different blocks as all engineers do, they were asked to reflect on the systems level operation of a global positioning system (that they are mostly familiar and need to think deeply at the systems level perspective). For both the phases, many students used a pictorial representation to express their ideas. Additionally, many students went the extra mile to describe the technical features that they understood. A summary of the indicator words that helped us assess the inquiry stage of the student may be found in Table 2. From Fig. 3, we also see that as the semester progressed many students transitioned from intermediate inquiry stages to higher cycles of learning and thinking.

Table 2: Keywords or indicators highlighting the student's verbalization in describing systems as they grew through the different inquiry stages

Inquiry Stage	Initial Indicators: Systems Level	Final Indicators: Systems Level
Identification	General verbalization, Input variables, Output variables	Unengaged with quick and easy steps and facts
Reflection	Understand input output with numerical or pictorial	With figures and connections
Personalization	Non-trivial and creative input-output with feedback	Figures and detailed attempts to explain

Fig. 3: Percentage of students in different inquiry stages measured through their reflection on systems level conceptualization



From these reflective assessments, we see that engagement in the cycle of inquiry helps students become self aware of their learning practices and grow as thinkers. Many improvements of this type are feasible in an inclusive and communal environment. Eventually, we expect that once each student engages with the cycle of inquiry, they will be able to believe in their own strengths and become self-reliant. As the students are embracing their personal identities and thinking patterns during their freshman year, special attention and care is required from all stakeholders in freshmen engineering. It is interesting to see the results of the reflection stage. While students show growth in personalization, their perspective on the systems level shows more technical approach and less reflective engagement. At the beginning they were reflecting more, but at the later state students worked on system level diagram and connection and made less use of words to express their thoughts. This has lead this study to start evaluating doodling and sketchnoting as a different approach to reflection [30].

Conclusions

From this work, it is apparent that through the process of reflection and more importantly metacognition, freshman students can become aware of themselves, their thinking and learning. At the same time, the texture of the students reflective activities and constant tracking enable us to track their process of learning, critical thinking and attainment of metacognitive states of learning and thinking. Ultimately, as students become self aware of their personal cycles of learning and inquiry, learn from their mistakes, their verbalization and texture of work changes and this is apparent in their work on the systems level conceptualization. Additionally, as a part of their community they can confidently adapt to varied challenges that they will face in upper level engineering courses.

Future Directions

There is a need to continue the reflective practice and try to get the students to reflect more and show their cognitive developments at all levels. For the freshman engineering classes, this is of utmost importance. The first class of engineering is one of the most transformative classes that shapes students' perceptions, learning, process of thinking, and initiation in their professional identity. The goal of this class needs to be helping students find their new identity as engineering students, a university students, and a future professionals. The process of maturity and growth in these classes is a start of a journey with the ultimate goal of reaching self actualization by the students.

One of the most important questions that needs to be asked remains to be "Are they ready?" As students are becoming more and more self centered [29] with a huge influence of quick answers via internet and participations in various forms of social media, we need to identify if they are ready to engage in the type of inquiry based growth that we are introducing them to. Are they ready for the type of felt discomfort, and questioning their learning, and teaching metacognition in their reflections on their growth, and actualization. This question has become one of the most important research question of this area. In the future, as we focus on further developing our process, we should also focus on identifying the readiness of our students and if so, the forms of the activities that suits their need to be engaged.

References

[1]. Villanueva, Idalis, and Louis Nadelson. "Are We Preparing Our Students to Become Engineers of the Future or the Past?." *International Journal of Engineering Education* 33, no. 2 (2017): 639-652.

[2]. Daly, Shanna R., Erika A. Mosyjowski, and Colleen M. Seifert. "Teaching creativity in engineering courses." *Journal of Engineering Education* 103, no. 3 (2014): 417-449.

[3]. Felder, Richard M., and Rebecca Brent. "Understanding student differences." *Journal of engineering education* 94, no. 1 (2005): 57-72.

[4]. Courter, Sandra Shaw, Susan B. Millar, and Lyman Lyons. "From the students' point of view: Experiences in a freshman engineering design course." *Journal of engineering education* 87, no. 3 (1998): 283-288.

[5]. Besterfield□Sacre, Mary, Cynthia J. Atman, and Larry J. Shuman. "Characteristics of freshman engineering students: Models for determining student attrition in engineering." *Journal of Engineering Education* 86, no. 2 (1997): 139-149.

[6]. Deveci, Tanju, and Nader Ayish. "Correlation between Critical Thinking and Lifelong Learning Skills of Freshman Students/Birinci Sinif Üniversite Ögrencilerinin Elestirel Düsünme ve Yasam Boyu Ögrenme Becerileri Arasindaki Iliski." *Bartin Üniversitesi Egitim Fakültesi Dergisi* 6, no. 1 (2017): 282.

[7]. Grundy, Shirley, “Curriculum: Product or Praxis”, The Falmer Press, 1987.

[8]. Grundy, Shirley. "Challenging and changing: Communicative competence and the classroom." In *Oral discourse and education*, pp. 31-41. Springer, Dordrecht, 1997.

[9]. Mina, Mani “Dewey and Engineering Education,” in Philosophical and Educational Perspectives on Engineering and Technological Literacy, III” 2016. Published by Technological and Engineering Literacy and Philosophy of Engineering (TELPhE), Division of American society of Engineering Education.

[10]. Mina, Mani and I. Omidavar “The Relevance and Significance of Deweyan pragmatism for Engineering Education”, in Philosophical and Educational Perspectives on Engineering and Technological Literacy, II” 2015. Published by Technological and Engineering Literacy and Philosophy of Engineering (TELPhE), Division of American society of Engineering Education.

[11]. Mina, Mani, John Cowan, and John Heywood. "Case for Reflection in Engineering Education- and an Alternative." *2015 IEEE Frontiers in Education Conference (FIE)*, 10 2015.

doi:10.1109/fie.2015.7344252.

[12]. Adams, Robin S., Jennifer Turns, and Cynthia J. Atman. "Educating effective engineering designers: The role of reflective practice." *Design studies* 24, no. 3 (2003): 275-294.

[13]. Prabhu Gaunkar, Neelam, Melissa Rands, and Mani Mina. "Variations in Student Learning in an Inquiry-based Freshmen Electrical Engineering Course." *2017 IEEE Frontiers in Education Conference (FIE)*, 10 2017. doi:10.1109/fie.2017.8190538.

[14]. Mina, Mani "John Dewey's Philosophical Perspectives and Engineering Education." Philosophical and Educational Perspectives in Engineering and Technological Literacy III: 52. (2016) Edited by John Heywood.

[15]. Pritchard, John W., Mani Mina, and Anthony Moore. "Work in Progress: A Comprehensive Approach for Mapping Student's Progress: Assessing Student Progress in Freshman Engineering." *2012 Frontiers in Education Conference Proceedings*, 10 2012. doi:10.1109/fie.2012.6462369.

[16]. Mina, Mani. "Making technological paradigm shifters: Myths and reality experiencing the electrical engineering learning community (EELC) at Iowa State University." *2002 ASEE Annual Conference Proceedings*.

[17]. Mina, Mani, and Anthony W. Moore. "Work in progress—Using cognitive development approaches in teaching electrical engineering concepts." In *Frontiers in Education Conference (FIE), 2010 IEEE*, pp. F3G-1. IEEE, 2010.

[18]. Anderson, Lorin W., David R. Krathwohl, P. Airasian, K. Cruikshank, R. Mayer, P. Pintrich, J. Raths, and M. Wittrock. "A taxonomy for learning, teaching and assessing: A revision of Bloom's taxonomy." *New York. Longman Publishing. Artz, AF, & Armour-Thomas, E.(1992). Development of a cognitive-metacognitive framework for protocol analysis of mathematical problem solving in small groups. Cognition and Instruction* 9, no. 2 (2001): 137-175.

[19]. B. R. Hergenhahn and M. H. Olson "An Introduction to Theories of Learning" by; Prentice Hall 1997.

[20]. Pritchard, John W., Mani Mina, and Anthony Moore. "Work in progress: A comprehensive approach for mapping student's progress: Assessing student progress in freshman engineering." *Frontiers in Education Conference (FIE)*, 2012. IEEE, 2012.

[21]. Duron, Robert, Barbara Limbach, and Wendy Waugh. "Critical thinking framework for any discipline." *International Journal of Teaching and Learning in Higher Education* 17, no. 2 (2006): 160-166.

[22]. Elder, E. "Critical Thinking: Basic Theory and Instructional Structures Handbook." *Tomales, CA: Foundation for Critical Thinking* (1999).

[23]. Paul, Richard, and Linda Elder. *Critical thinking: Basic theory & instructional structures*. Foundation for Critical Thinking, 1999.

[24]. Fullan, Michael, Joanne Quinn, and Joanne McEachen. *Deep Learning: Engage the World Change the World*. Corwin Press, 2017.

[25]. Reflection Resources: http://www.ed.ac.uk/edinburgh-award/reflection

[26]. Entwistle, Noel. "Introduction: Phenomenography in Higher Education." *Higher Education Research & Development* 16, no. 2 (06 1997): 127-34. doi:10.1080/0729436970160202.

[27]. Walsh, Laura N., Robert G. Howard, and Brian Bowe. "Phenomenographic Study of Students' Problem Solving Approaches in Physics." *Physical Review Special Topics - Physics Education Research* 3, no. 2 (12, 2007). doi:10.1103/physrevstper.3.020108.

[28]. Dall'alba, Gloria, Eleanor Walsh, John Bowden, Elaine Martin, Ference Marton, Geofferey Masters, Paul Ramsden, and Andrew Stephanou. "Assessing Understanding: A Phenomenographic Approach." *Research in Science Education* 19, no. 1 (12 1989): 57-66. doi:10.1007/bf02356846.

[29]. Will Store "Selfie: How we became so self-obsessed and what it's doing to us", Picador, London NI 9rr, 2017

[30]. Paepcke-Hjeltness, Verena, Mani Mina, and Aziza Cyamani. "Sketchnoting: A new approach to developing visual communication ability, improving critical thinking and creative confidence for engineering and design students." In *IEEE Frontiers in Education Conference (FIE),* 2017, pp. 1-5. IEEE, 2017.