A perspective on students' autonomy in learning and engaging in an inquiry-based learning environment

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A perspective on students' autonomy in learning and engaging in a freshman inquiry-based learning environment

Abstract

Present day workforce requires graduates to be self-starters, independent and willing to experiment, as genuine lifelong learners. One way to enable students with such skills is through an inquiry-based environment. Inquiry-based courses are designed for students to explore and learn being aware of their own style and pace [1]. Such courses are designed for students to ask questions, think and reflect in the space of the classroom and beyond [2]. The nature of freedom and openness in the inquiry classes, often requires students to rethink their approach to classes. Many students are tuned to change, and adapt this style when needed. Meanwhile some others fail to adjust due to prior notions or just due to their busy schedules and at times lack of flexibility. Through this work, we hope to explore how students perceive freedom in inquiry-based environments. Some questions we attempt to address are: "Does the freedom help them study better?", "Does it inspire them to think out of the box?" or "Does it deter them from trying to do better?"

The nature of the inquiry-based courses at our program is such that students can have the freedom to decide and modify their own learning path [3]. Students are given some basic background and are then encouraged to pursue their interests. Students can then start at a difficulty level of their choice and create stories of their own learning. While some students are at ease with the freedom, many are worried about grades and want to make sure that they are doing a sufficient amount of work. We support both groups of students, and while we follow our basic curriculum, students can have the freedom to adjust their path. Our study shows that overall, the lack of forced course deadlines and questions helps the students be more creative in their thoughts and actions. They are more willing to learn, communicate with other students and take risks. Such observations are hard to make when students are in a rush with packed courses and have hardly any avenues to reflect and think about their work.

A student's autonomy is sometimes challenging for instructors. They need to patiently wait for students to learn at their own pace and not prompt them with ready made solutions. This is commonplace when students don't want to learn and are studying for the grade. Such students struggle with the open-endedness of the course. In our class we have ways to handle that, and in some cases we need to provide a direct path to few students before they can see the value of autonomy. This work will provide a student's perspective on the autonomy they experience in inquiry based courses, their challenges and successes.

Introduction

The concept of an inquiry based engineering class is not necessarily new. Many instructors have tried and do try different versions of inquiry in their work [3-6]. However, the challenge of covering more material, and making sure that there are assessment results and a process of evaluation of the knowledge that has been lectured, does derail many instructors and students

from engaging in-depth with the material and engaging in true cycles of inquiry. This is one reason why many engineering students do not recall much of the important items in their classes in the following term after taking the class [7,8].

As faculty we need to ask how we can facilitate students' engagement and their retention of the fundamentals that are connected throughout classes, and curriculum, as well as their practice. So, the challenge is how to help students' to know beyond the basics, the fundamentals, and the essential points and dominant ideas. They need to remember the connections that make their knowledge more coherent and integrated to learn new things on their own. We need to educate and empower students' to become lifelong learners. This starts by asking good questions, being able to read, digest, take notes, and face new facts, challenges, and problems. The goal is to have a process of learning, sense making, making connections, and creating a knowledge base with confidence for them to learn on their own. Do we create lifelong learners by lecturing at them with a heavy dose of highly mathematical, process driven knowledge? Or are they better served if they learn how to learn, how to ask questions, reframe and break the problems into systems level steps and be ready for things unknown?

A self driven, self learning student has autonomy, with good self actualization of understanding the strength and the weaknesses of their knowledge based and capabilities. They have developed KSA: Knowledge, skills, and abilities [9]. Traditionally, engineering classes attempted to do this via lectures, homework, projects, and laboratory activities. However, in every engineering discipline the curriculum is growing, and there seems to be so much that needs to be covered. Classes are packed with material and assignments and do not necessarily have the creative overlap to promote synergy of the material and understanding.

Our research question is whether student autonomy (even if it is partial for selected parts of the class) and engagement of inquiry-based approach would be more beneficial for students and would help facilitate the journey of an engaged student with a connected knowledge base. Would an inquiry-based approach, with providing students' autonomy to create their connected knowledge and an ability to create their story and path of the subject, improve students' learning, and ownership of their knowledge?

Motivation

Our approach to inquiry based learning is through a Deweyan cycle implemented in a freshman engineering course. Our team has practiced the Deweyan cycle of inquiry in different forms over the past 15 years. The work has been focused on reflective practices and a strong emphasis on self-driven inquiries. The students have the freedom to seek and understand how they learn. To emphasize this the class discusses basic mathematical and electrical engineering concepts which most students know from their high school education. However, students who don't have this background would not fall behind since the reflective activities are repeated several times in different forms. In the labs the students are introduced to basic electrical engineering concepts, software and hardware. Since the students have different experience levels, it is considered prudent to not ask all the students to do the same labs at the same time. Thus, students are

provided with a basic overview and then given the option to select labs which they feel challenge them suitably. In this flexible environment, the students are expected to work on the lab and describe the process of answering three key questions (inquiries) which they have pursued during the lab. Since every student has a different approach and perspective, the difficulty level of the inquiries vary. Through our work, it is observed that the student's work and interest/curiosity changes over the semester. Since the students have the option to work freely, they are more prone to exploring due to interest than due to the threat of grade. Though mostly successful, the process has shown limited success with students who seek to study for a grade and for some others the task of pushing oneself to keep exploring is at times tedious. For such students, a guided inquiry process is suggested and implemented in the labs.

Deweyan Cycle of Inquiry

Since our course is predominantly a freshman engineering course, it is necessary to create an environment of free learning. Such an atmosphere encourages students to form their learning habits and teams for the upcoming semesters. Hence, we select an inquiry based approach where the students have a freedom of entering and exiting the cycle at a level they deem challenging. The highlight of the cycle of inquiry is its uniqueness to the user. Every person experiences situations, concepts and ideas differently. Additionally, every person has a personalized mechanism of self actualization as exemplified by Maslow's hierarchy of needs [10]. Thereafter, a student's entry or exit from the inquiry cycle are dependent on their approach and ways. The basic stages of a Deweyan inquiry cycle [11, 12] are depicted in Fig. 1.
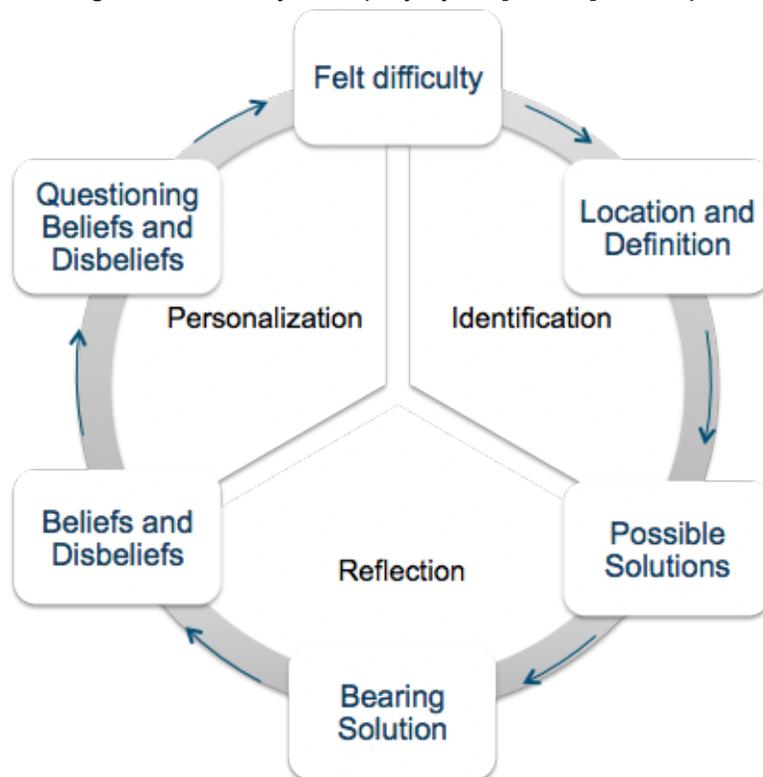

Fig. 1: A depiction of Deweyan cycle of inquiry

Here the student starts with a felt difficulty (or a problem that they encounter) and then goes through a cycle of identifying the source, finding solutions, reflecting on the identified solution and identifying possible new pathways. Internally, we define three different learning phases that the student progresses through. If understood and adopted, the process of inquiry becomes a "self-obsession" which means students will stay with it and try to make sense of the cycle in many classes and their everyday interactions. This stems from their desire to keep seeking, keep questioning, imagining and reframing. While many of these stages are routine and not necessarily characteristics of inquirers, the traits of critically examining, connecting and seeking are all found in proponents of inquiry. Such people are constantly learning from their mistakes, failures and trying things out. For them, deep thought isn't limited to specific moments but instead seems to be a continuum of deep thought, questions and actions. They live their inquiry and are obsessed with the pursuit of learning.

Research Method and Analysis

In this work, the students' inquiries were collected at different points during the semester. These inquiries were a part of their weekly lab reports. The depth of process, and the details of their work and development of their thoughts were studied via phenomenographic analysis [13-15]. The development in the students inquiries shows that the students are attempting to find their pathways and do things as per their interests. In some cases, it is apparent that a semester full of directed labs would not have helped the students reach the level they are at. The basic trends in the students inquiry development is captured via use of particular keywords and actions. A phenomenographic analysis is performed to classify the common themes that appear in the student writing over the time points in the semester. These are then further classified into the different sub-stages (Identification, reflection and personalization) of the Deweyan cycle.

In the initial weeks most students start with asking why or how a particular code segment works, how something occurs in their circuit when they change things etc. As the time progresses, there is a shift in their inquiries in trying to achieve or make something possible with the resources available. Their procedures following the inquiry become more detailed. They ask better questions and find better connections. Some examples of inquiry words which we used as instructors to track their progress can be observed in Table 1 and Table 2 that list examples of some inquiries that the students have written in their reports.

Table 1. Inquiry development with progression of the labs and engagement in inquiry

Week 1	Week 3	Week 6
What is the difference between … and ...	How does this… work? Or What does this … do?	How do I perform...action
How can I make sure...	What is … how does it work	Why is … not working as my prior work
Why does the output ...look	What are the inputs and	How do I go about connecting

	outputs for this … device?	… to this device
What would happen if I replaced .. with ..	Why do we need … to run this …?	Can I control two… with this device

Table 2. Examples of inquiries students wrote in their lab reports

Week 1	Week 3	Week 6
What is a command?	How does the circuit work on a basic level?	How do I write SOS in Morse code only when I press the button?
How can I use more than one command to create a program?	What is an inductor, what does it provide for our circuit?	I previously discovered that debouncing the encoder in software worked but had timing issues and made missing pulses more likely. How does a hardware debounce compare?
Why am I unable to get an output from the serial output of my program?	How does the circuit know when to turn on the light intensity?	What happens when there are two capacitors in a row?
How to discover the resistance of a resistor?	What are the voltages of the components in the system?	Can I play a song and simultaneously run a strobe light with the microcontroller?

A comparison of the inquiry stages over the different evaluation weeks is observed in Fig. 2.
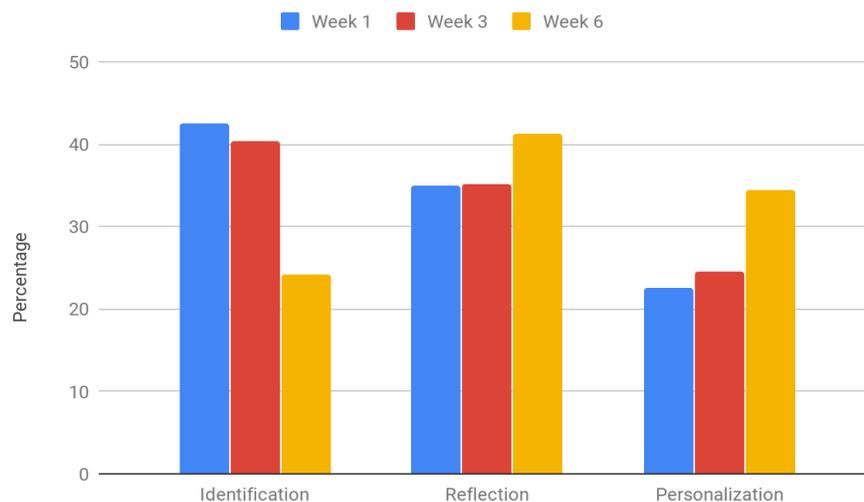

Fig. 2: Percentage of students in different inquiry stages over the initial weeks of the semester

Approximately 50-60 randomly selected inquiries were evaluated each week to identify the inquiry phase in which most students were present. Here we observe that as expected in the initial few weeks students are still identifying and trying to figure out how things are. Most students are trying to understand and reflect on how things work. A third of the class are already asking deeper questions and seeking to know more. This trend continues on to Week 3 where students are moving into reflecting and asking more inquiries related to their personal interests. Finally, by Week 6, reflection and personalization take the lead and a larger section of the class is working on learning by their own inquiries. These results demonstrate that they are far more engaged when operating with autonomy. It must be noted that the lab grading process is based on the students engagement and delivery in terms of reports/weekly updates. The grading is not based on the students level of autonomy. As long as the student provides detailed weekly reports, they are graded according to the pre-described evaluation rubrics.

Conclusions

In this work, the effects of student autonomy in selection of learning paths is studied in an inquiry based lab environment. The student's learning autonomy is tracked via inquiries (or questions) which they write in their lab reports each week. Since the labs are self-driven, the students pursue a self-guided inquiry and have complete autonomy in deciding how much they want to push themselves and learn more. Through the classroom, varying interest levels and inquiries are observed. Some students show initial excitement in a particular direction but don't have sufficient initiative to proceed once they encounter obstacles or challenges. Some others didn't get deterred by challenges and kept progressing with assistance from peers and lab mentors. In general, students recognized the need for openness and found it to be conducive for their learning and growth. Periodical feedback and intervention from mentors and facilitators was necessary to encourage students to keep pursuing their inquiries. Eventually, a successful class realizes that the focus of the class is not the content but the soft skills [16] of identifying their learning process, thinking about their own thinking (i.e. metacognition) and personal engagement in the process of inquiry. Since each person has a unique path, the success lies in making them realize their true potential and encouraging them to pursue the paths of their interest.

Future Directions

While the open environment and freedom was generally well received by students, especially in the time of difficult deadlines from other courses, there are many avenues for improvements. Firstly, since many students are previously trained to study for grades, there needs to be a provision for a guided inquiry approach. In this approach the students will receive moderate feedback and guidance from the mentors and course facilitators. Next, when the students are reviewing concepts which they have previously learned, once again they fail to realize the importance of restructuring their learning process. One way to emphasize this is by asking students to work in teams and obtaining solutions collaboratively. Lastly, further emphasis is needed on bringing the inquiry cycle to students in more than one way. While they do engage in

personal inquiries, methods to improve and work collaboratively will be necessary for students to be successful in other courses.

References

[1]. Abrams, Eleanor, Sherry Southerland, and Peggy Silva, eds. *Inquiry in the classroom: Realities and opportunities*. IAP, 2007.

[2]. Harada, Violet H., and Joan M. Yoshina. "Moving from Rote to Inquiry: Creating Learning That Counts." *Library Media Connection* 23, no. 2 (2004): 22.

[3]. Mina, Mani, Iraj Omidvar, and Kathleen Knott. "Learning to think critically to solve engineering problems: Revisiting John Dewey's ideas for evaluating engineering education." *Retrieved January* 5 (2003): 2004.

[4]. Waks, Leonard J. "Donald Schon's philosophy of design and design education." *International Journal of Technology and Design Education* 11, no. 1 (2001): 37-51.

[5]. Spencer, Trina L., and Tracy M. Walker. "Creating a love for science for elementary students through inquiry-based learning." *Journal of Virginia Science Education* 4, no. 2 (2011): 18-25.

[6]. Pedaste, Margus, Mario Mäeots, Leo A. Siiman, Ton De Jong, Siswa AN Van Riesen, Ellen T. Kamp, Constantinos C. Manoli, Zacharias C. Zacharia, and Eleftheria Tsourlidaki. "Phases of inquiry-based learning: Definitions and the inquiry cycle." *Educational research review* 14 (2015): 47-61.

[7]. Haertel, Tobias, and Claudius Terkowsky. "Where have all the inventors gone? The lack of spirit of research in engineering education." In *Proceedings of the 2012 Conference on Modern Materials, Technics and Technologies in Mechanical Engineering*, pp. 507-512. 2012.

[8]. Jones, Sara and Mani Mina. " Designing a curriculum that helps students create connected narratives in electrical engineering." In Proceedings of the 2018 ASEE Annual Conference and Exposition, 2018. https://peer.asee.org/30277

[9]. Hoffmann, Michael HW, Manfred Hampe, Gerhard Müller, Hans-Joachim Bargstädt, Hans-Ulrich Heiß, and Heike Schmitt. "Knowledge, skills, and competences: Descriptors for engineering education." In *Education Engineering (EDUCON), 2010 IEEE*, pp. 639-645. IEEE, 2010.

[10]. McLeod, Saul. "Maslow's hierarchy of needs." *Simply Psychology* 1 (2007).

[11]. Rodgers, Carol. "Defining reflection: Another look at John Dewey and reflective thinking." *Teachers college record* 104, no. 4 (2002): 842-866.

[12]. Prabhu Gaunkar, Neelam and Mani Mina. " Developing self-awareness in learning practices: Designing and implementing a survival tool for freshmen in engineering ." In Proceedings of the 2018 ASEE Annual Conference and Exposition, 2018. https://peer.asee.org/30312

[13]. Bowden, John A., and Eleanor Walsh. "Phenomenography." *Phenomenography* (2000): v.

[14]. Åkerlind, Gerlese S. "Variation and commonality in phenomenographic research methods." *Higher Education Research & Development* 31, no. 1 (2012): 115-127.

[15]. Entwistle, Noel. "Introduction: Phenomenography in higher education." *Higher Education Research & Development* 16, no. 2 (1997): 127 - 134.

[16]. Kumar, Sanjeev, and J. Kent Hsiao. "Engineers learn "soft skills the hard way": Planting a seed of leadership in engineering classes." *Leadership and Management in Engineering* 7, no. 1 (2007): 18-23.