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Exploring the Development of Undergraduate Research Experience

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Abstract

This paper describes a multi-year experiential reflection process examining the development of research awareness and integration for an undergraduate industrial engineering student. As a sophomore, I approached the faculty member in order to gain experience in an interdisciplinary human factors and systems engineering context. Because the explicit research emphasis of the faculty member's lab is on development and sharing of expertise, information, and knowledge, the student's learning of the research process represented an interesting context for focusing the student's experience. Thus, one aspect of the student's learning focused on tacit knowledge management and event-based knowledge development in the form of a student progressing through the undergraduate level of school while participating in a research lab. There are multiple multi-scale dynamic models that must be evaluated in order to create an effective process simulation of student learning from an expertise development context. Different perspectives, including the student as the system; the student as a product who is input to, and then transformed by, the "research lab-as-system"; or the student as a functioning component of the research lab system. In each model, experience versus expertise is evaluated through reflective case studies at multiple points along a learning curve. This allows a comparison of explicit, implicit, and tacit learning and to analyze at what point the student begins to think beyond the textbook with less of a process based mindset and more of an event based mindset. A learning-curve simulation of the student could be used to evaluate the rate at which the student becomes better at tasks. A social dynamics simulation addresses how different situations, such as human-human interaction or cultural learning, affect the student's progress and perceived efficacy of learning and laboratory participation. Looking at tacit knowledge management from the viewpoint of a student developing through the research lab process shows helps to elaborate different facets of contextualized learning when trying to develop engineering experience, expertise, and integration.

Introduction

This paper describes, from a participant observation standpoint, the development of expertise and situation awareness as applied to student experience in engineering research as an aspect of undergraduate engineering education. Because several critical aspects of educational transformation are both subjective and experiential, this "case study" approach is presented as a source of additional information to consider when examining the learning goals and processes associated with developing student capability and interest in the research process.

For background, one needs to know the experiences of the student author. As a sophomore I approached the faculty member with the purpose of joining a research lab to gain expertise within the field of human factors. From my perspective, it was overall viewed as a "graduate level research experience." But after spending two years in the research lab environment, it was realized that this was more than just writing a paper and gaining some knowledge; it was a development and integration opportunity both through the knowledge learned and the social integration of the student to the research lab and its organizational culture.

The knowledge development aspects of the student experience can be described as tacit knowledge management and event-based knowledge development in a knowledge sharing context[3, 6]. Tacit knowledge management, in this experience, can be described as the level of learning in the field of human factors gained by the student, the sort of "out of the textbook" learning. For example, at the beginning of the student's research experience, the faculty member required the student to manage the online database of research papers that the lab utilized. To the student at the time, this seemed like a monotonous task of moving documents and sorting them based on research topics. But after completing the project, the student realized that this was an effective way of transferring the basic knowledge about how research papers are written, how to distinguish the overall message from a paper, etc. This was a way of transferring the basic knowledge about research, which cannot easily be described, that an undergraduate student would not know.

The undergraduate classroom and textbook model does not allow for tacit knowledge management because it follows an explicit model. The knowledge is transferred on paper or verbally to the student and the student is expected to learn and be able to reproduce the knowledge at a later date. With the research lab experience, the student is able to learn based on the experiences that they and their peers go through to develop a research topic. Using a similar set of reference materials, with common situational and task context (the prior work of the lab itself) helps to foster components of information alignment and shared experience between team members[1]. The purpose of this exploration was on the conceptual and experiential insights developed by the student (the student as "I"), but also incorporated an examination of development of the student (the student as subject of analysis). The primary goal was to enable the student ("I") to internalize this understand as pieces of her personal and professional development. While the resulting understandings can lead to improved modeling and simulation of the student ("subject of analysis") experience as a member of a research lab, my research outcomes are not predicated on developing such simulations.

Modeling Research Lab Apprenticeships as Student Learning

In the experience of the undergraduate student, there is a large difference in progressing through a research lab versus undergraduate university education. In the research lab, there are multiple multi-scale dynamic models that can be evaluated in order to simulate the expertise development of the student. This multi-scale modeling of knowledge development and learning is the subject of ongoing research in the authors' lab[1, 2, 4, 5]. Elements of this multi-scale systems conception are presented below; it should be pointed out that the primary motivation for this work was the introspection of the student as its own learning objective (highlighting the first model of the student as learner).

The first is the student as the system or self-directed learner. The student is the system in which the knowledge from the undergraduate level as well as from the research lab experiences are inputted into and the expertise and developed knowledge is outputted. The student, as the system after having all of these inputs, is able to output knowledge gained during future experiences and apply past experiential learnings. From this perspective, experiences are inputted into the student as system, with expertise as a transformed output. This model can most effectively be applied by the student at the peak of her learning curve, where she is best able to examine and organize the patterns and relationships of knowledge entering the system. This ability to connect, coordinate, and integrate experience as a self-directed learner therefore creates a greater output and useful availability of expertise.

The second is the student as in input to the system (either the undergraduate classroom or the research lab). The student is transformed by the experiences of the classroom or lab, with the output being a student with more expertise and knowledge based on her experience. Over the course of the student's experience, the expectation is that her capabilities are improved, and that the student is expected to demonstrate what was learned and certify the knowledge acquired during the student's years within the system. This model is most effective at the beginning of the learning curve, when the knowledge of the student is low and scaffolded structures for her learning are not internalized. When the student progresses through the system, increases in learning will further increase the ability to demonstrate acquired knowledge in response to formal requests for structured presentations of knowledge (such as a job interview or conference paper). The success of the research lab as education subsystem may be evaluated by the "value" or "quality" of the lab's outputs, i.e., the demonstrated competence of its students as they are hired by companies or accepted into graduate programs.

The third multi-scale dynamic model is the student as a component of the research lab. In this model, the student contributes to the research lab as a member of the research lab, rather than just being a product of it. In one view, the student can be seen as a production component, or worker without a vested interest in being transformed by the work itself. As a member of the lab as a production system, the student may be expected to come out of the system having produced output (journal and conference papers) no matter what level of effect the output has had upon the student. However, the lab's ongoing success as a dynamic sociotechnical system[7] also emphasizes that members of the lab share their experience and learning with each other. The student's expertise and knowledge gained along with that of the other students and the faculty member combine to make a research lab that is functioning and always developing. This perspective highlights that while the student is the component of the research lab, most of the knowledge the student gains and develops is a result of interactions with the other members of the research lab. The current members of the lab transfer knowledge through discussion and collaboration. But, the output of the lab production could also be seen as the knowledge from past and present members of the lab. Within this perspective, the knowledge is the primary product that is transferred, sustained and increased via collaboration throughout the lab's development. Past members' knowledge is transferred to the current members and the amount of expertise is continuously growing as long as the lab is growing and changing. This approach is most effective at describing the student's contributions at her highest point of the learning curve because I am best able to provide the greatest benefit to other students (even as an undergraduate).

Each of these models shows how experience versus expertise is evaluated and developed depending on where in the system the student is located. One considerable challenge to an effective simulation model for such learning processes is the consideration of how to distinguish explicit, implicit, and tacit forms of knowledge development and contextualized expertise. Some initial efforts in this direction have addressed the organization of undergraduate required courses and skills development as a process of facilitating and meeting expectations of campus or college goals for specific ABET or local learning outcomes[5]. A fully integrated simulation is beyond the scope of this paper, mainly due to my passion (student as "I") for tying things one has to learn with what one wants to learn (student as "subject of analysis"). The process of going through this allowed me to develop in a way that was balanced on that continuum. But while this is true, examples of simulation components are currently in preparation as illustrations of the three models of experience and expertise development.

A simulation can be used to show the student's progress along a learning curve and evaluate the rate at which the student develops expertise within certain tasks and situations. For example, human to human interaction is developed during the course of the student's time in the research lab. As the student becomes more comfortable with the culture of the lab and the human dynamic, they develop stronger interactions with the other members of the lab. This also applies to the relationship between the faculty member and the student. As the student begins to determine what focus to have within the research lab, the faculty member is able to give the discussions direction and develop meaningful conversations with the student. Cultural learning also affects the progression along the learning curve. Depending on the type of members in the lab, the culture may be very effective in promoting each member's strength and providing a collaborative environment.

A simulation can also be used to show a student's progression from process based thinking to event based thinking. The process based mindset is thinking more along the lines of what one is taught in the classroom: learn a process and solve a problem that requires the same process to be used. As a student progresses through the classroom, research lab, and work experiences, one develops an event mindset. This involves collaborating all of the knowledge and expertise gained and applying it to a problem that might require multiple processes or learning elements to solve in a contextually sensitive and operationally robust manner.

In a hypothetical process flow model of student learning in a research lab apprenticeship, there would be three primary and coupled outputs for each student. For the self-directed learner, a process flow model is tremendously challenging. There is great difficulty in attempting to create a simulation based on experiences within a person, how it consciously and unconsciously affects that person, and when the gains in expertise are known in the person versus when they actually happen. For the student as production output, the simulation would be a traditional process flow model. Model characteristics could be developed but a multilevel simulation would have to be conducted based on the complexity of having multiple inputs and outputs to the system[5], as well as potential changes in the efficiency of learning transformations due to the student as self-directed learner. Finally, the sociotechnical knowledge production of the lab is not limited to a single level of production output. Not only explicit products (papers, grant awards), but implicit capabilities (informal practices of how best to share information with each other) and even tacit skills (increased self-efficacy to develop and share innovations and contributions) are results of the lab's activity. This is due to both the demonstrated learning outcomes by students, and their internalized awareness and structuring of their learning as distinct but linked products of the system.

Conclusion

My initial experience with the research lab was intended to develop very specific pieces of explicit content knowledge to support career development goals. However, the process of becoming exposed to both the context of research, and the collaborative knowledge sharing activities of a specific research lab, became an unexpectedly rich source of grounded learning. The goal of simulating student learning in explicit, implicit, and tacit knowledge domains remains a challenging task from both knowledge development and systems engineering process modeling perspectives. However, the longitudinal examination (as well as my ongoing introspection) regarding "Simulating Kelly" as an engineering process has helped to provide both personal benefits and research outcomes. In addition, it is hoped that the student's experience provides useful insights regarding the valuable role of research apprenticeships for undergraduate engineering students, regardless of their future industry, graduate education, or engineering domain career development plans.

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