Exploring Intrinsically Motivated Learning
by Engineering Students

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Abstract. While scholars suggest that teaching should be based on how people naturally learn, this type of teaching can be difficult. Thus, the need for this study was improved understanding of how people learn. The research question driving this study is: how do engineering students engage in and describe learning when the learning is intrinsically motivated?

The methods involved the grounded theory tradition of qualitative social research. The results of this study are a participant-based theory that showed that the central aspect of learning is authentic participation, which is defined as learning by taking part in the profession, sport, or hobby. The participant-based theory showed that learning occurs in a cyclic process that includes authentic participation, feedback, investigation, and experimentation. This cyclic process is a growth process that continually improves the skills, knowledge, attitudes, and values of the learners. This cyclic process is embedded in a structure or matrix that connects the individual, the physical environment, and the community. Within this matrix, community plays a central role because learning is accelerated and sustained by relationships that support people as they overcome challenges and attain their goals.

I. Introduction

Present engineering education practices emphasize coverage of fundamentals and passing of in-class exams as measures of success. Students in classrooms are passive and focused on attaining points needed to earn grades. Most professors and students seem content with traditional education. However, there is a new vision of education that is emerging. This new vision involves designing learning environments that align with the natural ways that people learn. For professors who are pursuing this new vision, there is a need to understand learning. This need motivated the present question: how do engineering students engage in and describe learning when the learning is intrinsically motivated? Here, intrinsically motivated learning is defined as learning that takes place when a person consciously chooses to learn and they act in ways that they believe will best help them reach their goals.

The present study uses grounded theory (Strauss and Corbin, 1998), one of the five traditions of qualitative social science research (Creswell, 1998; Creswell, 2003). The study was conducted at the University of Idaho during the spring semester of 2004 and involved six male and two female undergraduate engineering majors.

II. Literature review

Traditional education, as described by Dewey (1938), is transmission of knowledge:

The subject matter of education consists of bodies of information and skills that have been worked out in the past; therefore, the chief business of the school is to transmit them to the new generation …. Books, especially textbooks, are the chief representatives of the
lore and wisdom of the past, while teachers are the organs through which pupils are brought into effective connection with the material. (p. 17-18).

The purpose of traditional education is to prepare young people to acquire the organized bodies of information and well-known skills that lie within the textbooks. Traditional education, according to Wenger (1998), is based on unchallenged assumptions:

Our institutions, to the extent that they address issues of learning explicitly, are largely based on the assumption that learning is an individual process, that it has a beginning and an end, that it is best separated from the rest of our activities, and that it is the result of teaching (p. 3).

Wenger states that these assumptions lead educators to create plain and simple classrooms so that learners can focus on the teacher, and to use individualized tests where knowledge is demonstrated out of context and where collaboration is considered cheating. As a result, “much of our institutionalized teaching and training is perceived by would-be learners as irrelevant, and most of us come out of this treatment feeling that learning is boring and arduous, and that we are not really cut out for it” (ibid, p. 3). Another strong indictment of traditional education is stated by Arons (1990):

Finally I point to the unwelcome truth: much as we dislike the implications, research is showing that didactic exposition of abstract ideas and lines of reasoning (however engaging and lucid we might try to make them) to passive listeners yields pathetically thin results in learning and understanding—except in a very small percentage of students who are specially gifted in the field (p. vii).

While present educational practices are largely based on tradition, scholars and scientists suggest that teaching practices should be based on knowledge of how people learn. Instructional design is founded on theories of learning (Dick et al., 2005; Gagne et al., 1992). The National Research Council report by Bransford et al. (2000) reviews 30 years of learning sciences and discusses how this research can and will influence education. In describing models of teaching, Joyce et al. (2000) states:

Models of teaching are really models of learning. As we help students acquire information, ideas, skills, values, ways of thinking, and means of expressing themselves, we should also be teaching them how to learn. In fact, the most important long-term outcome of instruction may be the students’ increased capabilities to learn (p. 6).

The focus on learning extends to the arrangement of environments for learning. Bransford et al. (2000) describe four related functions for a learning environment.
1. Emphasize the needs of the learners by paying attention to their knowledge, skills, and beliefs.
2. Help learners acquire knowledge that helps them to function effectively in society.
3. Provide learners with clear goals plus opportunities for feedback and revision as the learners strive to reach these goals.
4. Provide norms for learners that emphasize learning from each other and continually attempting to improve.

Regarding the knowledge on how people learn, there is an extensive body of literature. Bransford et al. (2000) reviews and organizes 30 years of research on learning. Leonard (2002) reviews and organizes the educational literature into four categories: cognitivism, constructivism, behaviorism, and humanism. He also creates a fifth overlapping category called organizational
learning to describe practices associated with education in industry contexts. The bulk of his book presents extended definitions of 500 terms related to various learning theories.

In summary, traditional education is changing toward a type of education that is founded on how people learn. While the existing knowledge of how people learn is rich and deep, it is easy to get mired or lost in the complexity. The contribution of this paper is to look at learning through the eyes of the engineering student. The rationale is that a student-centered perspective may provide a more direct way to think about the design of instruction and learning environments.

III. Methods

We chose qualitative methods because the research question (how do engineering students engage in and describe learning when the learning is intrinsically motivated?) is open-ended with many possible domains of exploration. We chose grounded theory from the five traditions described by Creswell (1998) because the purpose of the research was to develop principles that inform the design of instruction and learning environments.

To acquire data we designed a semi-structured interview. Initial testing of the interview revealed that direct questions about learning and motivation were ineffective because participants would not have much to say or their answers would be misaligned with the intent of the questions. After revision, the interview had the form shown in Fig. 1. An extended text example is presented in Appendix A.

After the interview instrument was designed and tested, we gathered data from eight study participants. This number provided enough data so that the grounded theory methodology would be effective. Each interview lasted between 15 and 20 minutes. These interviews were tape recorded and then transcribed into written records. The written interview records were analyzed using the coding process of grounded theory.

1. Open Coding. Interview transcripts were printed. Each interview transcript was physically cut into parts, where a part is defined as a main idea. The set of main ideas was organized into collections of similar ideas in a pile. Each pile was assigned a label. The result of open coding was identification and labeling of the main ideas.

2. Axial Coding. The main ideas were organized to develop a preliminary theoretical model that showed how the varied ideas connected together. The central theme of the data was clarified. The result of axial coding was a central theme (participation) plus a preliminary

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The purpose of qualitative research is to gain deep and rich understanding in a limited context. Hence, qualitative researchers do not gather evidence that establishes that their results generalize to a larger population. Thus, considerations of sample size are not relevant to the research method used in this study.
diagram that showed the connections of the major ideas.

3. **Selective Coding.** The central theme from the data (participation) was systematically compared with each main idea, the relationship between participation and other main ideas was analyzed and revised, the labels and descriptions for the main ideas were analyzed and revised, and the diagram was analyzed and revised into two final diagrams. The product of selective coding is presented in the results section of this paper.

**IV. Results**

**A. Participant data**

Table 1 presents demographic data for the eight participants. All eight participants were undergraduate Mechanical Engineering students.

<table>
<thead>
<tr>
<th>Participant Demographic</th>
<th>Class standing</th>
<th>Domain of Learning</th>
<th>Main methods for improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1- Female</td>
<td>Sophomore</td>
<td>Fixing cars</td>
<td>Hands on, asking questions, planning what to do to fix the problem, driving cars</td>
</tr>
<tr>
<td>2- Female</td>
<td>Freshman</td>
<td>Math</td>
<td>Motivation to understand, comparison of two problems, figuring out what she didn’t know</td>
</tr>
<tr>
<td>3- Male</td>
<td>Junior</td>
<td>Rock climbing</td>
<td>Go rock climbing, talking to and watching other climbers, reading a book about climbing</td>
</tr>
<tr>
<td>4- Male</td>
<td>Junior</td>
<td>Down hill snow skiing</td>
<td>Direct feedback from others, watching other skiers, going skiing, taking lessons, competing</td>
</tr>
<tr>
<td>5- Male</td>
<td>Freshman</td>
<td>Boy scouts/leadership</td>
<td>Being a leader, feedback from others, training camp</td>
</tr>
<tr>
<td>6- Male</td>
<td>Sophomore</td>
<td>Frisbee</td>
<td>Watching others, playing Frisbee, isolating, team competition</td>
</tr>
<tr>
<td>7- Male</td>
<td>Senior</td>
<td>Documentation/report writing</td>
<td>Direct feedback from others, asking others for help using these skills in new situations</td>
</tr>
<tr>
<td>8- Male</td>
<td>Senior</td>
<td>Christian lifestyle</td>
<td>Being a Christian (prayer, church, reading Bible, living Christian principles), feedback from family, friends, or other Christians.</td>
</tr>
</tbody>
</table>

**B. Learning as a process**

Coding of the data revealed that the participants learn in a cyclic process as shown in Fig. 2. A process is a collection of interrelated and interacting steps that transforms inputs into results. The input to the learning process is motivation and foundation. Foundation includes the skills,
knowledge, attitudes, and values needed to engage in the profession, sport, or hobby. Motivation is the drive to improve the actual performance. For example, the ultimate Frisbee player wants to become better at this sport. The learning process, Fig. 2, has four discernable steps:

1. **Participation** is the act of taking part in the profession, hobby, or sport. Participation, which emerged as the central theme of the study, occurs when a person performs the actual thing that they want to learn. For example, participant 4 indicated that he improved his skiing by going to the mountain and skiing.

2. **Feedback** is the process of exploring and receiving information that helps the learner determine and sometimes extend the boundaries of their knowledge and abilities to participate. Feedback can be *internal* through the process of self-reflection or feedback can be *external* when it comes from the challenge itself or from other people.

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Figure 2 The process of learning comprised of inputs, essential steps, and outputs.

1. **Participation**: Take part in the profession, hobby, or sport.
2. **Feedback**: Discover barriers to performance and knowledge by experiencing varied levels of challenges and by receiving input and guidance from selected individuals.
3. **Experimentation**: Try out ideas for overcoming barriers, modify these ideas, and discover what works and what does not work based on the needs of the individual.
4. **Input**: Motivation, Foundation.
5. **Output**: Improved motivation, Foundation.

*Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition, Copyright © 2005, American Society for Engineering Education*
3. **Investigation** involves learners seeking information on what they want to learn. In this stage, learners explored what other people do, think, or know about a subject. Investigation was commonly done in three ways: asking questions, reading books specific to the interest, and watching and talking with others who participate in the hobby, sport, or discipline.

4. **Experimentation** is the stage where learners try out ideas they got from feedback and investigation. During this process, ideas are tried, modified, and learners discover what works and what does not work for them. Experimentation results in growth of the individual, which translates into two outputs: improved foundation, and improved motivation.

V. Discussion

A. **Participation is the central component of learning**

The integrating component of effective learning is participation. Without multiple opportunities for authentic participation, students will not learn at deeper levels because the knowledge and skills lose much of their meaning when they are out of context.

The data suggested criteria for quality in participation. Participation should involve a real or authentic experience. A person learning to ski wants and needs to ski. A person learning engineering wants and needs to do engineering. The amount of participation should be balanced with the amount of foundation. In general, a beginner wants and needs a small amount of foundation and wants and needs frequent participation to maintain motivation. Alternatively, an experienced person may do best with more foundation before engaging in participation.

Participation should emphasize performance in the discipline, where *performance* means practicing the discipline in the same way that it is practiced in its authentic contexts outside of schools. Some examples of engineering performances include design for a client, solving an open-ended problem, and making a recommendation for a manager.

It is not surprising that participation emerged as the seminal component of a learning system. Most people state that they learn best by doing. Engineering professors attribute significant value to their participation in research, professional practice, and in teaching of others. In the literatures of teaching and learning, the concept of participation is emphasized. Inquiry methods and problem-based learning are based on the idea of authentic participation. The *Teaching For Understanding* pedagogy developed by Project Zero at Harvard is founded on the notion that understanding is the ability to carry out a performance that demonstrates one’s grasp of a topic and at the same time extend it (Blythe, 1998; Wiske, 1998).

B. **Learning is a process**

The participant-based theory in Fig. 2 suggested that learning involves well-defined, interconnected, and essential steps that form a cyclic process. When people are placed in environments in which steps are omitted or de-emphasized, then the quality of learning is compromised. Also, the participant-based theory (Fig. 2) showed that the result of a cycle of learning is growth. This growth involves improved foundation and increased motivation.

While engineering professors do not commonly talk about a process of learning, there is support in the literature for the idea of learning as a process. Process education is the theme for a national community that has been growing for the past decade (Beyerlein and Apple, 2004). Kolb (1984) presents a viewpoint that learning for deep and real comprehension involves repeated cycles, each involving a sequence of experience, reflection, abstraction, and active testing. The role of feedback is aligned with the student-centered assessment literature (Black and Wiliam, 1998; Stiggins, 2000). The focus on growth as the output of a learning cycle is strongly aligned with the literature. Zull (2002) describes how neuroscience researchers have
established that learning is correlated with biological processes and physical changes in the human brain. Many scholars have used models of cognitive development to describe growth in people as they move through life (e.g., Perry, 1970; King and Kitchener, 1994; Duncan-Hewitt et al., 2001).

C. The Learning Matrix—What matters to the learner

The participants naturally and implicitly thought about learning as a system. A system is a whole that functions because it has the right individual components and these components work together in an appropriate way. An example of a system is the automobile; the overall quality depends on having all the necessary components plus the necessary component integration. Fig. 3 shows a system diagram labeled here as the learning matrix. We selected the label matrix because the definition is a structure in which something is imbedded or enclosed. In physiology, scientists describe bones as consisting of living cells that are embedded in a matrix that has both organic and inorganic components. By analogy, human learning consists of people who are embedded in a matrix or structure that has social and environmental components.

The most important aspect of the matrix involves the relationships between the learners and other community members. Participants frequently talked about other people and how they interacted with these other people. The participant data suggested that there are two distinctly different types of relationships. During feedback, the social interaction involves a trust relationship between the giver and receiver of feedback. A trust relationship is defined by three criteria: (1) the learner knows the person giving the feedback, (2) the learner cares about what the person has to say, and (3) feedback is given in an overall positive and helpful way. During investigation, the social interaction involves an opportunity relationship, which is defined as a chance to observe another person, listen to another person, or read what another person has written. An opportunity relationship does not require knowing the other person. In summary, the data support the conclusion that people learn better when they have trust relationships with others in the learning community.

The concept that learning is embedded in a matrix of social and physical factors is supported by
significant evidence. Professors seek out communities of like-minded researchers and practitioners. People who rock climb find others who climb, they share climbing-related interests, and they meet in places such as Yosemite National Park. The pedagogies of cooperative/collaborative learning are based in part on creating effective social environments. Wenger’s theory of learning (1998) is based on social structures called communities of practice. Boyer’s concept of the “basic school” (1995) is founded on building an integrated social and physical environment.

VI. Conclusions

This study addressed the question of how engineering students engage in and describe learning when the learning is intrinsically motivated. A grounded-theory was developed using data that emerged from semi-structured interviews of eight student participants. The primary findings are:

1. The participants in this study engaged in and described learning via participation, where participation is taking part in the profession, hobby or sport that they are trying to learn. Participation is of central importance; learning without authentic participation loses much of its potential value.

2. The participants engaged in learning with a cyclic process comprised of participation, investigate, feedback, and experimentation. Each cycle of learning builds a progressively stronger foundation of intertwined knowledge, skills, attitudes, and value.

3. Participant learning is embedded in a matrix that connects the individual learner, the physical environment, and the community. The community component of the matrix is central to learning. Learning is accelerated and sustained by relationships that support people as they overcome challenges and attain their goals.

Because this project used qualitative research methods, we did not generalize results to populations beyond the participants of the study. However, the findings seem intuitively correct, aligned with the literature, and useful for the design and implementation of learning environments. Future studies will expand the boundaries of this study with a long-term goal of understanding and enhancing learning.

Acknowledgements

This work was funded in part by the National Science Foundation: Grant Numbers EEC0212293 and DUE-0088591. This work was funded in part by the University of Idaho Department of Mechanical Engineering, College of Engineering, Research Office, and Office of the President.

VII. List of references cited


VIII. Biographical Information

BRIAR E. SCHUMACHER. Ms. Schumacher is a professional engineer employed by Cedric, Chong, and Associates in Honolulu, Hawaii. Her technical interests are product design and social research emphasizing grounded theory methodology. Ms. Schumacher graduated in December 2003 with a degree in Mechanical Engineering from the University of Idaho.

DONALD F. ELGER. Dr. Elger has been at the University of Idaho for 17 years; his technical interests are heat transfer, fluid mechanics, and design. Dr. Elger’s educational research interests are in qualitative and mixed methods involving mentoring, instructional design, science of learning, and organizational change via the creation of communities of practice.

JON A. LEYDENS. Dr. Leydens is the Writing Program Administrator for the Division of Liberal Arts and International Studies at the Colorado School of Mines in Golden. Dr. Leydens’ research interests lie in cross-curricular initiatives, teaching and learning, and the application of qualitative research techniques to engineering education.
Appendix A: The Semi-Structured Interview

Instrument used for Semi-Structured Interview

Part I. Setup and Transition

Intro: The interviewer states: “Think about something you are interested in, that is really a part of you. Something that those who know you well associate with you and who you are. An interest that you apply to many areas of your life.” The interviewer then gives an example by telling about how she is a dancer and how the dancing has translated into everyday life in the way she does things.

Q1—the interviewer asks: "Is there something that is like that for you?"

Follow-up: The interviewer asks questions about the specifics of the participant’s involvement in that interest. Some example might be “where do you participate?”; “who do you participate with?”; “how do you participate?”, etc. This gets participants talking about their interest and gives the interviewer some leads to use later in the interview.

Transition: Q2—the interviewer asks: "I suppose you are better today at (participant’s theme) then you were when you started?" Participant typically answers, "well, yes, of course" and rapport is built between the participant and interviewer as they laugh at the silliness of the question. This is a key setup for the next phase of the interview. Without asking this question it is hard to orient the participant into thinking about the entire journey of learning this interest. It sets up the breadth of the interviewing topic.

Part II. Exploration of the learning process

Q3: The interviewer asks, “How did you improve?” Participants will list a few topics. The interviewer records the topics on a data sheet. Participants generally mention something like “I did it.”

Q4: (follow up) The interviewer asks for each of the topics mentioned above: "You mentioned (one topic), how did that help you improve? Why was that effective for you?" The interviewer connects the new ideas to the original topic on the data sheet and helps the participant begin to see how the participant is learning. The interviewer can then draw a cycle and ask the participant if that is how he or she learned on this theme.

Q5: (optional follow up). If needed, follow up on each of the ideas surfaced by question 4 to clarify thoughts or if it seems like participants have more to say about the idea.

Part III: Ranking of elements of learning

Q6: The interviewer asks: "You mentioned topic, topic, and topic, of those which do you think contributed the most to your learning, second most,…?"

The interviewer thanks the participant.