An Exploratory Qualitative Study of the Proximal Goal Setting of Two Introductory Modeling Physics Students

Vashti Sawtelle
Florida International University, USA

Abstract. A qualitative investigation on the impact of goal-setting strategies on self-efficacy of two students taking Introductory Modeling Physics was conducted. The study found that the problem solving process can be divided into two main themes: goal-setting and self-efficacy. Self-efficacy plays a role in the goal setting process of these two students, and may be linked to the retention of students in physics.

Although many things contribute to the success of a student, many students see success in a physics class as impossible. Introductory Physics focuses heavily on problem solving, but few classes actually work to develop these skills. Over the recent decades, bachelor's degrees in physics have lagged behind the other sciences such as mathematics, the natural sciences, and engineering receiving only 2% of the undergraduate degrees awarded in these technical fields (Mulvey & Nicholson, 2007). Fencl and Scheel (2005) discussed the possibility of self-efficacy impacting the retention of students in the physics classroom. In 1977, Bandura provided the theoretical framework of self-efficacy in an effort to supply a theoretical explanation for human behavior change. He defined self-efficacy to be the beliefs in one's ability to perform a *specific* task, particularly stressing the specificity of the task. Thus though self-efficacy might be well understood in mathematics, it needs to be investigated separately in physics.

Betz and Hackett (1989) showed that in mathematics, self-efficacy expectations are strong predictors of mathematics-related educational and career choices. Physics is often considered to be directly related to mathematics, and furthermore studies of self-efficacy in career and educational psychology have strongly linked self-efficacy to both persistence in technical fields and success in those same fields (Brown, 1989; Lent, 1986, 1987). These works suggest that it would be beneficial to the science education community to explore the relationship between self-efficacy and physics in general, as well as in specific reformed instructional approaches such as Modeling Instruction.

To investigate self-efficacy in the physics classroom, it is necessary to return to the problem-solving structure of most physics classes. One of the primary components of problem solving is goal-setting. Schunk's (1983, 1991) research on self-efficacy looks at the relationship between self-efficacy and motivational factors, such as goal setting. Bandura and Cervone (as cited in Schunk, 1991) showed that providing students with feedback on goal progress increases self-efficacy. Furthermore, Schunk (1983) showed that setting goals enhances self-efficacy. However, Schunk (1991) also makes it clear that these goals must be proximal in nature (i.e. closely related to the students' task). To better understand self-efficacy in physics, and its impact on the retention of students in the field, it would be informative to also understand the goal setting habits of students in physics classes. This study uses the definition of goals provided by Wentzel (2000), "a cognitive representation of *what* it is that an individual is trying to achieve in a given situation" (p.106). With this in mind, this study will address this research question: How do two Modeling Physics students, one man and one woman, construct and use proximal goals?

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Method and Participants

A variety of students take Introductory Physics in college. The two-semester sequence is required for engineers, pre-health students, and physics major alike. Furthermore, the Modeling classes are conducted in such a way that the data gathered are necessarily information rich, as is necessary for a good qualitative study (Merriam, 2002). Due to the significant amount of group work and the focus on the students' learning, the Modeling classroom is ideal for studying goal setting in the physics learning environment. In the Modeling classroom, students work together on lab and guided inquiry activities in small groups (3 to 4) and also engage in large class discussions, where they present their ideas and results to their peers. The instructor spends a minimal amount of time lecturing, encourages group work, and engages students through Socratic questioning. Clearly, in the Modeling classroom, a lot of opportunity exists for students to set their own goals in learning the material.

The timing of the study was the first semester of a two semester sequence, and the students are focused mainly on Newtonian Mechanics during this time. Three sources for the case study were used: observation, interviews, and a research reflection notebook (Bogdan & Biklen, 2007). Data collection began with observing all students in one Modeling class for approximately two hours. The observation was during an in-class activity where the goal was to find the mass of the turkey in the set-up shown in Figure 1. Interaction between the researcher and participants was minimal with the students during the observation, and time was divided among all 9 groups. Observations were recorded in field notes during the 2-hour time frame. Due to the variety of career paths requiring Introductory Physics, these students ranged from entering freshmen to seniors. Also, the class is approximately 40% female and mostly Hispanic. There were 9 mixed-gender groups of 3 students each arranged in the classroom as seen in Figure 2.

To obtain information rich data, a researcher should choose participants to interview who have a great deal of familiarity with the course and its requirements (Rubin & Rubin, 2007). Two students were chosen: Giselle and John (gender-specific pseudonyms). Both John (Group 7) and Giselle (Group 4) are sophomores in college and are biology majors. Additionally, both students are in the pre-medical school track. Giselle never had any physics before this class and has participated in studies before with the researcher's research group. John had one physics class in high school in Brazil, and has never participated in a study with the researcher's research group before. The interviews took place in the middle of the semester and were conducted individually for approximately 45 minutes each.

At Florida International University, the Physics Department has incorporated Modeling Physics classes that are in part designed to give students the necessary problem solving skills. The physics community at Florida International University (FIU) is very tight-knit. Everyone knows one another and spends much of their time working together. As a graduate student in this environment, the researcher is necessarily a part of this community. However, the introductory students have very little connection with this physics community. They interact almost exclusively through the use of the tutoring sessions the undergraduates run. Thus, introductory students will have had little to no contact with the researcher. Throughout the research, a reflection notebook was used to monitor subjectivity, and member checking was used to ensure validity.

Results and Analysis

The analysis on the three sets of data yielded six final stages derived from the transcripts of the data: external influences, internal influences, introduction and representation, coordination of representation, applications, and checking for consistency. As expected, the internal influences were more evident in the interviews than in the observation. Similarly, the external influences were clearer in the observation of the in-class assignment. However, the remaining four themes were evident in both the interviews and observations. Furthermore, the themes of internal influences and external influences provide information as to how this process impacts the self-efficacy of the students in a fashion parallel to the goal setting process, while the other four themes—introduction and representation, coordination of representation, applications, and checking for consistency—exemplify the goal-setting process. To better understand self-efficacy in physics, for this paper, the focus is primarily on the interaction between the feedback to self-efficacy loop and the goal-setting process.

Feedback to Self-Efficacy

In this loop, two themes emerged: (a) external influences and (b) internal influences. External influences are the effects on the problem solving process that are from outside the student (i.e. outside resources, group work, etc.) Internal influences are the effects on the problem solving process that come from within the student (i.e. confusion, level of engagement, etc.).

External influences. Most of the time, the students begin their work in the self-efficacy feedback loop, often through the use of previously acquired resources, or external influences. As John notes,

> …the main strategy when we read a question is [to figure out] what we need to solve for. We try to implement what we already know from past problems we did, and laws that we learned and formulas. And once we gather all that knowledge, whether it's on a piece of paper or a big board, you start playing with it in order to be able to find the next step.

Here John describes accessing his previously obtained resources and applying them to the situation at hand. Similarly, Giselle relies on the materials provided by the professor: "He always uses a worksheet for the experiment we have to do. Then the worksheet tells us steps, and tells us what to do, tells us what's going on and stuff." These participants clearly show confidence to perform the task due to the impact of the external influences available.

Internal influences. Similarly, within the self-efficacy feedback grouping, the internal influence theme plays a role in understanding the level of perceived difficulty of the activity and the level of engagement of the student. John makes this theme evident with his statement:

> It's more of you need to come to class; you need to be active. You need to be willing to make mistakes, and if you're not really trying to solve something, and you're just looking around at the other people doing it, you won't learn. So you can read the book, but it won't be enough. You need to be active; you need to try.

Clearly these participants acquire a level of self-efficacy from their own internal perspectives on what is necessary to get to the end result. However, no actual goal setting appears to have taken place. Rather, these influences have a strong impact on how the students start the process of goal setting and moving forward. This is where Bandura's (1977) theoretical framework of self-efficacy plays a role. The perception of what outside resources are available, how difficult the problem will be, and the level of engagement necessary to succeed are all directly linked to one's belief in his/her ability to perform the task at hand.

Goal-Setting Process

Nevertheless, this self-efficacy feedback loop, while related to the goal-setting process, does not actually characterize the process itself. When students solved a problem in class, and later spoke of their experiences in interviews, a specific, non-sequential process was observed; this process had distinct stages. A student might be in any one of these stages while solving a problem. This process does not have a specific order, and the students seem to go through multiple cycles of the process before solving the problem. These stages are as follows: (a) introduction and representation, (b) coordination of representation, (c) applications, and (d) checking for consistency.

Introduction and representation. The first theme of introduction and representation is the depiction of the problem to be solved, and can take the form of equations, diagrams, or graphs. Almost all the students start the goal-setting process by creating a diagram that is an accurate introduction and representation of the situation at hand. This is evidenced early in the observation: “[Giselle’s group members] say they need to check some angles. They are drawing diagrams and trying to relate the angles in them.” Also, Giselle discusses drawing graphs in the interview: “No, [graphs] are helpful because you can see it more, and you kind of understand what’s going on a little bit more.” Giselle is clearly in the introduction and representation stage of the goal-setting process, but it’s also important to notice how she notes that the graphs are helpful. This stage of the goal-setting process is positively impacting her self-efficacy to move forward on the problem. We see a direct link to the self-efficacy feedback loop by her mention of an internal influence of understanding. Additionally, diagrams, equations, and graphs are all parts of the introduction and representation stage, and the students return to creating these representations throughout the problem solving process, thus impacting their self-efficacy along the way.

Coordination of representation. The second theme of coordination of representation occurs when the student relates the representations to one another, which may involve interpretation in words, or simply finding the relationship between the diagrams and equations. After students have a few different representations, there must be some coordination of representations. John most clearly explained this part of the goal-setting process:

> Ok, there’s different ways to find the weight. Some people used trigonometry, and found the components of the forces. Other people used geometry; they discovered that the triangle on the top of the turkey had to be the same as the triangle below, and then they found the forces somehow that way. Probably using calculus or something like that. We got the same answer basically.

In this segment, John discusses the relationship between the physical setting of the experiment, the physics concept, and the mathematical tools. He is coordinating all of the representations of the situations to create a coherent and complete design of the task at hand. Nonetheless, he is also transferring information back to his self-efficacy feedback loop. In his last statement, “We got the same answer basically” is an example of John using the external influence of other people’s result to positively impact his own self-efficacy. Similarly, students were observed trying to create a coherent relationship between the representations, “[John’s group was] confused about where the angle would go in their diagram. [They ask], ‘Does it start or stop at the turkey or at the sensor?’” They’re trying to coordinate their diagrammatical representation with the physical experimental setup (see Figure 1). However, this is an example where the coordination of representation negatively impacts the students’ self-efficacy through the internal influence of confusion apparent in the quotation.

Applications. The third theme, applications, occurs when a student employs the coordinated representations to move forward in the problem-solving process and includes putting the correct numbers in the equations or graphs. This theme arises out of the students making sense of all the information they’ve been working with so far. This is easily understandable when John says:

> Well there are different forces that act in each axis that affect the gravity and the normal force that oppose each other. So I can find the normal. And the tension, it was already provided. And since it was in equilibrium, the two forces in the x-axis would have to be in equilibrium or it would be moving. So I think we found that; I think we did solve for the mass. But we had to get a lot of measurements in order to find the forces.

John attempts to apply the coordinated representation of the equilibrium physics concept to his diagrammatical representation. This is why he refers to the forces in the different axes. He may not be pointing to a physical picture, but he is referring to a mental diagram. In addition, a direct connection to self-efficacy is evident in John's statement, "I can find the normal." Given his accurate coordination of representations, John's self-efficacy to move to the application step is positively impacted.

Checking for consistency. The applications stage does not end the goal-setting process; rather, a checking for consistency theme that emerges from the data ends this process. Checking for consistency is verifying the reliability of the end result, consisting mainly of checking units or making sense of the final number. This happened repeatedly in the observation: "One student, looking at his answer [for the mass of the turkey] says, 'I'm satisfied because it weighs about 4/5 of a pound," and "I hear, 'Our units do go!'" as well as, "'Wow, that's really too low, let me see what you did.'" Although clearly the students are checking for consistency at this endpoint, this step in the goal-setting process does not only happen at the end. Again, this stage transfers information to the self-efficacy feedback. The checking for consistency stage tells the students how confident they should be in their answer, which influences their self-efficacy for completing the next stage of the problem. The students also check at shorter intervals throughout the process. For example, Giselle describes trying to figure out which lengths they should measure to get the angle: "We were like 'this is too long' because we're trying to measure the angle here, not here." Also in the observation, when a particular group had figured out all the angles in their triangle, pointing at angles in a diagram drawn on their paper, they ask each other if the angles add up to 180°. These students are going through the checking process during the problem solving, and transferring positive feedback to their self-efficacy.

During the entire goal-setting process, information is transferred back to the self-efficacy feedback loop each time the students complete a stage and move to the next during the goal-setting process. In the final stages of the process, the students find the correct answer; regardless of whether they were correct, a variety of information passes between them. Externally influencing them is the professor revealing the answer: The professor gets the electronic scale out to measure the mass of the turkey. Everyone leans forward as he places the turkey on the scale. It reads 388g. As John states, "Some of the times we thought we got it, and we didn't. We totally got something else, or we forgot to add or subtract something, and we got a totally different number from everybody else." Clearly, the students look for an external validation on their goal-setting process, which gives them positive or negative feedback to their self-efficacy.

Conclusion

The observations and interviews of the two Modeling Physics students indicate the problem solving process can be divided into two main themes: goal-setting process and self-efficacy feedback. The goal-setting process consists of four primary stages that transfer information to the self-efficacy feedback loop. It is evident that each stage of the goal-setting process independently impacts the self-efficacy, supporting Schunk's (1991) conclusion that proximal goal setting affects self-efficacy. Considering the link between self-efficacy and the persistence of students in technical fields (Lent, 1987), and the impact of goal-setting on self-efficacy in the Modeling classroom, goal-setting should be further explored as a way to understand the retention of students in physics.

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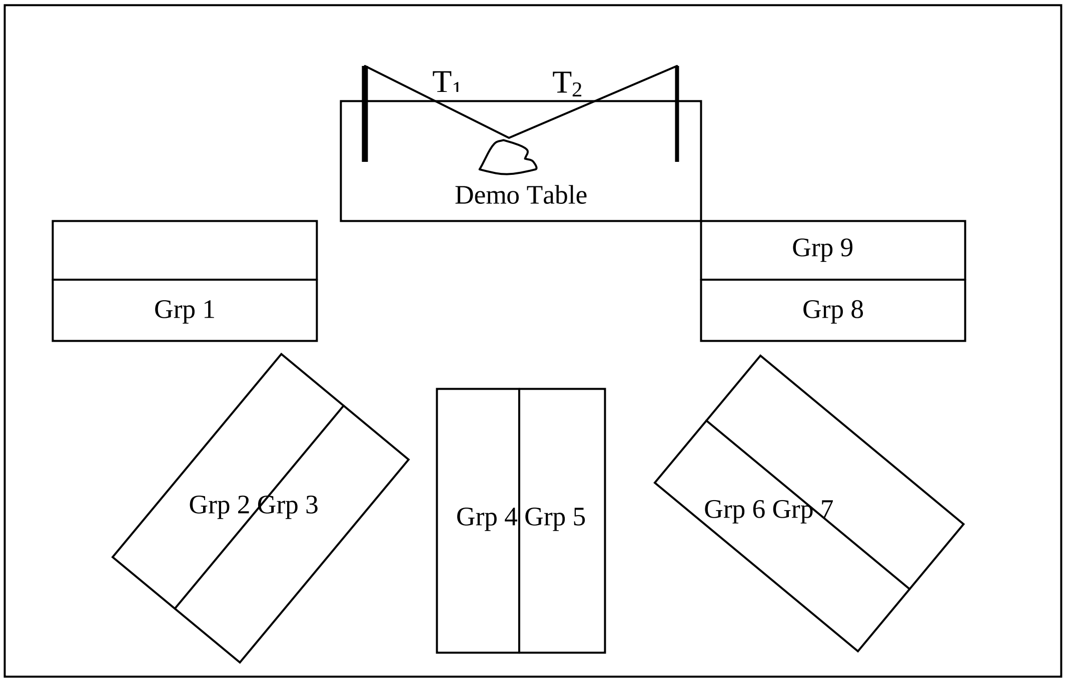

Figure 1. The experimental set-up for the in-class observation activity.

Table 1
Major Questions Used as an Interview Guide for Both John and Giselle.

Major Interview Guide:

A) I'm interested in understanding what a student does to succeed in [Insert Professor]'s physics class. What would you tell a friend is necessary?
B) Let's use an example of problem solving. Walk me through the activity you did when you tried to find the mass of the turkey.
C) How was this an example of a typical physics problem?
D) Are there any examples in this "find the mass of the turkey activity" of general things that you do when solving physics problems?
E) Generally, how would you say you attempt to solve a physics problem?