Creating Opportunities to Influence Self-Efficacy through Modeling Instruction

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Abstract. In this paper we present an initial analysis connecting key elements of Modeling Instruction (MI) to self-efficacy experience opportunities. Previously, we demonstrated that MI has positive effects on self-efficacy when compared with traditional Lecture instruction [1]. We also found a particularly strong positive effect on the social persuasion source of self-efficacy for women in the MI class. Our current study seeks to understand through what mechanisms MI influences self-efficacy. We demonstrate this connection through an in-depth analysis of video chosen to exemplify Modeling techniques used in a problem-solving episode by three female participants enrolled in a MI introductory physics class. We provide a rich and descriptive analysis of the *self-efficacy experiences opportunities* within this context and discuss how these opportunities provide a potential explanation of how MI influences self-efficacy.

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MODELING DEMONSTRATES POSITIVE IMPACTS

In an effort to increase retention rates of historically underrepresented minorities in the physics major, Florida International University (FIU) has implemented a reform effort in the introductory physics classrooms. This reform is centered around the implementation of Modeling Instruction (MI) [2], which has been in place since 2002. In the years following the physics education research group has demonstrated a marked improvement in retention rates of historically underrepresented groups [3] as well as improved attitudinal gains [4], large effects on conceptual understanding [3], and positive effects on self-efficacy [1] due to the MI course. This paper provides a description of a potential mechanism for how self-efficacy develops in the MI classroom.

WHAT MAKES MI SPECIAL?

Modeling Instruction (MI) is defined by a combination of pedagogical techniques and a shift in content focus. Primarily, MI focuses on designing and implementing robust models [2,5], creating an environment centered on group work [6], and extrapolating findings to a large group consensus building discourse [7].

While all of these elements are important to MI, some of them are also common in other reform efforts. In an attempt to discover the unique impacts of MI, we begin our analysis by focusing on one element: the explicit emphasis on robust model building and implementation. It behooves us, as a result, to spend a little time discussing how we operationalize a model and model building in the MI classroom.

When we refer to models in the MI discourse, we are referring to scientific models as discussed by Halloun [8,9]. Further, there are two distinct types of models we will use in this paper. The first is what Halloun deems a *basic* model (e.g. the uniformly accelerating particle model). These basic models are simple, yet comprehensive general models that build up a scientific theory (e.g. particle models and rigid body models build up Newtonian theory) [9]. The second type of model is a *specific* model. Specific models are more limited in scope and are often used as an intermediary step to constructing more generalized *basic* models (e.g. a particle in free fall model is a *specific* model within the uniformly accelerating particle *basic* model).

When constructing scientific models, we reduce the observances of the physical world to a limited number of what are deemed to be primary features [8]. For example, we assume we can use the uniformly accelerated particle model to describe the motion of a ball falling through the air because its edges are not moving differently from its center of mass. As such, the same *basic* model may be applied in various situations, but appear as different *specific* models.

SELF-EFFICACY OPPORTUNITIES

As described in the introductory section of this paper, our goal is to begin to understand how MI impacts self-efficacy in the classroom. Self-efficacy, the confidence in one's own capability to perform the actions necessary to achieve a particular goal [10], has been studied repeatedly in the sciences and found to be a strong predictor of both success and persistence [11-13]. An individual's self-efficacy derives from four sources: personal mastery experiences, vicarious learning experiences, social persuasion experiences, and current physiological state [10]. Typically, the influence of these experiential sources on self-efficacy has been investigated through reflective interviews or surveys [14-18]. In a forthcoming work we show that physics self-efficacy can be examined in a moment-by-moment analysis through the use of *self-efficacy experience opportunities* (*SEO*s), and demonstrate the validity of *SEO*s impacting self-efficacy [19]. While the analysis of *SEO*s does not allow us to say with certainty which events impact self-efficacy, using *SEO*s affords a focus on the ways in which particular events that potentially impact self-efficacy are constructed. In this paper we use this lens to identify *SEO*s in a model building session with three MI students.

CONTEXT OF THIS STUDY

The data for this study is a 1-minute clip of a larger problem-solving session completed with three female introductory physics students enrolled in a MI class. The session took place at the end of the first month in the first semester of physics, and the problem given was just at the edge of the skills the participants had developed up until that point in the classroom. At the time of this session the participants were developing the descriptive component of the *basic* model of a uniformly accelerating particle. They had developed a 1-dimensional component of this model, and had spent a little time on the 2-dimensional component. We have analyzed an additional 24 minutes of data to ensure the validity of the analysis presented here.

Participants

The participants in this study were three female students, Lisa, Gina, and Jessica, who were enrolled in the same Modeling Instruction course on Introductory Physics with Calculus I. At the time of the study all three women were in their junior year of college, were biology majors, and in the pre-medical school track. All three were colleagues as members of an academic cohort in the university. Lisa and Gina are twin sisters. Jessica is well known to both of them and described often working with Lisa. Prior to this class neither Lisa nor Gina had taken any physics. Jessica had three years of high school physics but reports learning more in one year of MI than all of high school physics.

Model Building Session

The problem solving session took place in a room adjacent to the participants' classroom that included whiteboards, a calculator, and physics textbooks at their disposal. The first author was present during the session, and asked the participants to spend 45 minutes working on the problem to get as far as they were able. The problem was chosen by their professor to be similar to what they solved in the MI classroom, but was also chosen to be at the edge of their ability. We hypothesized this would make the students work together and speak aloud their thoughts more readily. In this paper we will focus on the analysis of snippet of the session addressing the situation:

> *A mountaineer must leap across a 3.0m wide crevasse. In order to make the jump, she backs up 10m from the edge of the cliff, accelerates towards the cliff, and leaps at 35° above the horizontal. The mountaineer successfully makes the jump.* [20]

The expected outcome of this session consists of creating a *specific* model for this situation complete with the minimum velocity needed by the mountaineer to make the jump, and the time and acceleration required to achieve this speed. The model would include vector addition diagrams [21] and kinematic equations. Motion maps, and kinematic graphs could be included.

RESULTS & DISCUSSION

The clip chosen for this paper takes place at the end of the problem-solving session. The students have drawn a pictorial representation, successfully created a model of the 2-dimensional portion, but are having difficulties with the 1-dimensional component. As a result, they spend the last minutes, which this snippet focuses on, trying to construct a position-time (p-t) graph for the entire situation.

Assuming a Frame of Reference

In the few minutes leading up to this clip, primarily Lisa and Jessica have discussed where the

10m and 3m, from the respective 1d and 2d portions of the problem, should appear on the p-t graph. Jessica proposes that the mountaineer should first go 10m and then go an additional 3m for a total of 13m. Lisa is attempting to represent this on the graph when Gina breaks in with a question about what they are using for a frame of reference, and where the reference point for this *specific* model should be located.

Gina: What's our frame of reference? {looks at Lisa}
Lisa: {answering Gina} The ground.
Gina: The ground? {turns toward Lisa}
Lisa: Zero, yeah.
Gina: But she doesn't get closer to the ground.
Lisa: She's running {points at the picture drawn on the board}.
Gina: What's our frame of reference? The edge of the cliff? {turns toward Lisa}
Lisa: {Inaudible}
Gina: Because that's what I would think it would be. And then it would look like this, I guess? {Draws a negatively sloped line on the p-t graph starting at 10m and approaching 0m. Looks at Lisa}
Lisa: What would the edge of the cliff be? Zero?
{pause}
Lisa: ‘Cause if the edge of the cliff is the frame of reference...
Gina: Yeah, ‘cause...
Jessica: Yeah, that's true.
Lisa: ...you're moving towards the reference point {on the picture moves her finger along the path towards the cliff}, and away from the reference point {moves her finger along the path across the crevasse, erases line on p-t graph}.
Gina: But if this is the frame of reference {points to the cliff edge in the picture}, so you'd hit the frame of reference! {looks at Lisa} She gets to it. And then she would go away from it.
Lisa: So...{on the p-t graph draws a negatively sloped curve from 10m to 0m and then a positively sloped curve from 0m to 10m}...{inaudible comment, Lisa erases the positively sloped line}
Jessica: {inaudible}
Lisa: OK. {erases all the p-t graph}
Gina: So velocity would be negative.
Lisa: And then, why is the 13 up there {above the 10 on the y-axis}?
Gina: I have no idea. I don’t get that.
Jessica: {laughter}
Lisa: Then it's not supposed to be there. Then I think, in your model, it would be like this... {draws the 3 below the 10 on the y-axis}.

In this clip we see the students applying the *basic* model for uniform acceleration in order to build up the *specific* model for this mountaineer. This clip focuses on the student making an assumption about the reference point in order to limit the application of the *basic* model. We see that for Gina this is a particularly important step as she re-iterates her question (lines 1-2 and 9-10) until she achieves an answer that she thinks is coherent with the work they’ve done so far (12-13). However, we also see evidence that the students recognize that this is only an assumption. At the end of clip, Lisa says that in Gina’s model the 3m for the crevasse should be below the 10m for the 1d running (44-46). She does not say that the original drawing was wrong, only that Gina’s model required the picture to change, suggesting she understands that either assumption could be correct.

Within the context of discussing a frame of reference, however, we also see the students looking for coherency between representations. In choosing a reference point they move fluidly between the p-t graph and the picture of the mountaineer jumping the crevasse (lines 23 – 36). For the students, the two representations act as part of a whole and must agree.

Additionally, though the students successfully check for consistency between the representations, they forget that there is a difference between 1d and 2d kinematic graphs and do not break the position into components. When the students argue whether the ground or the cliff edge should be the frame of reference (lines 1-10) we might expect this to lead to a discussion about needing to split into the y-t and x-t graphs. However, this does not occur. We contend that this is evidence that the students are drawing upon the 1d pieces of the *basic* model of uniform acceleration when drawing the p-t graph.

Identifying *SEO*s

In a secondary analysis we describe the *SEO*s present in this clip. In the analysis we characterize each event by the type of self-efficacy experience it may represent. Thus we identify events as *mastery experience opportunities* (*MEO*s) by evidence that a task has been completed and evaluated, *vicarious learning experience opportunities* (*VLO*s) by the completion of a task by an individual and the observation of the task by a different person, and/or *social persuasion experience opportunities* (*SPO*s) by the messages communicated directly or indirectly about an individual’s ability.

As we work our way through the clip, the first opportunity for a self-efficacy building experience we see occurs with Gina's bid to think about what assumptions they are making about where the reference point is located. She asks, "What's our frame of reference?" (line 1) and then suggests that the cliff edge might be a good place to put it (9-10). There is a bit of discussion, then Lisa changes the p-t graph to represent the cliff edge as the reference point (32-36). The event of Gina suggesting a shift and then it being taken up and impacting the result characterizes a *MEO* for Gina. She may reflect on this event and remember that she raised the discussion about frame of reference and that it was taken up, which would impact her confidence in her ability to perform a similar task.

The second *SEO* we see in this clip is characterized as a *VLO*. In the beginning of the clip we see Gina and Lisa discussing where the zero for the frame of reference should be, (1-20) meanwhile Jessica observes the discussion. Thus Gina and Lisa serve as models for Jessica when considering where the reference point should be located. We know that Jessica is paying attention to the task because she responds to the query of whether Gina's argument implies that the edge of the cliff is zero (line 21). Jessica may recall this event in which she observed Gina and Lisa discussing the frame of reference when evaluating her ability to do a similar task.

We also see *SPO*s demonstrated in this clip. Throughout Lisa and Gina's discussion of about the frame of reference, Gina continually turns to look at Lisa (lines 2, 4, 10, 15, 30). This looking to Lisa for confirmation or evaluation sends a message to Lisa that she has the capability to evaluate the statements Gina has made. At another time Lisa may reflect upon these looks for confirmation and make a conclusion about her confidence in her capability to do a similar task in another setting.

MODEL BUILDING AFFORDS *SEO*S

Combining the two analyses of this clip, we see evidence that students are applying elements of the *basic* model of uniform acceleration while building a *specific* model for this particular phenomenon. We observed them discussing a key element to model building [8] in defining their assumptions about where the zero-point is located in their model. While they are doing so we see opportunities for self-efficacy building experiences unfolding. We contend that the model building provides opportunities for these events to occur.

While we do not intend for this work to generalize to all students solving physics problems, or to all Modeling Instruction students, the analysis does achieve specific goals of qualitative research. First, our analysis provides a detailed description of a potential mechanism for the complex issue of how self-efficacy develops in a MI classroom. Second, this study generates new questions about how other elements of MI work to create *SEOs*, and about how other classroom environments might compare. In future work, we hope to explore these issues and expand our understanding of the mechanism by which self-efficacy develops in physics classrooms.

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REFERENCES

[1] V. Sawtelle, E. Brewe, and L. H. Kramer, in the *PERC 2010 Proceedings,* pp.289 – 292.
[2] E. Brewe, *Am. J. Phys*. **76**, 1155 (2008).
[3] E. Brewe, V. Sawtelle, L. H. Kramer, G. E. O'Brien, I. Rodriguez, and P. Pamelá, *Phys. Rev. ST Phys. Ed. Res.* **6**, 0106 (2010).
[4] E. Brewe, L. Kramer, and G. O'Brien, *Phys. Rev. ST Phys. Ed. Res.* **5**, 13102 (2009).
[5] D. Hestenes, *Am. J. Phys*. **55**, 440 (1987).
[6] M. Wells, D. Hestenes, and G. Swackhamer, *Am. J. Phys*. **63**, 606 (1995).
[7] D. M. Desbien, PhD Arizona State University, 2002.
[8] I. Halloun, *J. Res. Sci. Teach.* **33**, 1019 (1996).
[9] I. A. Halloun, *Modeling theory in science education* (Springer, Netherlands, 2006), 24.
[10] A. Bandura, *Self-efficacy: The Exercise of Control*, edited by S. F. Brennan and C. Hastings (W.H. Freeman and Company, New York, NY, 1997).
[11] K. D. Multon, S. D. Brown, and R. W. Lent, *J. Couns. Pscyhol.* **38**, 30 (1991).
[12] N. E. Betz and G. Hackett *J. Couns. Pscyhol.* **28**, 399 (1981).
[13] R. W. Lent, S. D. Brown, and K. C. Larkin, *J. Couns. Pscyhol.* **34**, 293 (1987).
[14] E. L. Usher and F. Pajares, *Rev. Educ. Res.* **78**, 751 (2008).
[15] A. L. Zeldin, S. L. Britner, and F. Pajares, *J. Res. Sci. Teach.* **45**, 1036 (2008).
[16] A. L. Zeldin and F. Pajares, *Amer. Educ. Res. J.* **37**, 215 (2000).
[17] R. W. Lent, S. D. Brown, M. R. Gover, and S. K. Nijjer, *J. Career Assessment* **4**, 33 (1996).
[18] M. A. Hutchison, D. K. Follman, M. Sumpter, and G. M. Bodner, *J. Eng. Educ.* **95**, 39 (2006).
[19] V. Sawtelle, E. Brewe, R.M. Goertzen, and L.H. Kramer, *manuscript in preparation.*
[20] P. D'Alessandris, *Spiral Physics*. Available at < web.monroecc.edu/spiral/>
[21] D. Wheeler and N. Charoenkul, *Phys. Teach.* **36**, 274 (1998).