A Relationship Between Actor-Oriented Transfer and Mathematics Self-Efficacy

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Bandura's self-efficacy theory notes that self-efficacy determines how much time and effort students will put toward their work, meaning higher self-efficacy will lead to students working harder on their coursework. It should thus be in every mathematics instructor's best interest to understand how they can positively impact a student's self-efficacy related to mathematics. This theoretical report examines the intersection between an actor-oriented perspective of transfer of learning and Bandura's self-efficacy theory. I then propose a merging of the two through the concept of actor-oriented self-efficacy, which emphasizes using actor-oriented transfer methods to better understand students' mathematics self-efficacy levels. I conclude with an example of how one can apply an actor-oriented self-efficacy perspective to a study dealing with students' self-efficacy related to proving.

Keywords: actor-oriented transfer; self-efficacy; transfer

Introduction

Ampadu and Anokye-Poku (2022) confirmed that there is a positive relationship between a student's attitude toward mathematics and their achievement in mathematics courses. Since mathematics self-efficacy has been shown to be a reliable mediator between one's mathematics attitude and mathematics achievement (Randhawa, 1993), improving a student's mathematics self-efficacy may be an area of focus for student growth. Note that self-efficacy refers to a person's beliefs regarding how well they can perform a series of actions given a certain situation (Bandura, 1982). Mathematics instructors should then be concerned about how their instructional decisions in the classroom impact their students' mathematics self-efficacy, since this can directly influence how students perform in their courses. As Randhawa (1993) noted, "teachers should do whatever they can to assure all students in mathematics courses that they are capable and should venture forward in mathematics-related areas of study" (p. 47). If instructors can improve students' mathematics self-efficacy, they can improve students' abilities to achieve in their mathematics courses and how encouraged they are to consider pursuing mathematical-related majors and careers.

Mathematics instructors should also be concerned for their students' mathematics self-efficacy as it plays a significant role in students' decisions regarding pursuing STEM-related fields. Hackett (1985) noted mathematics self-efficacy is a reliable predictor of math-related major choice, meaning one's mathematics self-efficacy has a strong impact on if a student chooses a math-related major in college. Additionally, "a lack of confidence in mathematical ability" has been "a major contributing factor for women's decisions to leave calculus but not men's" (Ellis & Cooper, 2017, p. 7). Mathematics self-efficacy may therefore play a key role in women's decisions to stop pursuing mathematics at the calculus level. An instructor's interest in their students' mathematics self-efficacy may go beyond a desire for their students to perform well in their course, as it impacts each student's discernment process when they are deciding if they wish to continue studying mathematics.

While considering student mathematics self-efficacy, note that a personal efficacy belief is the "conviction that one can successfully execute the behavior required to produce the outcomes (Bandura, 1977, p. 193). It thus does not necessarily matter if an observer believes a student's self-efficacy has changed; rather, it matters if the student believes their own self-efficacy has grown. Therefore, to explore how instructors can positively impact students' mathematical self-efficacy, it is optimal to understand the impacts classroom decisions have on students' mathematical self-efficacy from the perspective of the students themselves.

As I am interested in the classroom decisions and learning situations that can positively impact mathematics self-efficacy, I am also interested in understanding what situations in the classroom raise students' self-efficacy so that students demonstrate this heightened self-efficacy in future situations. In other words, I am interested in how self-efficacy can be transferred. With this in mind, I consider using transfer of learning, which refers to "the ability to apply knowledge learned in one context to a new context" (Mestre 2003, as cited in Karakok, 2021, p. 103). Transfer of learning focuses on identifying how students learn knowledge in one moment, the learning situation, and apply it in another moment, the transfer situation (Lobato, 2012). Thus, there is a similar notion in studying transfer of learning to that of changing mathematics self-efficacy; there are moments where instructors hope to change self-efficacy and there are future moments where instructors hope to see that raised self-efficacy in action. Moreover, as I am interested in students perceived self-efficacy (meaning student perspective), I focus on one of the contemporary approaches to transfer of learning, namely, actor-oriented transfer framework (Lobato, 2012).

I note that there is a precedent for applying transfer of learning theory to other areas, specifically areas that are individualistic in nature, to better understand them, such as Karakok's (2021) discussion of the similarities between transfer of learning and student creativity. This suggests one can better understand student mathematics self-efficacy by first considering the intersection between the theories of self-efficacy and transfer of learning. Furthering this, Karakok (2021) specifically discussed how a researcher may use an actor-oriented transfer (AOT) perspective to study creativity and the transfer of creativity. While I discuss AOT in detail later, I note that it focuses on viewing situations from the actor's perspective where, in this case, actors are students in the classroom. I thus consider how one may use transfer and AOT framework to understand student mathematics self-efficacy and the transfer of mathematics self-efficacy. Moreover, I discuss how an AOT perspective can aid in our pursuit of understanding student mathematics self-efficacy and what pedagogical decisions impact student mathematics self-efficacy. This theoretical report is thus driven by the following research questions:

1. How can an actor-oriented transfer perspective be used to understand student mathematics self-efficacy and the impacts pedagogical decisions can have on student mathematics self-efficacy?
2. What similarities exist between actor-oriented transfer theory and methods used to study student mathematics self-efficacy?

Literature Review

Mathematics Self-Efficacy

I consider mathematics self-efficacy with Bandura's (1982) notion that self-efficacy refers to a person's beliefs regarding how well they can perform a series of actions in a certain situation in mind. As noted, mathematics instructors should be concerned about their students' self-efficacy, as it plays an important role in determining how much students are able to achieve while studying mathematics and if they choose to continue studying mathematics (Ampadu & Anokye-Poku, 2022; Ellis & Cooper, 2017; Hackett, 1985; Randhawa, 1993). Self-efficacy is also a significant piece of each student's mathematical journey as "efficacy expectations are a major determinant of people's choice of activities, how much effort they will expend, and of how long they will sustain effort in dealing with stressful situations” (Bandura, 1977, p. 194). Each student’s efficacy may directly impact the amount of time and effort they dedicate to mastering their coursework. Therefore, mathematics instructors should understand how their pedagogical decisions impact their students’ mathematical self-efficacy, as doing so enables instructors to positively influence the amount of time and effort students give toward their studies as well as students’ achievements in mathematics.

To understand how to influence students’ mathematics self-efficacy, I first discuss potential sources where students can gain self-efficacy. In his self-efficacy theory, Bandura (1977) outlined four principal sources for one’s self-efficacy: performance accomplishments, vicarious experience, verbal persuasion, and emotional arousal. Performance accomplishments, noted as the most influential source, rely on personal mastery experiences; self-efficacy rises through one’s own continued successes. Bandura also noted that “improvements in behavioral functioning” through performance accomplishments “transfer not only to similar situations but to activities that are substantially different from those on which the treatment was focused” (p. 195). Vicarious experience refers to observing others doing difficult tasks without adverse results, so that an observer more firmly believes that they can successfully navigate similar challenges. Bandura notes that this source is not as strong as performance accomplishments, and that any self-efficacy gained from it has a greater chance of being diminished later when compared to performance accomplishments. Verbal persuasion, involving suggesting to another that “they can cope successfully with what has overwhelmed them in the past”, will also be weaker than performance accomplishments; since there is no actual performance of tasks to base these suggestions off, their self-efficacy is less likely to be impacted than from the previous two sources (p. 198). Finally, emotional arousal relates to emotions that come from stressful situations and the effects they have on one’s self-efficacy relating to a task.

Note that Bandura’s four sources have been used previously in studies on students’ mathematics self-efficacy. Regier and Savic (2020) used Bandura’s four sources to identify changes to students’ mathematics self-efficacy for proving that were caused because instructors implemented teaching actions that aligned with Sriraman’s (2005) principles for fostering creativity. Watkins and Middleton (2021) focused on understanding which of the four sources could successfully predict mathematics self-efficacy in Black college first-year students that attended a predominantly Black campus. Usher and Pajares (2009) worked to validate Bandura’s theory of self-efficacy’s four sources for students studying middle school mathematics. Parsons et al. (2015) focused on which sources of mathematics self-efficacy (Bandura’s and others) engineering students identified as having changed their self-efficacy levels, noting that performance accomplishments were found to be the most important source while verbal persuasion was absent. There is therefore a precedent for researching students’ mathematics self-efficacy levels that utilizes Bandura’s four sources as a theoretical framework.

Instructors thus have the potential to impact students’ mathematical self-efficacy by understanding Bandura’s four sources; if a pedagogical decision leads to consequences related to these sources, that decision has the potential to change one’s self-efficacy levels. This leads to the following question: how can observers successfully identify the impact that choices made in the classroom have on students’ mathematics self-efficacy levels with respect to Bandura’s sources? To answer, I turn to transfer theory, which focuses on how certain situations in the classroom impact students (with respect to future situations). This draws a similarity to my question, as it is interested in understanding what students take from a situation (with respect to their self-efficacy) and how their effected self-efficacy impacts their future ability to perform in the classroom.

The Actor-Oriented Transfer Perspective

To understand which classroom decisions impact students' mathematics self-efficacy (and how they do so) with respect to Bandura's model, I consider utilizing the transfer construct, as this relates to how one event impacts a student's knowledge by considering a future event where they apply that knowledge. More specifically, I consider using an actor-oriented transfer (AOT) perspective to identify what impacts, with respect to Bandura's four sources, have occurred.

The actor-oriented transfer (AOT) perspective engages with the actor's (student's) point of view rather than an observer's perspective; instead of focusing on if a student performs a specific action or acts in a certain way (which an observer has pre-determined to be of significance), it examines the student's actions or behaviors related to a task, where knowledge is applied, regardless of their correctness (Lobato, 2012). Moreover, an AOT perspective aims to understand how previous experiences, where knowledge is learned, lead to a student's decisions, rather than focusing on if previous experiences lead to specific, pre-determined choices by the student (Lobato, 2012). While an observer perspective views "successful or improved performance on transfer task" as evidence of transfer, an AOT perspective believes that "regardless of successful or improved performance on transfer tasks, any influence of prior learning experiences is considered as evidence for transfer" (Karakok, 2021, p. 111). Therefore, AOT's framework values understanding students' perspective regardless of normative correctness so that such an approach could provide means to understanding perceived student self-efficacy. An AOT perspective thus enables observers to use each student's viewpoint when considering if certain pedagogical decisions had effects on a student's self-efficacy levels and, if so, which of Bandura's sources these effects may be related to.

The Intersection Between Actor-Oriented Transfer and Self-Efficacy

Note that AOT's view of 'transfer' is concerned with understanding "the processes by which individuals generate their own similarities" between a learning situation, where they are first introduced to a topic, and a transfer situation, where they attempt to apply their knowledge of this topic (Lobato, 2003, p. 18). Bandura's two most impactful sources, performance accomplishments and vicarious experiences, dealt with improving self-efficacy with respect to one situation so that an improved confidence can help an individual perform better in future situations that they perceive as similar to the prior experience (1977). There is thus a notion of transfer present in Bandura's model, meaning AOT framework can potentially be used to identify when there is a 'transfer' of mathematics self-efficacy between situations. Additionally, the AOT perspective "assumes that learners are making connections between situations nearly all the time, guided by aspects of the situation that they find personally salient" (Lobato, 2003, p. 19). An observer thus assumes learning situations *do* have impacts on students that become present in transfer situations. Applying this perspective to students' mathematics self-efficacy with these situations in mind, it is not a question of *if* there is an impact, but rather *what* this impact looks like and *why* it happened. Moreover, the AOT perspective means relying on each student's input to answer the question of what changes to their self-efficacy have occurred between learning and transfer situations. While an observer could believe that there has been a change from observing a student's time in each situation, studying self-efficacy can benefit from focusing on students' perspectives due to self-efficacy encompassing each person's personal beliefs regarding their ability to perform successfully.

The focus on students' beliefs in AOT agrees with other studies that highlight how the most important data comes directly from the students themselves when considering topics that deal with students' personal beliefs, such as self-efficacy and creativity. When gathering data on what teaching actions influence fostering creativity in a Calculus course, Satyam et al. (2022) note that

> these actions are from the students' (not instructor) perspective. We did not corroborate whether instructors in fact did these actions. Given our lens of creativity and that the individual themselves is the ultimate judge of whether they felt creative (independent of their reporting of it to us), students' judgments of what their instructor did that actively contributed to their sense of creativity are most valuable. (p. 542)

This stands as an example of why research topics focusing on personal attributes (as they depend on each student's beliefs), such as creativity, can benefit from gathering data based on students' viewpoints; it does not matter what the instructor intended to do, nor what an observer believes they see, as much as it matters that an actor believes something to be true.

Additionally, when Regier and Savic (2020) discussed the impacts teaching actions related to fostering creativity have on students' self-efficacy for proving, they coded sources of self-efficacy from student interviews "when a potential source (enactive experiences, vicarious role-modeling, verbal persuasion, physiological reaction) was described in relation to a change in student confidence in proving" during interviews with students (p. 5). Thus, there are previous studies that examine students' beliefs by using evidence of changes in self-efficacy or creativity only when students noted that to be the case.

Merging Self-Efficacy Theory with Actor-Oriented Transfer

After discussing the intersection between actor-oriented transfer and creativity, Karakok (2021) outlined her concept of actor-oriented creativity (AOc). AOc blends actor-oriented transfer and creativity research, as it means to "distinguish students' perspectives on creativity and perceptions of their own mathematical creativity from the ones observed or declared by others" (pp. 121 – 122). Actor-oriented transfer thus has the potential to be integrated with another area of research that can possibly benefit from its methods. With this in mind, I take a similar path by constructing actor-oriented mathematics self-efficacy, which means to consider mathematics self-efficacy through an actor-oriented transfer lens.

I consider using an AOT approach to study students' mathematics self-efficacy levels to highlight the student perspective on what pedagogical decisions could positively impact mathematics self-efficacy. When studying mathematics self-efficacy with Bandura's four sources of self-efficacy in mind, researchers may need to identify when a student's self-efficacy has changed and, if this is the case, the catalyst for this change with respect to the four sources. To do so, I propose the concept of actor-oriented self-efficacy (AOSE) which focuses on understanding each student's mathematics self-efficacy from their own perspective, rather than from that of an observer. This means AOSE requires researchers to turn to the student perspective for information on a) when their mathematics self-efficacy has changed and b) what situations, with Bandura's four sources in mind, led to those changes. Karakok (2021) noted a potential outcome of using actor-oriented creativity stems from how "inclusion of students' perspectives on mathematical creativity and their perception of their own mathematical creativity could help us detect nonnormative instances of students' mathematical creativity and provide processes that are not reported in earlier studies" (p. 121). Similarly, AOSE acknowledges that a student's discussion of what has impacted their mathematics self-efficacy can potentially illuminate researchers to instances that they may not have considered.

This AOSE perspective considers the nature of measuring self-efficacy; as self-efficacy is based on one's own beliefs regarding their ability to successfully perform a task, it follows that correctly determining a student's mathematics self-efficacy levels requires introspection on the student's part. This distinction agrees with Lobato's (2003) note on the usefulness of transfer models: "traditional models rely too heavily on the determination of transfer from an expert's point of view and, as a result, can lead to design decisions that are not informed by the specific generalizations that students have formed" (p. 20). An actor-oriented self-efficacy perspective would thus engage with students' specific generalizations regarding their mathematics self-efficacy and put the emphasis on their perspective, rather than that of any observers. While an instructor or an observer can hypothesize about whether a student's self-efficacy has changed and what it was that changed it, a student is the best person to discern what has happened to their own self-efficacy levels. Actor-oriented self-efficacy thus centers on highlighting students' viewpoints on their own mathematics self-efficacy. This can ensure that pedagogical decisions made with the intent to raise mathematics self-efficacy levels are made with students' perspectives in mind.

Applying Actor-Oriented Self-Efficacy to a Case Study

I apply an AOSE perspective to a previous study (Regier & Savic, 2020) conducted on the effects teaching principles of creativity have on self-efficacy levels related to proving. Regier and Savic (2020) created the Self-efficacy for Proving Scale (SEPS) which "consisted of three specific proving statements in which students were asked to rate their confidence of five subtasks related to proving each statement" and had students "rate their confidence in their ability (on a scale of 0% confidence to 100%)" to do five subtasks related to proving (pp. 4-5). SEPS surveys were given at the beginning, middle, and end of the semester so that results could be used to discuss the students' changes in self-efficacy related to each statement by comparing students' SEPS scores from the beginning of the semester to their scores at the end of the semester.

While the SEPS agrees with AOSE when determining if students' self-efficacy levels changed by asking students for their perspectives on their own self-efficacy levels, it does not ask students what events or teaching actions may have led to changes in their self-efficacy. An AOSE approach would try to understand what caused these changes in self-efficacy levels from the students' viewpoints. Note that Regier and Savic (2020) created another survey, the Five Principles Survey (5PS), that students completed at the end of the semester and contained questions regarding students' experiences with respect to each of Sriraman's (2005) five principles of creativity. Therefore, an AOSE perspective's additional goal could be realized by creating additional questions in the SEPS, like those in the 5PS, that ask students if (and if so, how) any of the principles of creativity impacted their self-efficacy levels with respect to each statement they needed to prove. This addition will agree with an AOSE approach by only identifying principles of creativity as having impacted a student's self-efficacy levels if a student declares them to have done so. This would provide data for the second half of AOSE's goals by creating data focused on how students' self-efficacy levels change and based on the students' perspectives.

Regier and Savic (2020) also conducted student interviews at the end of the semester that asked students "questions about their classroom experience, their relative confidence in proving now, and how they gained confidence in their class" (p. 5). Note that these interviews already agree with an AOSE perspective; they gather data on student self-efficacy levels by asking for the student perspective on if and how their self-efficacy changed because of their experiences in the classroom. I consider expanding this approach by gathering data on how specific situations in the classroom changed student's self-efficacy levels through an AOSE viewpoint.

Since interviews took place at the end of the semester, they focused on students' overall experience in the course and self-efficacy levels for proving. Therefore, students may not have remembered specific instances that helped change their self-efficacy for proving. Drawing inspiration from AOT's theory of learning and transfer situations, I consider doing interviews during the semester periodically and directly after students work on proving statements related to a subcollection of proving tasks that correspond to recent topics discussed in the classroom (for example, self-efficacy related to proving by contradiction). By using the same questions found in end of semester interviews, adjusted for this suggested timeframe, observers may receive data discussing more moments related to principles of creativity that changed students' self-efficacy levels for proving; it would give students a chance to reflect on more recent classroom content that they may have forgotten by the end of the semester. Overall, this approach would exemplify AOSE's viewpoint further, as it would allow students to reflect on situations that may have impacted their self-efficacy with respect to a certain subcategory of proving. This would mean students could potentially identify more explicit moments that changed their self-efficacy levels, thus giving researchers a better understanding (from the students' perspectives) of when and how principles of creativity impacted students' self-efficacy levels.

Future Work

I hope to apply our AOSE model to a study that examines the effects that teaching actions can have on how one's mathematics self-efficacy changes over the course of a semester. Specifically, I look to consider how the teaching actions stated in Satyam et al. (2022) can impact a student's mathematics self-efficacy in a calculus course setting. Calculus has been noted to be a 'gateway' course that impacts students' decisions to study STEM-related majors or not (Moreno & Muller, 1999). Moreover, Ellis and Cooper (2017) found that women were deciding to stop pursuing STEM-related majors due to experiences in their calculus courses. Thus, using an AOSE perspective to investigate teacher actions' impact on students' mathematics self-efficacy in a calculus course could potentially lead to more students deciding to continue studying STEM-related majors by deepening instructors' understanding of what teaching practices can raise students' mathematics self-efficacy levels.

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