"This *Began* My Journey of Confidence in Teaching Engineering on an Elementary Level!": Three Cases to Examine the Development of Preservice Teacher Self-Efficacy for Teaching Engineering in the Elementary Classroom

Program Abstract

Due to a nationwide emergence of K-6 engineering and computer science standards, there is a need to better understand how teacher educators can develop preservice teachers' teaching self-efficacy in these areas. Ed+gineering provided novel opportunities for PSTs to experience teaching and learning this content by building COVID-companion robots.

Proceedings Abstract

As a result of the increased inclusion of engineering and computer science standards for K-6 schools nationwide, there is a need to better understand how teacher educators can help develop preservice teachers' (PSTs') teaching self-efficacy in these areas. Ed+gineering provides novel opportunities for PSTs to experience teaching and learning engineering and coding content by building COVID-companion robots. Growing evidence supports robotics as a powerful approach to STEM learning for PSTs. In this study, Ed+gineering examined three cases to explore this overarching question: In what ways did PSTs' virtual robotics project experience develop their self-efficacy for teaching engineering and coding? Three PST cases were examined, within the context of their work with other team members (i.e., undergraduate engineering student(s), 5th graders). To understand each of three PSTs' virtual robotics project experiences, multiple data sources were collected and analyzed which includes mid- and post-semester CATME, end of course short-answer reflections, follow up interviews (including a modified *Big Five* personality inventory), and Zoom session recordings. Elementary PSTs Brenda, Erica, and Sarah experienced various levels of commitment and engagement in their five Zoom sessions. These factors, along with other personal and external influences, contributed to Bandura's four identified sources of self-efficacy. This study examines these contributing factors to create an initial working model of how PSTs develop teaching self-efficacy. In this conference session, science teacher educators will learn more about this model and pedagogical decisions that seemed to influence PST's self-efficacy for teaching engineering and computer science.

Problem

Increasingly to date, both national and state standards have added engineering and computer science into elementary curriculum frameworks. Thus, there is a dire need to better understand how to increase PSTs' self-efficacy in these areas. In order to provide opportunities for PSTs to experience teaching and learning new content in the area of engineering and coding, [blinded project name] partnered students in an instructional technologies course with undergraduate engineering students to teach robotics lessons to 5th graders. Growing evidence supports robotics as a powerful approach to STEM learning for PSTs (Jaipal-Jamani & Angeli, 2017; Schina et al., 2021). In this study [Blinded Project Name] used three cases to explore this overarching question: In what ways did PSTs' virtual robotics project experience develop their self-efficacy for teaching engineering and coding?

Theoretical Framework

Self-efficacy, or people's assessment of their capabilities within a specific domain (Bandura, 1993) is developed from social experiences and self-perception, and is influential in determining outcomes. Bandura named four sources of self-efficacy which draw from social interactions and self-reflection: mastery experiences, vicarious experiences, persuasion, and affect (1997). Recent research has explored these and other personal and interpersonal factors which can influence preservice teachers' self-efficacy for teaching.

There are direct links between aspects of preservice teachers' personalities and their teaching self-efficacy (Senler & Sungur-Vural, 2013). Using the *The Big Five* personality inventory including extraversion, agreeableness, conscientiousness, neuroticism, and openness to experience, John and Srivastava (1999) found that agreeableness was positively associated with three aspects of teaching self-efficacy: student engagement, instructional strategies, and classroom management.

Tschannen-Moran et al. (1998) proposed an integrated model of teaching self-efficacy (Figure 1). This model portrays the cyclical nature of teacher efficacy, highlighting that the variable degrees to which teachers feel self-efficacious is directly linked to the context and subject area in which they are teaching. Factors that affect teaching self-efficacy include grade level (e.g., Kindergarten vs. 5th grade), mode of delivery (e.g., face-to-face vs. online), and content area (e.g., engineering vs. language arts). Given that engineering and coding are newly required teaching areas for PSTs, there is interest in researching how to cultivate teaching self-efficacy for these subjects. There is also interest in understanding how virtual contexts may influence teaching self-efficacy.Teaching engineering and coding lessons has been found to enhance teaching self-efficacy for those subjects (Perkins-Coppola, 2019). This study examines how PSTs' social experiences within an elementary-level virtual robotics teaching experience influenced their self-efficacy for engineering and coding.

While global assessments of teaching self-efficacy can help predict teacher behaviors, efficacy judgments related to specific teaching domains and individual students have been identified as more valid and reliable predictors of key outcomes such as teachers' behaviors, effort, and persistence (Bandura, 1997; Tschannen-Moran et al., 1998). Most research on teacher self-efficacy explores this variable at the classroom level and there is a dearth of studies considering its nature toward individual students and in specific domains (Zee et al., 2016). Meanwhile, studies reveal that unsuccessful encounters with students who display externalizing behaviors (i.e., apathy, behavior issues) are likely to weaken teachers' perceived ability to effectively teach, motivate, manage, and emotionally support individual students (Zee et al., 2016). Furthermore, negative personal feelings, cognitions, and efficacy are more salient in less experienced teachers (Emmer & Stough, 2001) leaving PSTs particularly vulnerable to negative efficacy effects from interpersonal interactions with individual students. There is a need for greater understanding of PSTs' ability to manage particular students and challenging teaching domains. This study provides a unique opportunity to examine both aspects using a context that combines dyadic teacher-student interactions and the specific domain of engineering and coding instruction at the elementary level.

Methods

The robotics project, funded by two interrelated NSF grants, partnered elementary PSTs in an instructional technology course and undergraduate engineering students in an electromechanical systems course at a mid-Atlantic university to teach engineering lessons to fifth graders during an afterschool technology club. Both of the collaborating courses and all the club sessions were conducted entirely via Zoom. The robotics project occured over the course of approximately five 1.5hr lessons during which participants interacted in small teams. All participants were given a Hummingbird Robotics Kit® to design a bio-inspired COVID-companion robot to comfort individuals during the pandemic. Each participant's robot was expected to utilize lights, sound, movement, and sensing to interact with the user.

This study examines three elementary PSTs' (pseudonyms) experiences throughout the project. These PSTs are considered the cases, while their other team members (i.e., undergraduate engineering student(s), 5th graders) influence and affect the PSTs' experiences, affecting the overall context of the project. To understand each of three PSTs' virtual robotics project experiences, multiple data sources were collected and analyzed for triangulation (Creswell, 2012)—including mid- and post-semester CATME, end of course short-answer reflections, follow up interviews (including a modified *Big Five* personality inventory), and Zoom session recordings. Through an iterative process examining the data, we identified factors (e.g., individual context, interaction, lesson outcomes) that affected elementary PSTs' self-efficacy for teaching engineering and coding.

Findings

Case 1: Brenda's Story

Individual Context. Brenda is a White female elementary PST who would like to eventually teach students in grades K-3. Prior to this project, she had little experience teaching elementary students, rather she taught secondary students aspects of theater production (i.e., sound, lighting) as part of her first degree in production design. When asked to explain her degree of *extraversion* related to the personality constructs, Brenda explained that she is an "extroverted introvert," because at a point her "social battery dies." She described herself as moderately *agreeable* because she is mostly "kind to everyone" and goes on to explain that while she may occasionally get nervous or stressed about certain things, she often hides it well to external observers and thus, rated herself on the lower end of the *neuroticism* scale. Finally, Brenda rated herself most highly on the *openness* scale that emphasized imagination and artistic interests. In her interview, Brenda shared that her goal for the project was for all team members to "construct [the robot] and have it work…not like making it pretty or some spectacular thing, but just having it work and having our code work." She was also concerned with her 5th grade partners' affective experiences and described being "dead set on making sure that they felt comfortable."

Interaction. Brenda felt somewhat satisfied with her relationship with the two 5th grade girls with whom she was partnered and helped them "be more comfortable on camera." However, she perceived a lack of commitment from her two engineering partners and was discouraged by the slow progression of her relationship with the 5th graders–"My engineers' lack of effort greatly affected the success of our project and by being only on Zoom my shy students only came out of their shells towards the end of the project." Brenda explained in her interview that her education instructor stepped in and mediated the team dynamic through direct conversations with the engineering students and through conversations with the engineering students' instructor. Brenda exclaimed that her course instructor was "a lighthouse in the storm" and the teaching assistants saved her "butt a bunch of times!"

Lesson Behaviors & Outcomes. Table 1 outlines the team members who were present during each recorded Zoom session, as well as a description of what occurred during each session. Generally speaking, Brenda and at least one elementary student attended each meeting. Brenda took the lead in the meetings to ensure that the outlined lesson objectives were met. Only one of the team's COVID-companion bunny robots was fully functional at the end of the project and met all of the established criteria: Phylicity's (an engineering student)(see Table 2). Other team members had elements of their bunnies that functioned appropriately (e.g., lights, moving arm); however, the other team members were not able to meet the challenge fully. Brenda explained that they did not have enough time but, provided more time, all would have been successful.
Self-Efficacy. While Brenda's experience did not leave her completely confident, she explained that her confidence began at "zero," and by the end, she felt as if she could "understand and carry a conversation about engineering and coding." Zoom Session 4 shows her comfortable using engineering and coding-specific vocabulary and understanding that even slight differences in size and mechanism build and placement necessitates coding changes for proper functioning. In her interview, she acknowledged feeling "way more confident teaching somebody how to build something rather than teaching someone how to code." And, while she reports feeling nowhere close to 100% confident in these areas, she feels "able and willing to learn more" and believes that she "would be able to teach a lesson about engineering in [her] future classroom due to this project because [she] was able to write and create a lesson plan."

Case 2: Erica's Story

Individual Context. Erica is a Multi-racial elementary PST planning to teach at an early elementary level. The project was her first teaching experience. Previously she received an undergraduate degree in biology and served as an electrician in the U.S. Navy where she gained some familiarity with engineering. When presented with descriptors of *The Big Five* personality traits, Erica identified as very *agreeable*, *conscientious*, and *open*. She rated herself in the middle for *extraversion* and *neuroticism*. Erica explained in her interview that her goal for the project shifted over time. At first, she was focused on having her team successfully complete their robots and was concerned that her grade would depend on this. As the project progressed, she realized that "teaching the kids… and… figuring out how to work with them" was most important. She described trying to put herself in the children's shoes and wanting to give them a "fun" and "proper robotics experience."
Interaction. Erica and her engineering partner, Conner, appeared to have a positive and effective relationship marked by consistent communication, high levels of investment and enthusiasm from both partners, and an easy rapport. In CATME, Erica described Conner as "a great team member" who "responds timely", "[is] involved with the entire learning process", and is "interactive and encouraging" with the fifth graders. She said he went "above and beyond" expectations, "tak[ing] extra time to work on the projects assigned." Kaleb and Jake, the 5th graders assigned to Erica, both expressed interest in the project, but participated at different levels. Jake had competing extra-curricular activities that prevented him from attending some sessions. Kaleb was present during all the sessions and attended an extra session with Erica toward the end of the project to finish his robot. Both boys initially kept their microphones and cameras off during the Zoom sessions, but after prodding turned them on. Jake appeared confident with technology and comfortable speaking up in the sessions from the start. Kaleb seemed a little more hesitant and unsure of his ability to complete the project, but was very excited and expressed plans to work as a NASA scientist.

Lesson Behaviors & Outcomes. Erica's team met for five sessions to work on the robotics project, three of these were recorded (see Table 1). Erica and Conner were both present throughout all the recorded Zoom sessions. However, Erica often had her microphone muted and minimized speaking as she was simultaneously caring for her two children.Throughout the sessions, Conner took a dominant role, leading the design process and all the instruction related to coding. Erica played a predominantly supportive role, often reinforcing Conner 's instruction by holding up kit components and offering praise to the fifth graders. Erica explained in her follow up interview that she made a larger contribution off screen, creating slideshows and videos for the children. At the end of the project, Erica, Conner, and Kaleb had completely functioning robots; however, Jake's missed sessions prevented him from finishing his (see Table 2).

Self-Efficacy. Erica described gaining confidence in teaching engineering and coding, but still having room to grow. In her reflection she characterized this experience as the "*begin[ning]* of her journey of confidence in teaching engineering" at an elementary level. She acknowledged not having as much knowledge as Conner, and at times feeling he was more capable of teaching the fifth graders. However, she came to terms with this believing that "it is acceptable to not have all of the knowledge" and allowing herself to learn alongside the children. Erica reported gaining confidence in coding as she went through the project. This seemed to be reflected in the Zoom sessions. While she was almost entirely silent in Session 3 when Conner was teaching Kaleb how to code various Hummingbird components, by Session 5 she contributed actively, making suggestions and holding up components to illustrate Conner's verbal instructions.

Case 3: Sarah's Story

Individual Context. Sarah is a White female elementary PST planning to teach students in grades K-3. Sarah had no prior experience with either engineering or coding, nor teaching. When asked to explain her personality based on the *The Big Five*, she described herself as moderately *extraverted*, mostly *agreeable*, *conscientious*, and *open*. However, she described being sensitive to environmental stress (*neuroticism*). In her CATME and reflections, she explained that her personal characteristics might have affected the roles that she and her engineering partner played: "I naturally like to take the lead and Drake naturally likes to follow… I am a planner through and through… It is my belief that my disposition, my partner's lack of effort, and the consequential doubt that it inspired all led to my major (and his minor) role in this project."

Interaction. Overall, Sarah seemed to have a good relationship with her two elementary students—Henry and Anthony. In her reflection she described them as "endlessly helpful, funny, and a joy to work with." She also believed that they were better "collaborators than many of the adults she has worked with in my own educational career" as they "were willing to work on their robots outside of [the] club, and were genuinely proud that one member of their group (me) was able to successfully create a working tongue mechanism in spite of their inability to do so (which was beyond their control)." According to Sarah's CATME responses, overall she was unsatisfied with her engineering partner—Drake. In her reflection Sarah expressed that their relationship was "effective in that our team was able to present a finished product, but not an effective partnership." She specifically indicated that Drake was "a very kind person" but was not "as invested in this project as she was." As a result, Sarah "manage[d] the team's schedule and progress" and took the lead on preparing and teaching the sessions.

Lesson Behaviors & Outcomes. In mid-semester CATME, Sarah indicated that she "wanted the kids to enjoy themselves," so she planned to have elementary students "get their hands dirty." However, as she was mindful of finishing the robots in time, she transitioned her instructional strategy from inquiry to a "copying-code-and-then-building" mode. Though Sarah was not satisfied with the change in her instructional strategy, both elementary students were engaged in the project. They attended all the zoom sessions and built their robots during the sessions with Sarah, sharing their progress with her. As a result, both elementary students had a functioning robot at the end of the project. At the beginning of the project Sarah expected "to share the teaching responsibilities" with Drake; however, as sessions proceeded, Drake's motivation and engagement declined. He attended only the required sessions and built his robot after all these sessions were over, in time to meet the engineering course deadline. As a result, Drake's final robot was never shared with the team members; and, his robot included different functionality as compared to the other team members (see Table 2).

Self-efficacy. In the reflection, Sarah specifically reported that she "didn't feel confident in either coding and engineering prior to this experience." She reflected that she was constantly "worried about her ability to understand—let alone teach—coding" during the training sessions with other elementary PSTs. After devoting personal time every weekend to master the coding she "felt comfortable teaching the codes and was prepared to answer any questions that may have risen." Her practice with the Hummingbird Kit® and teaching experience (e.g., preparing & teaching lessons) contributed to gains in her confidence in engineering and coding, and its instruction.

Discussion & Contributions to Science Education

While all three PSTs reported developing self-efficacy from their experience teaching robotics virtually to the fifth graders alongside their engineering partners, the factors that influenced their growth differed across the cases. While Brenda had the least successful outcomes as judged by the success of her team's robots and the struggles she faced with her partners, she seemed to derive confidence from her ability to create a lesson plan and have a conversation about coding and engineering. She appears to have focused on the progress she made (i.e., starting from zero confidence and the girls' increased comfort-level) rather than her final achievement level. Erica's team was marked by successful relationships and final outcomes. Erica's engineering partner was very proactive and Erica may have gained self-efficacy through the vicarious experience of his interactions as well as from slowly increasing her own participation overtime. Despite Sarah's frustrations with her engineering partner, she and her fifth graders produced successful robots and she reported feeling efficacious at the culmination. Her personal characteristics may have strongly influenced the role she adopted in the project as well as the expectations she set for herself and her assessment of how well she met those goals.

This study seeks to make a scholarly contribution in the area of elementary science educator preparation as teacher educators are tasked with developing their students' self-efficacy in engineering and computer science. This case study spurred the authors to examine the Tschannen-Moran et al. (1998) model and think critically about the ways in which personal characteristics, interactions, and lesson behaviors and outcomes contribute to PST's self-efficacy (see Figure 2). In this conference session, science teacher educators will learn more about these patterns and pedagogical decisions made by teacher educators that seemed to influence PST's self-efficacy for teaching engineering and computer science. Moving forward, the research team will continue to revise the model by analyzing additional cases.

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Tables

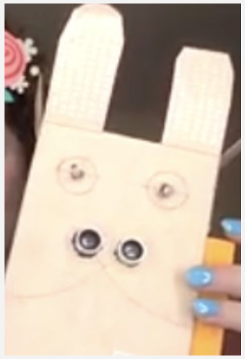
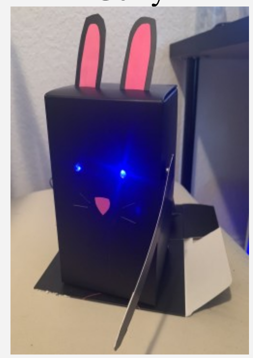
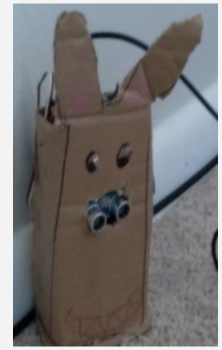
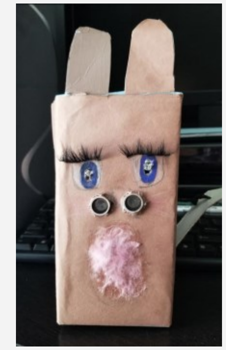
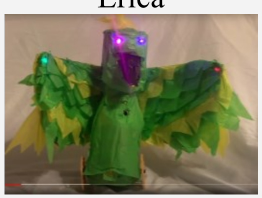
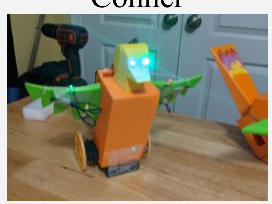
Table 1. Summary of the Analyzed Zoom Team Meetings

Case (PST)	Session 1	Session 2*	Session 3*	Session 4*	Session 5
Brenda	All attended	Only Phylicity (engineering student) attended for first 30 minutes; and only Jalisa (5th grader) attended	All attended	Both elementary students attended (one each part), neither engineering partner attended	N/A
	Session was focused on generating team slides, explaining how Wevideo works, and brainstorming and filming the videos.	Session was focused on the construction of the robot. More specifically, the majority of the time was spent finding string, creating a mechanism, breaking said mechanism, and repeating the process.	Session focuses on both coding of the robot and trying to finish assembly of the physical aspects of the robot (i.e., string mechanism), and troubleshooting issues (i.e., getting the USB connected and working properly)	The entire session, broken into 2 parts, consisted of teams coming up with their shark tank pitch and creating their slides and shark tank video.	There was no session 5; however, session 4 was broken into two parts. It is important to note that only one engineering partner was able to make a fully functioning robot.
Erica	N/A	All attended	All attended, except Jade (elementary student)	N/A	All attended
	No recording	Session was focused on team bonding activities, explaining bio-inspiration and the engineering design process, talking about different components of the Hummingbird kits, and brainstorming ideas for their COVID companion robot.	Session started with an engineering quiz. Then, coded tri-LED Hummingbird Kit, built with their robotics kit, testing out their codes with the kit and troubleshooting, and discussing their robot and brainstorming for the next week.	No recording	Session began bty Conner presenting a coding video that he made and asked elementary students to go over it and catch themselves up outside of the session; built robot with Erica and Conner with instruction, troubleshooting, and videos to help guide them;

					and discussing how to present their robots.
Sarah	All attended, except Drake (engineering student)	All attended	All attended	All attended	All attended, except Drake (engineering student)
	Session was focused on recording themselves in the video and changing greenscreen backgrounds in the WeVideo.	Session was focused on introducing the biomimicry concept and EDP, deciding on the animal type and features of the robot, and plugging in and coding the LED lights.	Session was focused on reviewing the last session; and developing step-by-step instructions of how to connect the controller to the computer, how to code tri-LED, how to save, code, and download it to micro:bit.	Session was focused on coding blinking eyes with the tri-LED light, coding tail movement with the position servo, building the robot to put in the position servo, and addressing elementary students' issue with the position servo.	Session was focused on plugging in a light sensor cord to the controller, coding tongue function using a rotation servo, building the tongue so that it connects with the rotation servo, and building the head part of the comfort cats.

Note. * Required session for the undergraduate engineering student(s).

Table 2. Robot Process/Outcome Table

Robot Concept	Preservice Teacher	Engineering Student	Engineering Student	Elementary Student	Elementary Student
Case 1 Brenda's Team: *During COVD-19 many people exhibiting symptoms of the virus had issues with congestion, or they may have simply been sad. These COVID-companion bunny robots were designed to grab tissues to assist a person when they came near.*	Brenda 	Phylicity 	Gerry 	Jalisa 	Neveah 
	Brenda's robot did not function how it was intended. It matched the other robots in look and design and was in the process of creating a functioning advanced mechanism.	This was the only functioning robot of the team; it picked up a piece of tissue and had a distance sensor that activated the motion. The design generally matched that of the rest of the group.	While the lights were functional and the arm did move, it did not match the rest of the group in design (it is a very different color) and it was not capable of completing the original design function as intended.	This robot featured LED eyes and a distance sensor to activate the intended mechanism. The robot did not function as was intended, but it did match their teammates' robots in looks and design.	Similar to Jalisa's robot, it featured LED eyes and a distance sensor, but did not function properly. The application of lashes and a mouth made this robot distinct from the others in the team.
Case 2 Erica's Team: *A colorful parrot that will make sound, flap its wings, and light up when activated by a sensor.*	Erica 	Conner 	N/A	Kaleb 	Jade
	Erica built a lot of her robot during the zoom session with the	Conner 3D printed a parrot that met all of their goals and took it	N/A	Kaleb's robot could turn, light up, and its wings moved	Jade was frequently absent and busy outside of WoW club.

	elementary students. It was successful and could spin, flap its wings, and light up.	to the next level. For example, his wings sensed the orientation of the bird and flapped only right or left wings when needed.		sporadically.	As a result, he did not share a completed robot.
Case 3 Sarah's Team: *"Comfort Kats" help people during the COVID-19 pandemic by calming them down and making them feel less alone.*	Sarah 	Drake 	N/A	Henry 	Anthony 
	Comfort Kat 4000 Sarah's robot was the only one that included all the intended mechanisms and functions. Her robot included a tongue mechanism and functions that goes in and out when an object comes close to the mouth. Thus, her robot was recognized as an advanced model.	**Christmas Kat** Drake had three different modes for his robot: relaxing mode, play mode, and sleep mode. Each of the modes had different mechanism and functions. His robot did not match the other teammates' designs nor functionality.	N/A	**Comfort Kat 3000** Except for a working tongue mechanism, Henry had a functioning robot at the end of the project. His robot featured LED eyes (purple) and the tail that moved constantly by using position servo.	**Comfort Kat 3000** Anthony's robot's eyes lit green. When the hand goes closer to the cat using a distance sensor, its tail moved by using a position servo and it played a song.

Note. N/A = not applicable (Cases 2 & 3 only had one undergraduate engineering student).

Figures

Figure 1. Cycle of Teacher Self-Efficacy (Tschannen-Moran et al., 1998, p. 228)

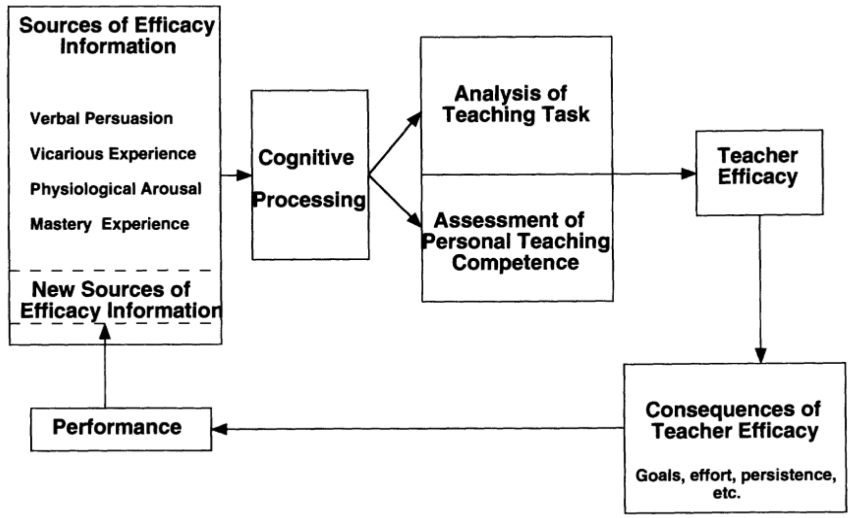


Figure 2. Observed Patterns and Factors that Affect Elementary Preservice Teachers' Self-efficacy for Teaching Engineering and Coding from the Three Cross-case Analysis