IMPROVING PRESERVICE SCIENCE TEACHERS' QUESTIONING SKILLS USING SELF-REGULATED LEARNING

by

HONG H. TRAN

(Under the Direction of Daniel K. Capps)

ABSTRACT

This dissertation study is about using self-regulated learning (SRL) to improve teacher questioning ability for preservice science teachers (PSTs). The aim of the study was threefold: (1) designing a novel approach that integrates SRL into professional learning and coaching during student teaching for PSTs, (2) improving PSTs' questioning ability, and (3) fostering SRL skills for PSTs.

This research was a multi-case study using multiple analysis methods. The participants were three PSTs representing low, intermediate, and high self-regulated PSTs in a certification program for teaching secondary science. Professional learning was part of the coursework, which provided PSTs with both broad principles and concrete strategies. Lessons 1 and 2 provided PSTs with broad principles for SRL and teacher questioning. The last three lessons showed PSTs concrete strategies to implement some of the broad principles in the context of science teaching. Coaching occurred in Spring 2022 semester, along with five observations for each participant. Research data came from classroom materials, semi-structured interviews about planning classroom questions, classroom observations, classroom audio recordings, and semi-structured interviews about enacting questions.

Findings show that (1) the PSTs who were better at self-regulating planning and enacting questions asked a greater number of higher-level cognitive questions, (2) even though the changes that happened in each case had some unique characteristics, the quality of their SRL practice and asking questions all increased, and (3) coaching during student teaching contributed to the PSTs' improvement in different aspects of asking questions (e.g., perceptions regarding planning questions, self-efficacy for asking questions, and quality of asking questions). The analysis elicits PSTs' SRL practice in the context of planning and enacting classroom questions. The research suggests ways to improve PSTs' questioning ability by integrating SRL into teacher preparation and offers a window into how PSTs' SRL skills can be better developed. Another suggestion from the findings is the need to differentiate coaching during student teaching based on PSTs' initial SRL skills. In addition, this study suggests that some adjustments within the current structure of university supervision could give the institutions more control over the quality and better prepare teacher candidates for the profession.

INDEX WORDS: Self-regulated learning practice, teacher questioning, student teaching, preservice science teachers, self-regulation of teaching

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

To be submitted to *Teaching and Teacher Education*

Abstract

Self-regulated learning (SRL) is a goal-directed process in which learners are metacognitively, motivationally, and behaviorally active participants in their learning process (Zimmerman, 1986). Although studies have shown that SRL is critical for success in learning in academic life and beyond, many students do not use SRL strategies to serve their science learning. One way to promote students' SRL is to provide teachers with an understanding of what SRL is and how to develop SRL skills in their students. At present, there have been no systematic reviews on SRL professional development (PD) for science teachers (STs). This critical literature review systematically reports on 14 empirical studies related to SRL PD for STs. We first discuss the role of SRL, explain the rationale for this literature review, provide a SRL model, and then examine the salient features and learning outcomes of the SRL PD. Findings revealed that SRL PD used various instructional approaches, lasted for a few hours to a yearlong, had diverse learning objectives, and yielded positive outcomes. The SRL PD supported STs in learning new science concepts, improved teachers' arrangement of SRL environments, enhanced knowledge transfer, fostered constructivist beliefs, increased lesson-designing skills, and developed STs' ability to implement SRL processes.

Subject/problem

Self-regulated learning (SRL) is a goal-directed process in which learners are metacognitively, motivationally, and behaviorally active participants in their learning process (Zimmerman, 1986, 1989). Most learners self-regulate learning to some degree, but the extent to which they consciously do so differentiates achievers from underachievers (Zimmerman & Risemberg, 1997). Highly self-regulated learners often feel empowered because they believe that success in learning largely depends on their skill in effectively using and adjusting strategies (Cleary & Zimmerman, 2004). Studies show SRL is critical for success in learning in academic life and beyond (Boekaerts, 1999; Cleary & Zimmerman, 2004; Perry &

Vandekamp, 2000; Pintrich, 1999). Many scholars argue that SRL is teachable; several studies have supported this premise (Cleary & Platten, 2013). Despite the importance of SRL, many students do not use SRL skills to serve their science learning (Cleary & Platten, 2013; Cleary et al., 2008). One reason is that many students are not taught strategies that could help them regulate their learning. Another reason is that students are not given sufficient opportunities to regulate their learning in the classroom and develop SRL skills (Buzza & Allinotte, 2013). One way to improve this situation is to provide teachers with SRL professional development (PD).

Studies indicated that teachers need more training in SRL (e.g., Cleary, 2009; Cleary et al., 2010). If teachers experience the effectiveness of SRL skills themselves, they will be more inclined to foster such skills within their students (Dembo, 2001; Gordon et al., 2007; Kramarski & Michalsky, 2009). Gordon and colleagues (2007) showed that self-regulated teachers who exhibit mastery goals become teachers who believe in the strength of SRL, apply a mastery goal orientation in their classrooms, support a more humanistic classroom control ideology, and likewise create an environment conducive to SRL development. Correspondingly, due to their own SRL development, self-regulated teachers are better able to understand the development of student learning strategies and to recognize and cope with the needs and difficulties that students may face in becoming more self-regulated (Delfino et al., 2010; Paris & Winograd, 2003; Tillema & Kremer-Hayon, 2002).

Rationale: Given the importance of SRL in teaching and learning, and the critical role teachers play in supporting students in becoming self-regulated learners, there is a need to better understand the ways in which teachers have been supported in learning about self-regulation. To this end, we have conducted a literature review on SRL PD for science teachers. To our knowledge, this is the first systematic review focused on the existing literature on how science teachers can be supported in implementing SRL in their learning

and teaching. The present literature review seeks to advance the field by providing guidelines for leveraging SRL in science teaching and learning. The guiding questions for the review were:

1) What are the salient features of existing SRL PD for science teachers?

2) What are the key learning outcomes that are supported by these programs?

Theoretical model of SRL

Although there are several SRL models, here we present Zimmerman's cyclical phases model of SRL (Zimmerman, 2000; Zimmerman & Moylan, 2009) as it is the most common model in the literature. The model includes three phases: forethought, performance, and self-reflection. Each phase comprises different processes and subprocesses (figure 1). In the forethought phase, learners analyze their learning tasks, set goals, and plan to achieve the goals. Learners' self-motivation beliefs affect the way they set goals and plan for their learning. During the performance phase, learners use different strategies to monitor their learning process. The self-reflection phase is when learners evaluate their performance and identify possible causes of their learning outcomes. The way learners attribute their success or failure affects their motivation and learning behaviors in the next SRL cycle (Zimmerman & Moylan, 2009).

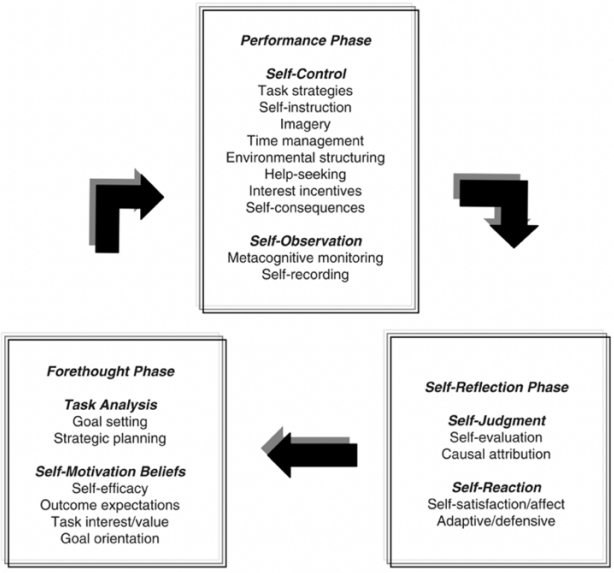

Figure 1. Zimmerman's Cyclical Phases Model of SRL (Zimmerman & Moylan, 2009)

Design/procedure

Articles for this review were selected from January 1986 to July 2021. The beginning date was set based on the year scholars distinguished SRL from metacognition (Panadero, 2017). Four databases were used to search for articles: APA PsycInfo, ERIC, PD collection, and Education Research Complete. Advanced searches were used with three different groups of keywords: "self-regulated learning," "science teacher*," and "professional development." We also replaced the first group of keywords with other relevant terms for SRL: Self-regulation, self-monitoring, metacognitive monitoring, goal setting, self-reflection, self-evaluation, strategies, forethought, performance, goal, and plan. Further, we replaced the last keywords with "intervention." Articles were chosen by reading the titles, the abstracts, checking for the presence of keywords, and screening to ensure they meet the following selection criteria:

- PD program that focused on SRL
- The PD was for science teachers (preservice or inservice)
- Articles included peer-reviewed journals and book chapters.

The above search procedures yielded 12 articles. Then, we conducted another search on Google Scholar with the keywords "SRL PD for science teachers." We searched the results until all relevant articles had been exhausted. One article and a book chapter met the criteria, for a total of 14 studies (13 articles, and a book chapter).

Analysis and findings

Table 1 includes a summary of the results of our review. First, SRL PD for science teachers is a relatively new area of inquiry in science education. The first publication we found was in 2009. Even though there have not been many SRL PD programs for science

teachers in the past 12 years, the number of SRL PD for science teachers is increasing. Nine out of 14 articles were published in the last five years.

Regarding the salient features, the existing SRL PD implemented different instructional approaches. Four out of the 14 studies embedded prompts into the training. For example, Adler and colleagues' study (2019) used metacognitive prompts to encourage monitoring and reflecting upon learning, reminiscent of key aspects of Zimmerman and Moylan's (2009) metacognitive monitoring subprocess and self-reflection phase. The other studies' approaches were also drawn from the SRL theoretical models such as including lesson planning-monitoring scaffolding, reflecting on teachers' learning processes, training the dual self-regulation roles, and teaching the processes of Zimmerman's model of SRL. There were also approaches that came less directly from the SRL models such as integrating systematic learning from problematic and successful experiences, and engaging in a researcher-facilitated professional learning community. The duration of the PD ranged from three to 96 hours. The PD's learning objectives were diverse. Some studies focused on using SRL for science teachers' own learning such as SRL practice as learners and reflection on the dynamic characteristics of open inquiry (Kramarski & Kohen, 2017; Adler et al., 2019). Two studies targeted teachers' beliefs (Kramarski & Michalsky, 2015; Barr & Askell-Williams, 2020). Two others used SRL as a means for teachers to learn the science content knowledge (Earth science content) (Lewis et al., 2011; Peters-Burton & Botov, 2017). Most of the PD aimed to improve science teachers' ability to foster students' SRL skills.

The PD programs showed the overall positive outcomes on science teachers learning and teaching. Twelve of the programs achieved their learning objectives, whereas two others showed the science teachers needed more support on one or two aspects of the expected training outcomes. Eilam's study (2017) showed the PD promoted teachers' metacognitive considerations and reflection and their planning and teaching, but the science teachers need

more support to make changes in enacting their lessons. Porter and Peters-Burton's study (2021) enhanced the use of SRL coaching strategies of observation and emulation, but the science teachers did not often encourage their students to self-reflect.

In conclusion, the SRL PD used diverse instructional approaches. Some of the approaches were drawn from SRL theoretical models, while others came less directly from the literature. The PD had different learning objectives (skills, processes, beliefs, concepts). Regardless of the variability in the duration of the PD, which ranged from three to 96 hours, the PD programs showed the overall positive effects on science teachers learning and teaching. Table 1. Review of the Literature on SRL PD for Science Teachers

Study	Salient Features			Learning Outcomes
	Approach	Duration	Objective	
Kramarski and Michalsky, 2009	Modeling metacognitive self-questioning	3 out of 56 hours of total training	Metacognitive self-questioning	Supported SRL conditions outperformed the unsupported condition on all professional growth measures
Lewis et al., 2011	Integrating reflective prompts into the course assignments	96 hours	Understanding of some flooding concepts	Self-regulatory learning prompts supported teachers' learning
Michalsky, 2012	Embedding self-questioning prompts into instructors' teaching guides and written tasks	6 hours out of 23 hours	Problem-solving processes	SRL-scaffolding conditions outperformed the un-scaffolded condition on all

				professional growth measures
Michalsky and Schechter, 2013	Integrating systematic learning from problematic and successful experiences into the program	96 hours	Capacity to teach students SRL strategies	The teaching of SRL strategies and arrangement of SRL environments were improved
Kramarski and Michalsky, 2015	Applying SRL to Technological pedagogical content knowledge (TPCK) by using the TPCK-SRL model in a hypermedia environment	56 hours	Pedagogical beliefs, technology self-efficacy, TPCK-based lesson design	Adding the SRL model to TPCK practice enhanced teachers' ability to transfer knowledge gained in training to the design of TPCK-based lessons
Eilam, 2017	Including lesson planning-monitoring scaffold, monitoring of plans' enactment, and reflections on lessons' goal achievement	36 hours	Goal-directed lesson planning and monitoring	Teachers' metacognitive considerations and reflections on their planning and teaching were promoted, yet no substantial changes in enacting the lessons

Peters-Burton and Botov, 2017	Reflecting on teachers' learning processes	45 hours	Understanding of teaching Earth science content using scientific inquiry methods	Teachers improved their goal-setting skills, self-monitoring performance, and learning tactics
Kramarski and Kohen, 2017	Training the dual self-regulation roles using generic and specific prompts in the context of analyzing videotaped learning and engaging in videotaped teaching.	16 out of 28 hours of training	SRL practice as learners and as teachers	The specific-prompts condition outperformed the generic-prompts condition on self-awareness of own SRL, noticing authentic videotaped students' SRL, and explicit usage of SRL
Michalsky and Schechter, 2018	Integrating systematic learning from problematic and successful experiences into the program	96 hours	SRL-based lesson design	Preservice teachers who contemplated both problematic and successful experiences developed better SRL lesson-designing skills
Adler et al., 2019	Using metacognitive prompts to encourage monitoring and reflecting upon	Six months	Teachers' reflections on the dynamic	Metacognitive prompts focused teachers' attention on the

	learning and inquiry process		characteristics of open inquiry	characteristics of open inquiry
Barr and Askell-Williams, 2020	Engaging in a researcher-facilitated professional learning community	12 weeks	Teachers' epistemic cognition about SRL	SRL content knowledge, pedagogical content knowledge, and constructivist beliefs were improved consistently for three of the four teachers
Michalsky, 2020	Training in the professional vision for SRL mapping	12 weeks	Teachers' progress in mapping and teaching SRL	Professional vision for SRL and SRL teaching were improved. Hint prompts had a greater positive effect on both measures than guided or self-guided prompts
Peters-Burton et al., 2020	PD on argumentation in science and the use of SRL microanalysis	About 38 hours	Twelve sub-processes of self-regulated learning, adapted from Zimmerman, 2000.	Teachers who were able to use SRL strategies had deeper learning outcomes and created lesson plans that engaged students in higher levels of argumentation
Porter and Peters-	Teaching the processes of Zimmerman's model	32 weeks	Supporting students' SRL development	The teachers largely used the SRL coaching strategies of observation

Burton, 2021	of SRL and how to support student SRL processes			and emulation, but did not often encourage students to use self-reflection

Contribution to the teaching and learning of science

Providing science teachers with SRL PD improves both their learning and teaching that should contribute to their students' learning. All the SRL PD we reviewed showed positive effects on the participants: supporting teachers in learning new science concepts, improving teachers' arrangement of SRL environments, enhancing knowledge transfer, promoting teachers' SRL skills, fostering constructivist beliefs, increasing lesson-designing skills, and developing science teachers' ability to teach students SRL strategies. However, the relatively small number of studies on SRL PD over the past three decades shows PD programs in science education do not emphasize the concept as much as they should.

The studies reviewed show that SRL supports science teachers' learning (e.g., learning new science concepts, enhancing knowledge transfer, and fostering constructivist beliefs) and teaching (e.g., arrangement of SRL environments, increasing lesson-designing skills, and developing the ability to implement SRL processes). Teacher questioning is an important aspect of science teaching because teacher questions affect different aspects of learning outcomes. However, none of the studies leveraged SRL to improve science teachers' questioning skills. Thus, this dissertation study integrated SRL into professional learning and coaching during student teaching for PSTs to improve their questioning skills.

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CHAPTER 2

COACHING DURING STUDENT TEACHING: USING SELF-REGULATED LEARNING TO IMPROVE PRESERVICE SCIENCE TEACHERS' QUESTIONING SKILLS

To be submitted to *Journal of Science Teacher Education*

Abstract

Although student teaching plays a crucial role in teacher preparation programs, very little of the research on student teaching examines features of the experience that create a positive impact for science teacher candidates. This multi-case study adds to the body of research on student teaching by presenting findings of a teacher preparation program that integrated self-regulated learning into professional learning (PL) and mentoring to optimize preservice science teachers' (PSTs) asking question competence. The PL and mentoring during student teaching contributed to PSTs' improvement in different aspects regarding asking higher-level cognitive questions. Mentoring enhanced PSTs' application of strategies they were taught in PL, and learned more from the act of teaching.

Keywords: Student teaching, asking questions, self-regulated learning, mentoring/university supervision, preservice science teachers

Introduction

Student teaching is the final clinical experience where teacher candidates are provided opportunities to develop and demonstrate teaching competencies in real classrooms to determine whether the candidate will be recommended for certification as a licensed teacher (Greenberg et al., 2011). Student teaching often plays the role of bridging academic coursework and the realities of classroom teaching (Kagan, 1992a). A uniformly strong student teaching experience has the power to dramatically improve the vision of teaching excellence and foster effective instructional techniques (Greenberg et al., 2011). New teachers state that student teaching is the most important part of their teacher preparation programs (Levine, 2006). Although student teaching plays a crucial role in teacher preparation programs, very little of the research on student teaching examines features of the experience that create a positive impact on science teacher candidates (Greenberg et al.,

2011). Institutions understand the importance of student teaching, but they feel powerless to make it better (Greenberg et al., 2011). This study seeks to understand using self-regulated learning (SRL) processes to optimize asking question competence for preservice science teachers (PSTs) during student teaching; thus, contributes to the area of science teacher preparation by providing insights on how to ensure the quality of student teaching and better prepare teacher candidates for the profession.

Teacher Questioning

Science teachers are expected to facilitate students to work with and learn with their peers (National Research Council, 2012; Wells & Arauz, 2006). One way that helps science teachers meet this expectation is to improve the questions they ask students (Lee & Kinzie, 2012; Resnick et al., 2010). For example, studies show that teacher questions play a key role in student interaction during argumentation practice (Banilower et al., 2013; Chin, 2006; Chin, 2007). Similarly, Lustick (2010) found that teacher questions in inquiry-based instruction are to support student understanding as they participate in the process of scientific inquiry. Furtak (2006) stated that in inquiry classrooms, students need to self-direct their learning activities, so teachers need to withhold answers. Therefore, it is important for teachers to ask questions place students in a position to be responsible for doing the thinking (Koufetta-Menicou & Scaife, 2000; Van Zee & Minstrell, 1997). Unfortunately, many teacher questions are closed-ended and typically characterized by a lower level of cognitive demand, requiring students only to show that they remember the content presented to them earlier. Corresponding to the teacher questions, student answers are short and simple, and usually lists of learned facts (Parker & Hurry, 2007; Sedova et al., 2014). In other words, most teacher questions require students to recall what they have learned (Benedict-Chambers et al., 2017; Chin, 2007; Eshach et al., 2014; Morris & Chi, 2020).

Research has shown that to foster student understanding and achievement, teachers need to find the balance between lower-level cognitive and higher-level cognitive questions (Crawley & Krockover, 1979; Timmins, 1998). However, teachers often experience difficulties in asking higher-level cognitive questions and tend to pose shallow short-answer rather than deep long-answer questions (Chin, 2007; Dillon, 1988). More importantly, teachers do not often critically analyze their own questioning practices to determine the effectiveness of their questioning techniques (Sahin et al., 2002). During practicum, preservice teachers do not ask many questions, and the quality of the questions is low (Ahtee et al., 2011; Eshach et al., 2014). Furthermore, while teaching, student teachers often eliminate some of their challenging questions (Davis et al., 2016). Fortunately, research suggests that teachers' questioning behaviors can be improved through professional learning (PL), modeling, and appropriate practices (Lee & Kinzie, 2012). Teacher questioning competence needs to be taught in teacher preparation programs because the competence is not generated spontaneously (Joglar & Rojas, 2019). Reflection on teaching practice is also needed to optimize teacher questioning competence (Mellado, 2004; Vázquez et al. 2007). According to Napell (1987), teachers who have learned the skills of effective questioning are able to model how to acquire and classify information and think logically. They help students shift from passive classroom spectators to active, creative participants.

Self-Regulated Learning

SRL is a broad term that encapsulates different variables which influence learning (e.g., goal orientation, self-efficacy, metacognition, motivation, and strategic thinking and action (Panadero, 2017). In general, learners with high SRL skills are associated with higher learning gains (Azevedo & Cromley, 2004), while the opposite is true for less self-regulated students (Land & Greene, 2000). Students who can self-regulate their learning can benefit more from active learner-centered pedagogies like inquiry (Dent & Koenka, 2016; Manlove

et al., 2009; White et al., 2009). Teachers benefit from SRL as well (Dembo, 2001). Teachers need to be able to learn in and from practice since the knowledge to teach can hardly be fully obtained before or apart from practice (Randi, J., 2004). About seventy percent of teacher learning occurs through everyday learning (Fullan, 2007). Additionally, teachers work in a rapidly changing environment and need to continuously update their teaching skills (Randi, Judi, Corno, & Johnson, 2011). SRL skills not only contribute to the attainment of teacher learning goals, but they also affect the process of improving teaching (Van Eekelen et al., 2005). Hence, teacher programs should not be limited to transmitting subject-matter knowledge and pedagogical knowledge using predefined, fixed methods, but rather should find ways to construct knowledge through SRL (Kramarski & Michalsky, 2009). Such programs should afford opportunities for developing practices associated with supporting SRL, as well as developing knowledge and skills that will enhance teachers' self-regulation in their own learning and in their teaching (Perry et al., 2006; Randi, J., 2004; Randi, Judi & Corno, 2000).

Rather than waiting until ineffective strategies have been adopted, it is recommended to start SRL promotion early on in teacher preparation programs. Likewise, teachers should be offered plenty of opportunities to develop self-regulation capacities and student-centered beliefs about teaching before entering practice (Kramarski & Michalsky, 2009; Randi, J., 2004). Teacher professional development programs that include the promotion of teachers' SRL have shown to have a positive impact on student teachers' comprehension and design of lesson plans, classroom performance, creative problem-solving capacities, internal locus of control, professional growth, student-centered beliefs of teaching and learning, and the promotion of students' deep understanding and SRL (Delfino et al., 2010; Dembo, 2001; Kramarski & Michalsky, 2009; Perry et al., 2008; Randi, Judi et al., 2011). Moreover,

traditional teacher tasks such as lesson plans and assessments can also facilitate teachers' own learning and self-regulation (Randi, J., 2004; Randi, Judi et al., 2011).

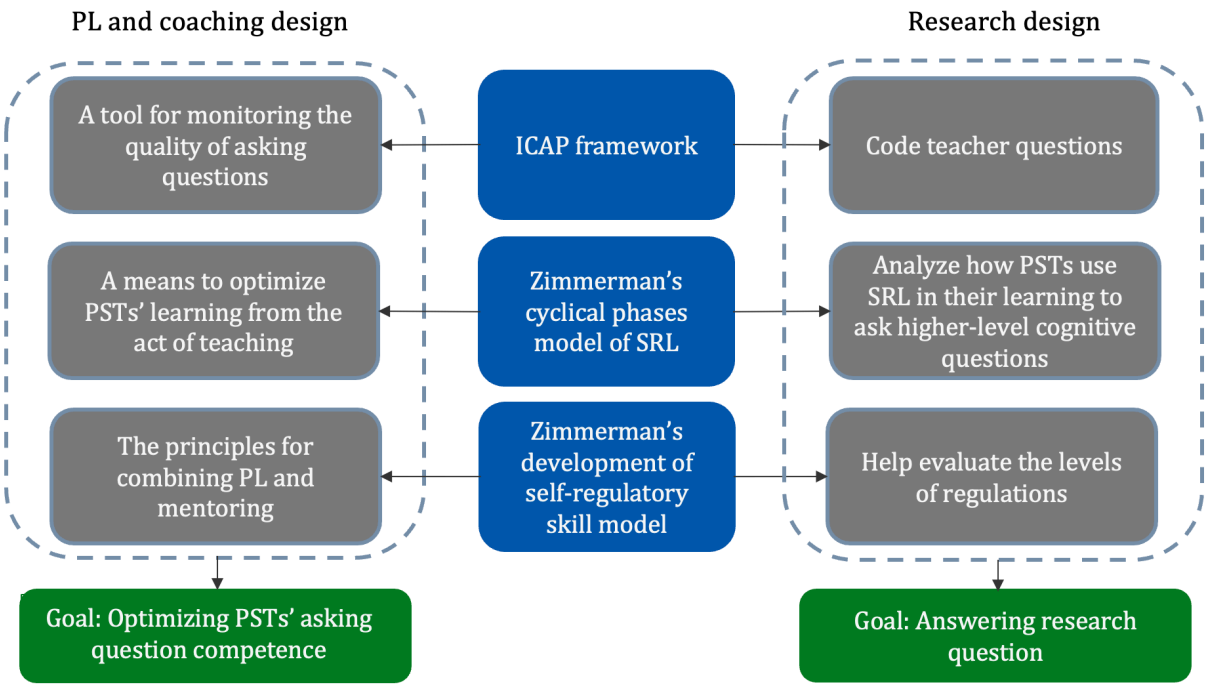
As a potential means for enhancing science teachers' asking question competence, we integrated SRL into a secondary science teacher preparation program and examined the effects of the integration by answering the research question: In what ways, if any, does using SRL processes in coaching PSTs during student teaching contribute to their growths in asking questions?

Theoretical Framework

The study is framed by three theoretical frameworks: the Interactive, Constructive, Active, and Passive (ICAP) framework of cognitive engagement (Chi & Wylie, 2014), Zimmerman's cyclical phases model of SRL (Zimmerman, 2000; Zimmerman & Moylan, 2009), and Zimmerman's development of self-regulatory skill model (Zimmerman, 2002). Figure 1 summarizes how these three frameworks inform both the PL and coaching design as well as the research design of this study.

Figure 1

Theoretical Frameworks that Inform this Study



Interactive, Constructive, Active, and Passive (ICAP) framework of cognitive engagement

The ICAP framework includes four modes of student engagement: interactive, constructive, active, and passive (Chi & Wylie, 2014). Each mode of engagement goes with a knowledge-change process, which leads to a certain cognitive outcome. Passive engagement leads to storing new information in an isolated way; thus, students can only recall the facts. Active engagement helps students integrate new information with activated prior knowledge, leading to the ability to apply the knowledge in similar situations. Constructive engagement supports the inference of new knowledge from activated and integrated knowledge, which allows students to extend what they have learned to new contexts. Interactive engagement fosters students' ability to co-create because students need to exchange constructive ideas with their peers.

There are four types of cognitive questions that align with the four modes of engagement. Passive questions are those that do not expect learners to verbalize an answer; for example, "So… where's the gene? It's on the chromosome, right?" Active questions ask learners to recall information from background knowledge or previous lessons; for example,

"Who remembers what we talked about yesterday with predator and prey, about the relationship between predator and prey?". Constructive questions ask learners to go beyond the presented materials; for example, "What will happen to the mice that have the mutation described in the text?" (Morris & Chi, 2020). Interactive questions are those that require students to exchange their constructive ideas with a partner(s) (Chi & Wylie, 2014). One example of interactive questions is when students are asked to mutually exchange ideas with another student on "What real-world applications are there for Phylogenetic tree?". Thus, asking constructive questions and interactive questions are preferred in terms of stimulating student thinking. This framework was introduced to PSTs as a tool for monitoring the quality of their questions because the defining characteristics of constructive and interactive questions in ICAP are easier for teachers to utilize compared to other question typologies (Morris & Chi, 2020). The framework was also used to develop a coding scheme to analyze teacher questions.

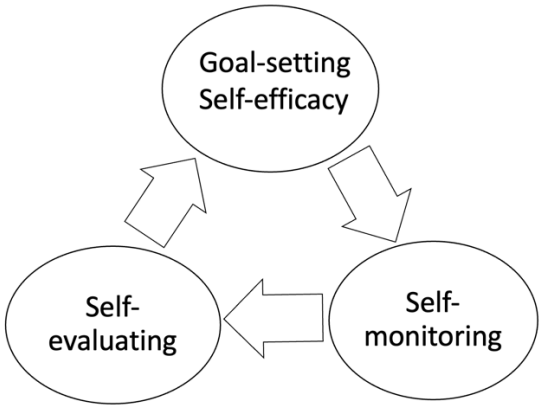
Zimmerman's cyclical phases model of SRL

Zimmerman's cyclical phases model of SRL consists of three phases: forethought, performance, and self-reflection (Zimmerman, 2000; Zimmerman & Moylan, 2009). In the forethought phase, learners analyze their learning tasks, set goals, and plan to achieve the goals. Learners' self-motivation beliefs affect the way they set goals and plan for their learning. The self-motivation belief this study focused on is self-efficacy, which refers to one's judgment of their ability to perform a certain task (Tschannen-Moran et al., 1998). Teachers' self-efficacy affects the way in which they approach the task (Trentham et al., 1985; Tschannen-Moran & Hoy, 2007). During the performance phase, learners use different strategies to monitor their learning process. The self-reflection phase is when learners evaluate their performance and identify possible causes of their learning outcomes. The way learners attribute their success or failure affects their motivation and learning behaviors in the

next SRL cycle (Zimmerman & Moylan, 2009). The study focuses on goal setting and self-efficacy in the forethought phase, self-monitoring in the performance phase, and self-evaluating in the self-reflection phase (Figure 2). This framework was included in the SRL PL and coaching for PSTs. It was also used while analyzing data from the interviews.

Figure 2

Zimmerman's Cyclical Phases Model of SRL



Zimmerman's development of self-regulatory skill model

There are four levels of self-regulation in Zimmerman's development of self-regulatory skill model: observation, emulation, self-control, and self-regulation (Zimmerman, 2002) (Table 1). At the observational level, learners need the presence of models and vicarious reinforcement. The emulation level of regulation is attained when learners approximately duplicate the general form or style of a model on a similar task. That is, learners primarily emulate the strategic features and blend them into their own way. Learners' accuracy and motivation to emulate are enhanced if they receive guidance, feedback, and social reinforcement (Zimmerman, 2002). To acquire the self-controlled level, learners must practice what they have learned in structured settings outside the presence of models. At this level, learners who focus on fundamental processes or techniques rather than on learning outcomes are more successful in achieving automaticity (Zimmerman & Kitsantas, 1997). To accomplish the self-regulated level, learners should practice in unstructured settings. At this

level, learners can practice with minimal process monitoring so their attention can be shifted toward performance outcomes without detrimental consequences. The self-regulated level is acquired when learners can adapt their performance to changing situations (Zimmerman, 2002). The existing study's approach, which includes both PL and coaching, was designed based on this theoretical framework. The PL targeted observation and emulation level of regulation. Then, coaching focused on emulation and self-control level of regulation with the goal that at the end of the program, the PSTs could move to the self-control or self-regulated level. We also used this framework to evaluate the level of regulation in learning from the act of teaching the PSTs reached at different times during student teaching.

Table 1

Social and Self-Sources of Regulation

	Features of regulations			
Levels of regulations	Sources of regulations	Sources of motivation	Task conditions	Performance indices
Observation	Modeling	Vicarious reinforcement	Presence of models	Discrimination
Emulation	Performance and social feedback	Direct/social reinforcement	Correspond to models	Stylistic duplication
Self-control	Representation of process standards	Self-reinforcement	Structured	Automatization
Self-regulation	Performance/ outcomes	Self-efficacy beliefs	Dynamic	Adaptation

Professional Learning and Coaching

Asking good questions is difficult to be mastered; thus, our study combined PL and coaching to support PSTs in developing the competence. The PL directly teaches PSTs about SRL and teacher questioning both theoretically and practically to provide them with the knowledge foundation and a tool to learn more by themselves. That tool is SRL processes. Upon completion of the PL, the PSTs should (1) be familiar with SRL processes, (2) have a good understanding that not all classroom questions are the same, and (3) be able to classify the four types of cognitive classroom questions according to the ICAP framework. Coaching facilitates PSTs learning from the act of teaching during student teaching. The PL happened during the Fall of 2021. Coaching occurred in the Spring of 2022 during student teaching.

Professional Learning

When PL focuses on broad principles, teachers will have the foundational knowledge of the concepts, but broad principles are insufficient to support classroom implementation. While concrete strategies can help teachers see the application of the principle in action, providing only concrete strategies does not allow teachers to make instructional decisions if the strategies are not meeting expectations (Marchand et al., 2022). The PL of this study provided PSTs with both broad principles and concrete strategies. Lessons 1 and 2 provided PSTs with broad principles for SRL and teacher questioning. The last three lessons showed PSTs concrete strategies to implement some of the broad principles in the context of science teaching.

All the lessons were delivered face-to-face except the lesson “Teacher questions in the context of implementing computational thinking practices”; this lesson was delivered asynchronously online because the goal was to guide the PSTs to practice using SRL processes in learning by themselves. Below we discuss some details regarding each of the lessons.

SRL lesson 1 – How to become a self-regulated learner

This lesson started with five Kahoot questions that severed two purposes – engaging PSTs and formative assessment (check to see how much the PSTs get out of reading a book chapter assigned to them prior to the lesson). Then the instructor showed them two different definitions of SRL. The instructor emphasized the common points of the two definitions and then asked the students to define SRL in their own words. All PSTs answered on Slido.com, so the class went through three of the PSTs' definitions that reflect the essence of SRL. After that, the instructor discussed with the students the reasons for promoting SRL. The instructor first provided reasons from the SRL literature, then showed them a four-minute video and asked questions regarding the reasons for promoting SRL mentioned in the video. The instructor also gave them a real-life example of how SRL can be applied in various situations. After PSTs understood what SRL is, and why promote SRL, the instructor discussed with them why this lesson is for them as a learner. Then, PSTs answered a recap question to check their understanding.

In the next section, the class discussed the three components of SRL: metacognition, motivation, and strategic thinking and action. The instructor showed PSTs two definitions of metacognition, one formal and one informal, but easy to remember. After that, the instructor used a metaphor (the general and the soldiers) to explain the differences between metacognition and cognition. To check students' understanding, the instructor reminded them of three types of knowledge (propositional knowledge, procedural knowledge, and conditional knowledge) and asked: "In which type of knowledge does metacognition involve more?" For motivation, the instructor asked two questions "How to increase our motivation for doing things?" "Which option is the most doable one? Why?" and showed a concept map of motivational constructs such as need, task value, attribution, and self-efficacy. The class discussed the links between the concepts before PSTs answered the two questions above. The

emphasis the instructor did regarding motivation was the positive feedback loop at the center of the concept map (i.e., motivation follows action). For strategic thinking and action, the instructor discussed the roles of strategies, distinguished task strategies from SRL strategies, and emphasized the importance of flexibility in strategy use.

The instructor introduced the three-phase model of SRL. The class formed six groups, and PSTs had 10 minutes to discuss in their groups some examples of how they use SRL processes in their learning. Each group shared their examples. Then, we discussed most of the subprocesses in the three-phase model: task analysis, goal setting, strategic planning, self-motivation, environmental structuring, attention control, self-monitoring, help-seeking, and self-reflection. The focus was self-questioning strategies for each SRL process and subprocesses. For each of the subprocesses, the instructor discussed with the PSTs what it was and provided some relevant content. The instructor asked PSTs to come up with self-questioning questions that might support them in each of the subprocesses and provided them with some more questions from the SRL literature. For example, the self-questioning questions for self-monitoring the instructor provided to the students were:

- Am I making good progress toward my goal?
- How well are my strategies working?
- What changes in strategies should I make, if any?
- What material is the most important?
- What material am I having trouble understanding?
- How does what I am learning relate to what I already know?
- How is my thinking on the topic changing?

The last section of this lesson was about the characteristics of self-regulated learners. The instructor showed PSTs a table in a book chapter they read that included some characteristics of self-regulated learners. Then, we formed six groups to discuss the listed

characteristics and find five more. The instructor ended the lesson with a question that asked students three take-away points from the topic. After this lesson, the instructor read and gave feedback on all PSTs' writings for their assignment.

Teacher questioning

This lesson was created with the objective of helping PSTs reduce the number of fact-recalling questions and increase the number of higher-level cognitive questions. The lesson included five sections. First, the class discussed the roles of teacher questions in terms of the amount of school time occupied with question-and-answer recitations, teachers' quality, and the purposes of asking questions. Then, the PSTs were asked to distinguish good classroom questions from bad classroom questions.

Second, the class discussed the ICAP framework for questioning. The instructor introduced the framework to the PSTs and emphasized the relationship between teacher questions and students' cognitive outcomes. The instructor explained each type of question by providing the definition and two examples. Then, the instructor linked the four types of questions with other terminologies (e.g., active learning, hands-on learning, minds-on learning) to help PSTs see the big picture. The most important point of this section was using the ICAP framework as a tool for monitoring the quality of asking questions. The instructor let PSTs practice doing this by showing them a six-minute video of a science teacher teaching in the classroom. The PSTs were provided the transcripts of the video and asked to classify the questions based on the ICAP framework. Then, the PSTs shared with the whole class how and why they classified the questions the way they did, and what they learned from the teaching in the video. The main point of watching the video was to show PSTs that even though the teaching seemed to be good at first, most of the questions the teacher asked were factual recall questions, so they need to pay attention to the quality of questions they ask in the classroom.

Third, PSTs had a group discussion (six groups, 10 minutes) about other types of questions. After PSTs shared about other types of questions they could think of, the instructor showed them a few other types of questions. Then, the instructor focused on three types of questions: questions that elicit student ideas, questions that probe student ideas, and questions that challenge student thinking. While explaining each type, the instructor discussed the purpose, the features of those questions, when to ask them, and examples of the question type. The instructor also asked PSTs to use the ICAP framework to rename those questions (mapping those questions to the ICAP framework). Then, the instructor gave each PST a worksheet that contained a classroom dialogue between a teacher and two students. The instructor asked the PSTs to classify the questions in the dialogue in two ways (elicit, probe, or challenge and ICAP). This activity was to help PSTs better understand the overlap among different question classification systems. More importantly, doing so could help PSTs see how teachers build their questions on each other and move from active questions to constructive questions (elicit to probe and then to challenge).

Teacher question construction was the next section of this lesson. We discussed question design tactics for directing attention, stimulating cognitive, and promoting productive discussion. Finally, the instructor briefly discussed with the PSTs four other relevant topics: planning for productive questioning, dealing with answers, dealing with students' questions, and feedback for students. PSTs reviewed the major points of this lesson by answering five questions on Kahoot.

Asking questions in the context of implementing data practices

The main goal of this lesson was to show PSTs how to ask constructive questions in the context of implementing data practices. The instructor explained the definition of data practices and each of the data practice (create, collect, prepare, visualize, analyze, and interpret). The instructor asked questions to help PSTs link this lesson with an assignment

they had just submitted in which the PSTs designed a lesson that engage K12 students in data practices. Then, the instructor introduced a context of a biology lesson to the PSTs, which focused on factors that affect the rate of enzymatic reactions. The PSTs formed six groups; each group worked on one data practice. The PSTs were asked to come up with questions teachers could ask in the classroom while implementing the practice. After 10 minutes, the instructor provided each group with a list of questions from a journal article (Peters-Burton et al., 2020) to compare with their questions before they shared with the whole class. The instructor asked PSTs to use the ICAP framework to classify the questions they shared. The instructor discussed with PSTs to show them that the questions they shared with the class were transferable, which means they could use the questions when implementing data practices in other contexts (not only for the biology lesson). After that, the PSTs answered five questions on Kahoot to review what they had learned. The instructor ended the lesson by recapping take-away points and highlighted the role of asking higher-level cognitive questions in engaging students with scientific investigations.

SRL lesson 2 - How to foster SRL skills in students

The instructor started this lesson by showing students the links between the concepts they had learned so far (SRL unit 1, teacher questioning, data practices) and the concepts they would learn next (SRL unit 2, computational thinking practices). Then, the class went through five main sections of the lesson. First, the instructor asked a few questions regarding a book chapter the students were assigned to read before class (Cleary, 2018, chapter 9). The book chapter discusses the reasons for fostering students' SRL skills and strategies to do so. Second, the instructor introduced Zimmerman's development of self-regulatory skill model. This model helped PSTs understand that students at different levels of regulation need support differently. The model also showed general strategies to foster students' SRL skills.

Third, we discussed asking questions as a strategy to foster students' SRL skills. This was the focus of this lesson. We formed six groups to discuss and write down questions to ask students in each phase of SRL (forethought, performance, reflection). Many of the questions PSTs came up with were from modifying self-questioning questions that they learned from the first SRL lesson. And this met the lesson's intention. The instructor wanted to reinforce PSTs' understanding and show them that the questions they had learned could be modified and used for different purposes. Fourth, students worked in groups to analyze a lesson plan (Cleary et al., 2018) for strategies to foster students' SRL skills. Then, they shared what they found with the whole class.

Fifth, in the last section, PSTs were asked to put all that they had learned together to analyze strategies in a video of a science teacher teaching. The instructor gave students two questions (Which SRL skills did the students need to do well in the classroom? What did the teachers do to foster SRL skills in their students) and showed them a 12-minute video. The video showed good science teaching that required high students' SRL skills. Then, the PSTs discussed in their group to answer the questions and shared with the whole class. The instructor recapped the main strategies the teachers used and showed the video again. During the second time watching the teaching, the instructor stopped and pointed out the main strategies. The instructor ended the lesson by asking two reflection questions to ensure PSTs understood the key points. The assignment for this lesson was to integrate SRL strategies into their lesson plan for practicum.

Asking questions in the context of implementing computational thinking practices

The goal of this lesson was to give PSTs an opportunity to use SRL processes in their learning. PSTs spent about one hour taking this lesson asynchronously. The lesson was designed to help students learn about how to use computational thinking practices to support data practices. The strategy we focused on was teacher questioning – how to ask questions

that make students think and apply computational thinking practices. The reason the instructor chose this topic was that most of the questions teachers ask in this context were constructive questions. The main ideas for this lesson were from Peters-Burton and colleagues' paper (2020). Before studying computational thinking, the PSTs answered some questions regarding their prior knowledge of this topic. During the lesson, there were four SRL questions that aimed to make them apply SRL processes in their learning. Then, at the end of this lesson, they answered some questions to evaluate their understanding.

Coaching During Student Teaching

Research on teacher questioning show asking productive classroom questions is not a skill that many teachers master. Therefore, after getting the PL, this study offered PSTs coaching, which was designed based on suggestions from previous studies on teacher questioning PL. For example, Crawley and Krockover's study (1979) concluded that PL for asking different types of questions needs to be more holistic in nature. This might be accomplished by directly involving university supervisors in the work. With the aid of observations made while the student teacher conducts class, valuable comments, suggestions, and encouragement could be offered immediately after the lesson. Not only would this promote the goals of the teacher preparation program, but it would convey to the student teacher that teaching is truly a growing, learning experience. Boyd et al (2009) found that the most effective student teaching supervision consists of five observations with one visit every two to three weeks.

The first author worked as a student teaching supervisor during the Spring 2022 semester and conducted five observations with each participant. The supervisor aimed to spread the observation evenly over 12 weeks. The PSTs could ask the supervisor for assistance and feedback anytime during the semester. Before the observation, the PSTs sent their lesson plans and instructional materials to the supervisor. The supervisor examined the

plans and materials and gave feedback and suggestions as needed. After each observation, the supervisor had a post-observation discussion (10 to 20 minutes meeting) to (1) learn how the PST felt about their teaching, (2) prompt the PST to think and learn more from one's own teaching, (3) collaboratively analyze and evaluate the instruction, (4) give feedback and suggestions, and (5) determine an action plan of next steps for the PST to implement. Two post-observation discussions were about all aspects of the teaching, including asking questions. In three other meetings, when there was an interview after the teaching, the discussions were about all aspects of the teaching except SRL and asking questions (feedback on those two areas was given after the interviews). Additionally, part of the interview questions before and after three lessons are SRL microanalysis questions (Cleary & Platten, 2013)that were useful in eliciting learning processes for the PSTs and provided opportunities for them to reflect on their SRL practices (Peters-Burton et al., 2020). Furthermore, conducting structured interviews with preservice teachers can improve their questioning skills (Jenkins, 2010; Moyer & Milewicz, 2002).

Method

This research is a multi-case study (Yin & Campbell, 2018) using multiple analysis methods. The analyses focus on exploring the experiences of three PSTs representing high, intermediate, and low self-regulated PSTs to understand how integrating SRL into PL and coaching helped improve their competence in asking higher-level cognitive questions.

Participants

To represent variance among PSTs, three participants were purposefully selected from 18 PSTs enrolled in a certification program for teaching secondary science. The participants represent low, intermediate, and high self-regulated PSTs. Table 2 shows the rubrics for participant selection.

Table 2

Rubrics for Participant Selection

	High self-regulated learner	Intermediate self-regulated learner	Low self-regulated learner
Survey score Reflection writing	Upper 25% Saw themselves as a good self-regulated learner	Middle 50% - Saw themselves as an average self-regulated learner - Or good at one aspect of SRL but not the other - Or try to self-regulate their learning sometime, but not often very effective	Lower 25% Did not see themselves as a good self-regulated learner
Observation during Fall 2021	- Did not submit their assignments late (except for special circumstances) - The quality of their work was high most of the times - If they got feedback on improving something, they would significantly improve it the next time	- Submitted their assignment late once or twice - The quality of their work depended on the topic (good or quite good), but it was always higher than average. - Improved most of the points they get feedback on	- Submitted their assignment late more than twice during the semester without special reasons - Their work often did not meet all the requirements - Did not improve their work's quality

	much after getting feedback

Context of the Study

The main content subject of the three selected participants is biology and they all taught grade 9 and 10 honors biology. Alex, the high SRL PST, was assigned to teach in a biology classroom as his main classroom. Alex also taught in an environmental science classroom as his minor student teaching assignment. During the first ten weeks of student teaching, in the environmental science classroom, Alex only observed the mentor teacher teaching. Then, he was allowed to design and teach. The two other participants taught only in biology classrooms. In their biology classrooms, all three participants were allowed to teach from the first week of their student teaching. And all the observed lessons were biology, except the last observation of the high SRL case, which was environmental science for grades 10 to 12.

The participants' reasons for participating in the study were somewhat overlapped. Alex said he appreciated the researcher's instruction and help during the Fall semester, was interested in helping with research, and knew that it was not easy to recruit participants. Mia, the intermediate case, gave four reasons: (1) her interview time would be compensated, (2) she would be observed with or without participating in the study, (3) it was hard to recruit participants for studies, and (4) the participation did not require much commitment. Ara, the low case, said the compensation for her interview time was the main reason she agreed to participate in the study.

The three participants were placed at three different secondary schools in three different districts. The quality and standards at those schools were comparable. All three participants said that their mentor teachers were supportive and allowed them to design and

teach the lessons the ways they wanted. The mentor teachers were also willing to provide feedback, materials, and equipment when requested.

During student teaching, the university supervisor did not see Alex show any worries regarding his content knowledge. Mia mentioned twice talking to her mentor teacher to double-check a point in the lesson to ensure she did not say anything wrong in her teaching later. Ara mentioned two or three times that she focused on delivering the science content correctly. Ara also mentioned practicing her lesson the night before her observation to ensure she remembered all the scientific concepts.

Student teaching took place in the Spring of 2022 when students came back to school after the pandemic. Since a few students had to be absent some time, the number of students in each class fluctuated more than normal. Thus, the average number of students in the classrooms was 20 (ranging from 15 to 27). Alex and Mia's classes were 55 minutes. Ara's classes were 90 minutes. However, due to administrative reasons (i.e., school announcements), the actual class time was a little shorter for a few observed classes. Thus, we used the actual class time when calculating the number of questions per minute for each lesson.

Data Sources

Research data were collected from multiple sources as part of the effort to minimize bias in the study.

The Effects of Coaching

The primary data sources regarding the effects of coaching were interviews and classroom observations. Semi-structured interviews about planning the lesson were conducted to gather data about how the PSTs used SRL processes while planning the lesson and their planned questions. These interviews were conducted after the PSTs completed their lesson plans (before the teaching). Classroom observations helped researchers get a

sense of the context of the classroom and what the teaching entailed. During classroom observations, the researcher took notes of the discourse and activities in the classroom. Within 24 hours after the lesson, the researcher conducted interviews with the PSTs to understand how they thought about the questions they asked during the instruction, why they asked the questions, and how they used SRL processes while teaching. Interviews followed Patton's (1990) recommendations for standardized, semi-structured interviews. However, the interviewer was flexible about the follow-up questions based on the participants' responses. The interviewer asked probing questions to get participants to elaborate on some aspects of their answers. After each interview, the researcher typed an interim case summary as the first attempt to drive a coherent, overall account of the case.

Teacher Questioning

Data for teacher questioning were primarily collected via classroom materials and audio recordings. Classroom materials (lesson plans, slides, worksheets, etc.) of the first, middle, and last lesson of student teaching were collected and examined before the first author observed the PSTs teaching the lessons. Those materials and other data sources helped determine whether the content was explicitly provided to the students; this information was necessary to code the types of questions the PSTs asked. Audio recordings of the teaching were also collected.

Data Analyses

Inductive thematic analysis was used to analyze how coaching contributed to the PSTs' learning from the act of teaching. We conducted two coding cycles. The first cycle used in vivo coding, and the second used pattern coding (Miles et al., 2014). First, a content analysis was conducted to identify relevant sections that emerged from the interview transcripts. We began by reading the transcripts to familiarize ourselves with the PSTs' ideas. We then re-read each of the transcripts to identify sections that might help answer the

research question. After identifying the relevant sections, we copied and pasted them into a spreadsheet for analysis. We read each participant's sections, added a separate column next to the content, and conducted in vivo coding by using short phrases from the participants' language in the data record as codes. The codes reflected the participants' descriptions and explanations of what they learned from student teaching and/or how coaching supported their learning. Then, we conducted pattern coding and identified sample responses for each theme (Miles et al., 2014). We placed the codes on a spreadsheet and grouped them based on the meaning of the perspectives/practices. Using the groups of codes, we searched for themes across all three cases. In developing these themes, we aimed to stay as close to their sentiments as possible. Then, we reviewed the themes and named them in ways that covered all the sub-themes (i.e., reorganized themes and sub-themes). We also returned to the transcripts to find sample responses for the coding categories.

Classroom recordings were transcribed using Otter.ai. Once transcribed, the questions were coded as either interactive, constructive, active, or passive according to a coding scheme developed based on the ICAP framework (Chi & Wylie, 2014). After that, the total number of questions and the percentage of each type of questions was calculated. Two coders co-coded the data, and all disagreements in coding were resolved through discussion.

Findings

Coaching during student teaching contributed to the PSTs' improvement in different aspects of asking questions (e.g., perceptions regarding planning questions, self-efficacy for asking questions, and quality of asking questions). Below we present the findings regarding those professional growths.

Coaching Enhanced PSTs' Understanding and Promoted Application of Strategies They Had Learned from the PL

While Alex remembered concepts he learned from PL and tried to apply them in his teaching, Mia and Ara needed prompts to recall what they had learned and needed guidance to apply the strategies in their teaching. Responding to the question, are there any topics you learned that help you with questioning? Alex said,

> "I like to think about the ICAP framework when I think about questioning. I think that there's some things some teaching strategies that are brought up in academia that don't you don't see them play out in the classroom very often, a lot of times just because the logistics of the classroom or the school, but I kept questioning, I feel like it's one where you can incorporate higher level questions into every single lesson no matter what. It's not always feasible to fit in maybe inquiry less than a lesson plans into every lesson, it's ideal, and I think it could be done. But sometimes you might not have the time as an instructor or incorporating lab work. But I think that you can almost always incorporate ICAP questioning into your content. And so that's a piece of, I guess, research that I use when I think about questions because I try to ask all types of questions except passive questions, but especially focus on constructive questions because I want them to come to discoveries by themselves, as opposed to learning about cool things through a textbook. I want them to learn about cool and interesting things because they're capable of knowing them and figuring them out given evidence" (Alex, first teaching interview).

So, Alex remembered the ICAP framework and the type of higher-level cognitive questions. He also mentioned that he aimed to ask constructive questions and avoid passive questions. Below is another quote that shows Alex understood the ICAP questions and used the framework the way it was supposed to.

> "I did use the ICAP framework in my questioning and in the questions that are written down for them in the lab… Because in group work, I wanted to focus a lot on I

> [interactive] questions. And then I always aim for C [constructive] questions where people are constructing their own knowledge. That's different from just what the text says, are different from memory recall of what the text says" (Alex, second planning interview).

Unlike Alex, Mia and Ara remembered some ideas about good questioning from PL, but they did not use the ICAP framework until the supervisor prompted them. The second teaching interview was the first time Mia mentioned the names of the questions based on the ICAP framework without any prompts (in the first teaching interview, Mia did not remember the four types of questions, and the supervisor reminded her). She said, "When I was in the little [small] groups, I kind of guided them to the right answer by asking small. I guess they would be active questions, just recalling the information to help them get started answering my more constructive question" (Mia, second teaching interview). When asked to elaborate on the usefulness of the ICAP framework, Mia said, "that helped me because I do kind of want to stay away from the passive… it helped me focus more of my time on the constructive and interactive. And purposely put more emphasis on the higher-level questions" (Mia, first teaching interview).

Ara did not remember the SRL processes. In the first planning interview, when the interviewer mentioned SRL, she opened the documents about SRL that she got from PL to remind her of the concept. So, the interviewer gave her a summary of the SRL lessons and examples of strategies for different SRL processes. Similarly, Ara did not remember the four types of teacher questions in the ICAP framework. But she could recall them quickly when the interviewer reviewed the question types with her.

Coaching supported PSTs Realized Asking Good Questions Requires Planning

At the beginning of student teaching, all three PSTs thought teaching experience alone would help improve their question-asking competence. For example, Alex said, "it's a

trial-and-error process". Alex also added, "I think that I've practiced teacher questioning a lot… I've practiced by just throwing myself into it and failing at times, like asking a question to a blank face and then just giving up and saying the answer." However, Alex did plan his classroom questions before his teaching.

Ara thought that practicing in the classroom (without planning questions in advance) would help improve her competence in asking questions. Ara said, "I really feel like this is a skill that is best learned with practice… I think just experience would be like my best friend here in actually it like improving this skill" (Ara, first planning interview). She also emphasized that she thought she would ask better questions just by being more comfortable in the classroom: "So my main goal is to just get more comfortable [in the classroom]... So, I think, um, that [asking good questions] can be accomplished purely by just being in my place more and taking over the class more" (Ara, first teaching interview).

Later, the PSTs learned that without planning it was hard for them to ask good questions. Commenting on asking questions that were not planned before class, Mia said, "I don't think they were very good questions. I think it was more of like yes or no, low-level questions" (Mia, first teaching interview). Similarly, Ara said, "I did ask some additional questions, but they would have been of a very similar nature to the ones that I did write down like nothing I added nothing radically different" (Ara, first teaching interview). This shows that planning questions was helpful because even though PSTs did not exactly remember their planned questions, they asked similar questions.

Over time, the participants shifted from not paying attention to planning classroom questions in advance to appreciating the benefits of doing so. For example, in the first teaching interview, Mia said, "I think that going in with a plan to ask certain questions was a challenge." The response shows Mia did not have the habit of planning questions in advance

during her practicum and the first few weeks of student teaching (the first observation occurred in the third week of student teaching). After teaching the second observed lesson, Mia started seeing the benefits of planning questions. She said,

> “I realized it's worth putting thought into when you ask the questions. I need to put more effort into the front hand. Usually, I'm like, oh, I'll just go in and like see when it's good. But it's not fair to first period because first periods are like the guinea pig, and I feel like it's worth putting effort into planning when you question before you get any periods” (Mia, second teaching interview).

Thus, the second teaching interview was the point of change for Mia. In the first interview, she thought just more practice would help her get better at asking questions. At the second teaching interview, she appreciated the need to plan a little bit more and had a few more questions on hand. This shows the importance of planning questions in advance. Mia also thought that if she came up with questions in the classroom without planning, the questions might not be correct (in terms of content). She thought that to do better with questioning in her next teaching, she needed to (1) plan some more questions, (2) make sure the content of the questions is correct, (3) plan when to ask, and (4) word questions in different ways for different students. Mia added that she did not ask questions that were not in her lesson plans, and she knew how to use active questions to guide students to think about the answer for constructive questions: "I kind of just relied on the active questions to get their brains thinking, and then kind of prompted them to make some sort of connection. And then they were usually able to answer my constructive questions after that" (Mia, third teaching interview). The second teaching interview was also the first time Ara really practiced thinking about her questions, “this was this is my first real practice on thinking about my

questions… this was kind of the first time I had really sat down and thought about my questions" (Ara, second teaching interview).

Coaching Facilitated PSTs Become More Purposeful in Asking Questions

The PL and coaching supported the participants in planning and enacting classroom questions with a goal. For instance, Alex said coaching made him apply what he had learned at the university to teaching: "It [coaching] required me to call back on knowledge from block one a lot and make sure that my lessons and lesson plans are rooted in some sort of research-based pedagogy" (Alex, third teaching interview). In the third teaching interview, Mia got what the coaching aimed to make the PSTs realize. Mia realized (1) asking higher-level cognitive questions supports achieving learning objectives, (2) students can answer higher-level questions, (3) there should be a goal/reason for asking a certain question. She said,

> "I think I realized that it's important for me to challenge them more in that I wasn't necessarily hitting my learning objectives before either. Because the learning objectives are not just passive and active questioning a lot of the learning objectives and the GSC [Georgia Science Curriculum] and everything are like construct an explanation or like, give evidence for. And I feel like I wasn't preparing them to do that at the end of the unit. And with my questioning, I felt like they just kind of needed more of an open-ended question. And I wanted to kind of take my hands off a little more. I kind of realized, if I have higher expectations of the way they're going to answer my questions, they'll rise to those expectations. And yeah, I felt like they the act of question a lot of times were just, I wasn't really asking them for a reason. I was just asking them because I could and they knew it, and we were doing it. But there was like not a huge reason behind all of them. And the constructive questions. I felt

> like there was a better reason for them and it made them think harder and connect what they've learned from the past to now and actually build their own explanation about things."

Mia also said the study helped her to ask purposeful questions: "I learned how to ask purposeful questions, why am asking those questions... And how to specifically have a goal for my questions and regulate to achieve it. I would say like connecting my questioning with the learning objectives" (Mia, third teaching interview). Furthermore, Mia learned to connect her questioning with the learning objectives of the lesson, "And how to specifically have a goal for my questions and regulate like self-regulate my questioning. And with that, I would say like connecting my questioning with the learning objectives".

Ara also learned from coaching that she should be more purposeful with asking questions. She said,

> "I learned that, um, you should be more purposeful with it [asking questions] than I had initially thought going into teaching. I kind of thought it was a small, more natural just part of teaching that you just do automatically. And then I learned after failing at it a few times that no, okay, you need to be more. You need to plan it out. And although it won't come out the exact way that you've planned it. Planning that the act of planning really helps you do it, like more naturally" (Ara, third teaching interview).

Moreover, even though Ara refused to try some suggestions she received, she thought coaching was helpful in terms of helping her to be more purposeful in approaching teaching tasks and learning from her teaching.

> "I mentioned that a lot of what I learned was more about SRL, and like how that works. That really enabled me to be more purposeful in how I approached, like all of

> my teaching skills that I've been trying to develop it that really that act of learning how to learn, can be applied to so many different things that I would say, yes, this study did help because it helped me with SRL, which in turn helped me with learning everything that I've been trying to learn" (Ara, third teaching interview).

PSTs' Self-Efficacy in Asking Questions Increased

There was growth in the PSTs' self-efficacy in planning and enacting questions (Figure 3). For example, Mia rated her confidence in asking classroom questions as two out of five at the beginning and four at the end of the coaching. She said,

> "Two at the beginning because I felt like I naturally could ask questions in the classroom but didn't understand how to plan for it, and didn't understand what types are the best types of questioning… I definitely feel like I made a huge improvement in the way that I plan my questioning and the way that I organize it, and then the way that I actually implement it in the classroom" (Mia, third teaching interview).

Similarly, Alex said,

> "I would say, a two and a half at the beginning and a four now. I think that one definite, quantifiable thing that is improved about my questions is just my general confidence to ask questions. And my confidence to think that answering a question with a question is the right thing to do… And I'm more confident now to ask more targeted questions or build off of that question in case the initial thoughts aren't going well" (Alex, third teaching interview).

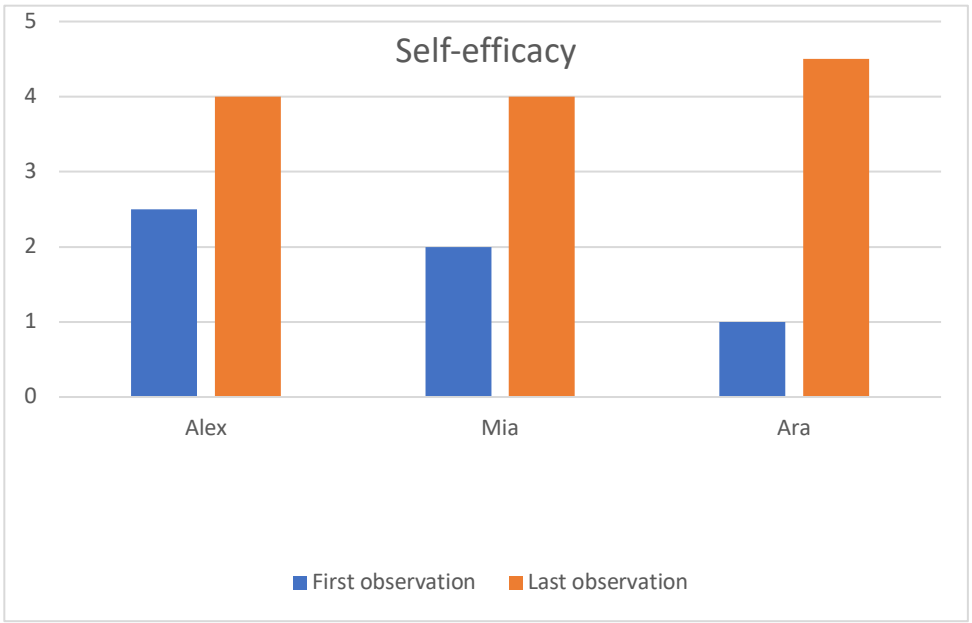
At the beginning of student teaching, Ara did not know much about teacher questioning. By the end of coaching, she felt more comfortable and confident in asking questions. She said,

> "It is definitely one I began with, I came in like not knowing anything… So I felt like I was new at this. I had a lot to learn. And then right now,…I certainly don't feel embarrassed to get up there and ask a bad question anymore. Um, if I ask a bad question, I really tend to look at it now like, Oh, oops, alright, let's try that again. Let's reroute that and figure out a different way to ask that" (Ara, third teaching interview).

Interestingly, Ara rated her confidence in asking questions at the end of student teaching even higher than Alex and Mia. It is worth noticing that Alex's and Mia's responses were based on their confidence in their ability to plan and enact high-quality questions. Whereas Ara rated based on her confidence and comfort in asking questions in the classroom regardless of the quality.

Figure 3

Change in PSTs' Self-Efficacy for Asking Questions



PSTs' Asking Questions Competency Was Enhanced

Overall, all the PSTs got better at asking questions. Over time, Alex asked many more interactive questions (increased from 1% to 14%). Mia asked more interactive (increased from 0% to 6%) and constructive questions (increased from 10% to 43%). Ara changed from turning her planned questions into explanations to being able to ask more questions during her lessons. Even though Ara did not do better with asking higher-level cognitive questions, she asked fewer passive questions (decreased from 43% to 20%). In addition, Alex implemented different instructional approaches (lecture, data collection, developing models) to practice asking questions in dynamic classroom conditions. Mia mostly lectured during the first two lessons, then integrated developing models in her third lesson (for 15 minutes). Ara mostly lectured in all three observed lessons.

Discussion

Our findings show that not all PSTs remembered and applied what they had learned from PL; thus, coaching was needed to enhance their understanding and application. Mia and Ara needed reviews to better understand SRL and the ICAP framework and needed prompts to apply the strategies in planning and enacting classroom questions. These findings indicated the need for coaching during student teaching. Besides giving feedback on PSTs' teaching, university supervisors should find a way to link their teaching with concepts taught in teacher preparation courses. This aligns with previous research that found beginning teachers often shift from idealistic notions of teaching to pragmatic approaches, which are often contradictory to the aims of many teacher preparation programs, because they are overwhelmed by the demands of the profession (Kagan, 1992; Wideen et al., 1998). Thus, university supervisors should support PSTs in balancing ideal teaching and pragmatic approaches. Greenberg et al. (2011) conducted a study with 134 higher education institutions and found that slightly less than half of the institutions require at least five observations and roughly a third do not require supervisors to conduct conferences with the teacher candidate

after their observations and provide written feedback to the teacher candidates. The current study showed that universities should pay more attention to the quality of university supervision during student teaching due to the potential benefits of coaching.

Another suggestion from the finding is the need to differentiate coaching during student teaching. To maximize the effectiveness of coaching, the three PSTs needed support in different ways. And Zimmeman's (2002) development of self-regulatory skill model offers a framework for differentiating coaching preservice teachers in the field. To improve her teacher questioning skills, Ara, the low self-regulated PST, needed the university supervisor to model and give examples of good questions. Mia, the intermediate case, needed to collaborate with the supervisor via determining an action plan of the next steps. While Alex, the high self-regulated PST, needed dynamic teaching environments to practice questioning and learn from. To do these, university supervisors need to have teaching and coaching skills (Greenberg et al., 2011).

We were surprised by the PSTs' initial thought that good teacher questioning does not require planning and that teaching experience itself will help them get better at asking questions. Based on research, the thought was not wrong but not completely right (Joglar & Rojas, 2019; Lee & Kinzie, 2012). We think teaching experience is important but not sufficient to support questioning. It would be better if PSTs know tools that help them to come up with good questions (e.g., higher-level cognitive questions) like the ICAP framework. Also, setting goals for questioning and monitoring asking questions in the classroom are needed to ask purposeful questions. Being proactive in improving their questioning competency is better than being passive and waiting for teaching experience to help itself.

Microanalysis interview questions facilitate PSTs' reflection on planning and enacting classroom questions, hence, promoting further learning from the act of teaching (Peters-

Burton et al., 2020). This finding corroborates previous studies. For example, dialogue with others facilitates co-construction of knowledge, revision of conceptual frameworks, the articulation of tacit knowledge, and learning and teaching strategies (Gordon et al., 2007; Kremer-Hayon & Tillema, 1999; Paris & Winograd, 2003; Pintrich & Zusho, 2002). Teachers' SRL knowledge is mostly tacit and remains unconscious until they explain SRL strategies to someone (Delfino et al., 2010; Perry et al., 2008; Pintrich & Zusho, 2002; Randi, J., 2004). In addition, PSTs' reflection enhances their learning from the next cycle of teaching. Self-regulation of teaching follows a spiral process: teachers set goals for teaching, plan appropriate actions, enact instructional strategies, monitor and evaluate outcomes, and revise their approach when needed (Bartimote-Aufflick et al., 2010; Butler et al., 2004; Van Eekelen et al., 2005). Assisting PSTs to become self-regulated teachers means providing them with SRL knowledge and facilitating practice and engagement in SRL (Cleary & Zimmerman, 2004; Paris & Paris, 2001). Our study did this.

Bellman (1974) suggested that teachers do not ask high-quality questions because they (1) are not familiar with a questioning technique that is relatively easy to implement, (2) have not had training in a questioning technique that is manageable, (3) have little or no evidence that the use of a questioning technique can increase student achievement, and (4) have little or no evidence that the use of a questioning technique can lead to a longer period of retention of knowledge. The existing study chose the ICAP framework, which consists of four types of cognitive questions, that is relatively easy for PSTs to keep track of the types of questions they plan and ask in science classrooms. Teachers do not always critically analyze their own questioning practices to determine the effectiveness of their questioning techniques (Sahin et al., 2002). The ICAP framework could be used to analyze and monitor PSTs' questioning practices; as Mia said, she used the ICAP framework not to ask passive

questions. Furthermore, the three primary SRL processes (i.e., goal-setting, self-monitoring, and self-evaluating) provided PSTs with a technique to manage the quality of their questions.

Implication

First, to facilitate PSTs' asking higher-level cognitive questions, teacher preparation programs need to provide teachers with descriptions that are more elaborated, easy to remember, and grounded in a learning theory. The present study attends to this issue by providing PSTs with a questioning framework that is easy to remember and grounded in cognition engagement theories.

Second, integrating SRL in PL and coaching suggests a novel approach to optimize PSTs' asking question competence. Such an approach is possible within current teacher education programs as most secondary science teacher preparation programs include coursework in advance of student teaching where PSTs could receive feedback from a supervisor on their teaching. Since SRL skills are transferable (Schuster et al., 2020), the approach will likely work for other teaching competencies.

Finally, there is a lack of research that support institutions to ensure the quality of student teaching. We would suggest that some adjustments within the current structure of university supervision could give the institutions more control over the quality and better prepare teacher candidates for the profession. One way to do so is to use SRL processes in coaching to enhance teacher candidates' learning from the act of teaching. Furthermore, we think establishing shared goals between university supervisors and cooperating teachers would enhance the gain in the teachers' professional growth. Thus, future research in this area should involve cooperating teachers.

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CHAPTER 3

PRESERVICE SCIENCE TEACHERS' SELF-REGULATED LEARNING PRACTICE WHILE PLANNING AND ENACTING CLASSROOM QUESTIONS: A CROSS-CASE ANALYSIS

To be submitted to the *Journal of Teacher Education*

Abstract

This multi-case study investigates preservice science teachers' (PSTs) self-regulation of teaching. The participants were three secondary PSTs representing high, intermediate, and low self-regulated PSTs. The data came from classroom materials, semi-structured interviews about planning questions, classroom observations, classroom audio recordings, and semi-structured interviews about enacting the questions. Findings show that all three PSTs aimed for more student engagement in answering classroom questions, with the two more proficient self-regulated teachers engaging more of their students in answering questions. The PST who was better at self-regulating planning questions was also better at enacting questions. Similarly, the PST who was better at self-regulating planning and enacting questions asked a greater number of higher-level cognitive questions. Furthermore, the PST who asked the lowest number of higher-cognitive level questions was not good at self-monitoring and self-evaluation and was less willing to enact what she had learned. The research shows that fostering PSTs' SRL skills has the potential to help improve their questioning competency.

Keywords: Teacher education, self-regulated learning, teacher questioning, preservice science teachers

Introduction

In science education, higher-level cognitive questions are crucial to student learning because in the process of constructing scientific knowledge, the type of cognitive processes that students engage in is influenced by the kinds of questions the teacher asks (Chin, C., 2008). Science teachers are expected to facilitate students in working with and learning from

their peers (Windschitl & Stroupe, 2017). One way that helps science teachers meet these expectations is to improve the questions they ask (Lee & Kinzie, 2012). However, most teacher questions require students to recall what they have learned (Benedict-Chambers et al., 2017; Eshach et al., 2014). Galloway and Mickelson (1973) stated that teaching experience alone does not lead to improvement in the types of questions asked, while a study by Morris and Chi (2020) showed inservice science teachers had minimal success in asking higher-level cognitive questions after professional development.

A systematic literature review on self-regulated learning (SRL) professional learning for science teachers showed that SRL improves both science teachers' learning and teaching (Capps et al., 2021). The review also noted there is a lack of learning opportunities for teachers that leverage SRL practice to optimize teacher questioning. Therefore, we propose a novel approach to increase the number of higher-level cognitive questions preservice science teachers (PSTs) ask during student teaching. The approach includes professional learning and coaching that leverages SRL practice and the use of a question classification system. In the context of enacting professional learning and coaching, we aim to answer the following research questions:

1. How does the quality of PSTs' questioning in the classroom differ across cases?
2. How does the quality of PSTs' SRL practice in planning and enacting questions differ across cases?
3. How does the PSTs' reaction to coaching differ across cases?

Literature Review

Teacher Questioning

The primary purpose of teacher questioning is to promote student learning (Chin, Christine, 2007; Lee & Kinzie, 2012; Morris & Chi, 2020; Oliveira, 2010; Redfield & Rousseau, 1981). Teachers use questioning to prompt and challenge thinking and reasoning

(Erdogan & Campbell, 2008; Koufetta-Menicou & Scaife, 2000). A key feature of productive classroom interactions is the cognitive purpose of the talk, which focuses on building students' capacity to think and reason (Alexander, 2006). Teachers cannot assume their teaching has been effective in developing higher-level thinking unless they ask higher-order questions, which stimulate learners to think more deeply (Koufetta-Menicou & Scaife, 2000). The effect of good teacher questions on student learning outcomes has been evident in the literature for years. For example, Winne (1979) stated that regardless of the nature of the research, the use of higher-order thinking questions has positive effects on students. Similarly, a review of 18 studies on teacher questioning found a positive relationship between teacher questions and student achievements (Redfield & Rousseau, 1981). More recently, Koufetta-Menicou and Scaife (2000) identified a strong correlation between teachers' use of open-ended and higher-level cognitive questions and students' metacognitive awareness. Similarly, Chi and Wylie (2014) showed the need for higher-level cognitive questions in promoting productive cognitive engagement.

In science education, the instructional emphasis is on knowledge construction (National Research Council, 2013). One way for teachers to create learning environments that emphasizes knowledge construction is to ask open-ended questions which facilitate students' active inquiry (Koufetta-Menicou & Scaife, 2000). Asking higher-level cognitive questions increases the degree of student-centeredness, which is needed for inquiry-based lessons (Oliveira, 2010). Open-ended questions are useful for developing students' cognitive skills, as these questions encourage students to express and elaborate upon their thinking and to provide rationales for their thoughts rather than focusing on a correct answer (Lee & Kinzie, 2012). Good questioning is the starting point for promoting the development of complex scientific skills such as problem-solving and argumentation (Banilower et al., 2013; McNeill & Pimentel, 2010). Teacher questions also play a crucial role in enhancing students' self-

regulated learning skills (Chin, Christine, 2007). Teachers can also scaffold students' interactions with their peers by asking them for discussion and idea exchanges (Morris & Chi, 2020). Thus, teacher questions affect different aspects of learning outcomes, such as cognition, metacognition, and student agency.

Despite the importance of higher-level questions, there is abundant evidence that teachers tend to overuse lower-level questions, which ask students to recall learned concepts or to manage the classroom (Chin, Christine, 2007; Ho, 2005; Massey et al., 2008; Morgan & Saxton, 1991; Wragg & Brown, 2002). The lack of teacher questioning competency occurs in many education systems. In the U.S., Gall's study (1970) showed 60% of teacher questions aimed at memorizing facts, 20% of the questions asked about procedures, and only 20% promoted active thoughts. Current research (Morris & Chi, 2020) indicates that the percentages are still valid. Similarly, Stronge et al. (2007) conducted a study with science teachers in Chile and found that only between 13 and 17% of classroom questions are open and are aimed at the development of critical thought. Therefore, supporting teachers in developing their questioning skills is still an urgent need.

Asking good questions is a competence that needs to be taught, and a good place for it to begin is in teacher preparation programs. As discussed in the previous paragraphs, teachers often experience difficulties in asking higher-order questions. This problem is even more salient in student teachers where the number of questions asked is low, and the quality is poor (Ahtee et al., 2011; Eshach et al., 2014). Moreover, student teachers tend to eliminate some of their challenging planned questions (Davis et al., 2016). Questioning skills are not generated spontaneously; however, many teachers believe their common sense and teaching experience will enhance those skills. Research shows that teaching experience alone does not lead to good teacher questioning (Galloway & Mickelson, 1973). We would argue that professional learning, purposeful practice, and reflection are needed for teachers to perceive

the complexities involved in teacher questioning and to improve their questioning competency over time. And SRL processes can serve as a means for teachers to practice purposefully and reflect more effectively on their questioning.

Self-Regulated Learning

SRL is a complex and multifaceted process that is linked to goal orientation (Pintrich, 2000). There are six models of SRL in the literature (Panadero, 2017). Those models emphasize different aspects of SRL. For example, Zimmerman's cyclical phases model emphasizes the importance of goals and the SRL processes; Winne and Hadwin's model sees metacognitive monitoring as the gateway to SRL; Pintrich's SRL model considers individual attempts to monitor and control the environment are an important aspect of SRL. However, the models all share some common features and a few general assumptions. For instance, the models define SRL not as a trait but as a temporal, dynamic, and adaptive process (Zimmerman, 2013). All the models view learners as active, constructive participants in their learning process. In all the models, learners are assumed to be able to monitor, control, and regulate certain aspects of their cognition, motivation, and action (Pintrich, 2000). Additionally, all six models comprise different constructs and processes that make SRL a broad term. Furthermore, all the SRL models are supported by empirical evidence from studies (Panadero, 2017).

Success in this era of information and knowledge acquisition requires lifelong learning skills, which are built upon the ability to regulate one's own learning (Kotaman, 2018). Modern students need to be able to regulate their academic activities by setting goals and monitoring to achieve the goals. Students' success should be evaluated in relation to their formulated goals instead of standardized tests. Self-regulated learners are good strategy users. Students with high SRL skills tend to use more productive learning strategies (instead of focusing on memorization) and have a better understanding of how one area of knowledge

can be transferred to another (Weinstein et al., 2000). Moreover, SRL processes facilitate learners to be more self-aware of their learning. However, research has demonstrated that a significant minority of learners, across a wide range of ages, lack SRL skills to serve their learning (Azevedo & Cromley, 2004; Pintrich, 2000). Fortunately, SRL skills can be fostered effectively at all learner levels, from kindergarten to higher education, through evidenced-based designs for learning activities and learning environments (De Corte, 2019). To promote SRL skills in K12 students, the first step is to assist teachers in acquiring SRL knowledge and skills.

Teachers do not often enact SRL; thus, students are not adequately prepared to learn independently (Bolhuis & Voeten, 2001; Dignath & Büttner, 2008; Spruce & Bol, 2015). One of the reasons for the lack of SRL implementation is teachers' insufficient content knowledge and pedagogical content knowledge about SRL (Dignath-van Ewijk & Van der Werf, 2012; Spruce & Bol, 2015). Providing teachers with knowledge of SRL during pre-service learning enhances their awareness of the importance of SRL and provides them with the foundation needed to learn more from teaching experience (Zambrano-Matamala et al., 2019). Research shows a positive relationship between teachers' attitudes towards SRL and their enactment of SRL in classrooms (Steinback & Stoeger, 2016). Teachers who understand and apply SRL in their learning and teaching are more likely to foster such knowledge and skills in their students (Zambrano-Matamala et al., 2019). In addition, teachers who have experienced SRL as effective and useful are more likely to promote such strategies and better at modeling of how to use SRL (Peeters et al., 2016). Thus, preparing PSTs with SRL knowledge and practice benefits their learning, their teaching, and K-12 students.

For teachers, there are three aspects of SRL: self-regulation of learning, self-regulation of teaching, and promoting SRL skills in students (Kramarski & Heaysman, 2021). Self-regulation of learning focuses on learners self-regulating their learning of content

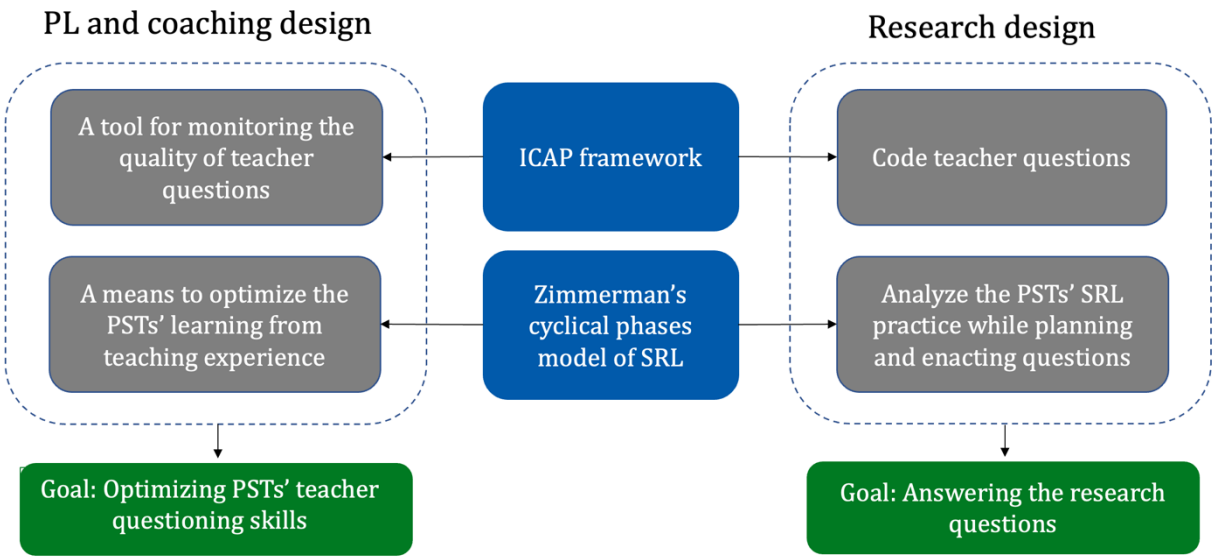
knowledge and pedagogical content knowledge. Self-regulation of teaching focuses on how teachers regulate their teaching practices, such as lesson planning, in-class monitoring of instruction effectiveness, and evaluating instructional decisions (Kramarski & Heaysman, 2021). Promoting students' SRL skills is where teachers implement instructional approaches that support students in developing their SRL knowledge and skills. This study focuses on the self-regulation of teaching where PSTs self-regulate planning and enacting classroom questions.

Theoretical Framework

This study is framed by two theoretical frameworks: the Interactive, Constructive, Active, and Passive (ICAP) framework of cognitive engagement (Chi & Wylie, 2014), and Zimmerman's cyclical phases model of SRL (Zimmerman, 2000; Zimmerman & Moylan, 2009). Figure 1 summarizes how these two frameworks inform both the professional learning and coaching design as well as the research design of the study.

Figure 1

Theoretical Frameworks that Inform the Study



Interactive, Constructive, Active, and Passive (ICAP) framework of cognitive engagement

The ICAP framework consists of four modes of cognitive engagement: interactive, constructive, active, and passive (Chi & Wylie, 2014). Passive engagement leads to storing new information in an isolated way, so students can only recall the facts. The active mode of engagement helps students integrate new information with activated prior knowledge, leading to the ability to apply the knowledge in similar situations. Constructive engagement supports the inference of new knowledge from activated and integrated knowledge. The learning outcomes of constructive engagement allow students to extend what they have learned to new contexts. Interactive engaging happens when students work with peers to co-create. Therefore, interactive is more productive than constructive, which is better than active, and active is better than passive.

There are four types of cognitive questions that lead to the four modes of cognitive engagement. Passive questions are those that do not expect learners to verbalize an answer; for example, “So… where’s the gene? It’s on the chromosome, right?” Active questions ask learners to recall information from background knowledge or previous lessons; for example, “Who remembers what we talked about yesterday with predator and prey, about the relationship between predator and prey?”. Constructive questions ask learners to go beyond the presented materials; for example, “What will happen to the mice that have the mutation described in the text?” (Morris & Chi, 2020). Interactive questions require students to exchange ideas with their peers and those ideas need to go beyond what they were taught (Chi & Wylie, 2014). One example of interactive questions is when students are asked to mutually exchange ideas with another student on “What real-world applications are there for Phylogenetic tree?” Thus, constructive questions and interactive questions are preferred in terms of stimulating student thinking. This framework was introduced to PSTs as a tool for monitoring the quality of their questions because the defining characteristics of constructive and interactive questions in ICAP are easier for teachers to utilize compared to other question

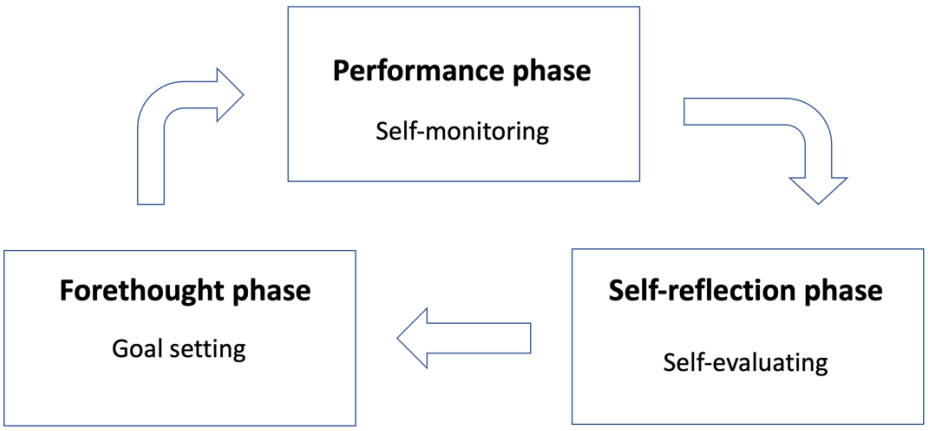
typologies (Morris & Chi, 2020). The framework was also used to develop a coding scheme to analyze teacher questions in classroom recordings.

Zimmerman's cyclical phases model of SRL

Although there are several SRL models, this study used Zimmerman's cyclical phases model of SRL (Zimmerman, 2000; Zimmerman & Moylan, 2009) as it is the most applicable model for learners in the literature. The model consists of three phases: forethought, performance, and self-reflection. Each phase comprises different SRL processes. In the forethought phase, learners analyze their learning tasks, set goals, and plan to achieve the goals. Learners' self-motivation beliefs affect how they set goals and plan for their learning. During the performance phase, learners use different strategies to monitor their learning process. The self-reflection phase is when learners evaluate their performance and identify possible causes of their learning outcomes. The way learners attribute their success or failure affects their motivation and learning behaviors in the next SRL cycle (Zimmerman & Moylan, 2009). In this study, we focused on three SRL processes: goal setting for the forethought phase, metacognitive monitoring (self-monitoring) for the performance phase, and self-evaluation for the self-reflection phase. This framework was included in the SRL professional learning for PSTs, and it helped analyze data from reflective writings and semi-structured interviews.

Figure 2

Zimmerman's Cyclical Phases Model of SRL (Zimmerman & Moylan, 2009)



Method

This research is a multi-case study (Yin & Campbell, 2018) using multiple analysis methods. The analyses focus on similarities and differences in teacher questioning, SRL practice, and reaction to coaching across cases. We aimed to minimize bias by using multiple data sources, co-coding and cross-checking, and member checks for correct representations of the findings with participants (Maxwell, 2012).

Context of the Study

SRL lessons and teacher questioning lessons were integrated into two typical courses for PSTs: Methods of Science Teaching and Technology for Science Teaching. The professional learning included five lessons where PSTs were directly taught about SRL and teacher questioning, both theoretically and practically, during the Fall of 2021. Coaching occurred the next semester, Spring 2022, during student teaching. The coaching focused on self-regulation of teaching, specifically, self-regulation of planning and enacting questions.

Participant Selection

To represent variance among PSTs, three participants were purposefully selected from 18 PSTs enrolled in a secondary science teacher education program. The participants represented low, intermediate, and high self-regulated learners. As part of the selection process, the PSTs were asked to read a book chapter by Cleary (2018) that defined SRL and the characteristics of self-regulated learners and write a one-page reflection on the extent to

which they self-regulated their learning. The PSTs also completed a survey that included the SRL achieve subscale and SRL negative subscale of an instrument to test preservice teachers' beliefs consistent and inconsistent with self-regulation theory (Darmawan et al., 2020). Agreement with items in the SRL achieve subscale means the PSTs believe in constructive learning and positive impacts of SRL. Whereas agreement with items in the SRL negative subscale means the PSTs have negative views on SRL. The Cronbach alpha of those subscales were 0.82 and 0.78, respectively. These two pieces of data along with the first author's observations while working with the PSTs during the Fall semester were used to select the participants for this study. Table 1 shows the rubrics for participant selection.

Table 1

Rubrics for Participant Selection

	High self-regulated learner	Intermediate self-regulated learner	Low self-regulated learner
Survey score	Upper 25%	Middle 50%	Lower 25%
Reflection writing	Saw themselves as a good self-regulated learner	- Saw themselves as an average self-regulated learner - Or good at one aspect of SRL but not the other - Or try to self-regulate their learning sometime, but not often very effective	Did not see themselves as a good self-regulated learner

Observation during Fall 2021	- Did not submit their assignments late (except for special circumstances) - The quality of their work was high most of the times - If they got feedback on improving something, they would significantly improve it the next time	- Submitted their assignment late once or twice - The quality of their work depended on the topic (good or quite good), but it was always higher than average. - Improved most of the points they get feedback on	- Submitted their assignment late more than twice during the semester without special reasons - Their work often did not meet all the requirements - Did not improve their work's quality much after getting feedback

Data Sources

Research data were collected from multiple sources representing different dimensions of PSTs' SRL and questioning practice. Table 2 shows the timeline for data collection.

Table 2

Timeline for Data Collection

Data types	Data Sources	Timeline (Spring, 2022)											
		Jan				Feb				Mar			
		W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4
Teacher questioning and reaction to coaching	Classroom materials (lesson plans, slides, worksheets, etc.)												
	Audio recordings of the teaching												
Teacher questioning, SRL practice, and reaction to coaching	Interviews about planning questions												
	Classroom observations												
	Interviews about enacting questions												

Classroom materials for three lessons of student teaching were collected and examined before a researcher observed the PST teaching the lessons. Those materials and other data sources partly helped determine whether the content had been explicitly provided to the students before a question was asked; this information was necessary to code the types of questions the PSTs asked. Semi-structured interviews about planning each lesson were conducted to understand how the PSTs used SRL processes while planning classroom questions. These interviews were conducted after the PSTs completed their lesson plans (before the teaching). Classroom observations helped researchers get a sense of the context of the classroom and what the teaching entailed. During classroom observations, the researcher took notes on the discourse and activities in the classroom. Audio recordings of the teaching were also collected.

Within 48 hours after the lesson (within 24 hours for most of the interviews), the researcher conducted interviews with the PST to understand what they thought about the questions they asked during the instruction, why they asked the questions, and how they used SRL processes to serve the teaching. The interviews were semi-structured in nature following recommendations by Patton (1990). During the interviews, the researcher's responses to the PSTs were a combination of non-leaning leads and low-inference paraphrasing (Carspecken, 2013). All the interviews were conducted with one PST via Zoom.

After each interview, the researcher typed an interim case summary as the first attempt to drive a coherent, overall account of the case.

Data Analysis

Percentages of classroom questions

Classroom audio recordings were transcribed using Otter.ai. Once transcribed, the questions were coded as either interactive, constructive, active or passive according to a coding scheme developed based on the ICAP framework (Chi & Wylie, 2014). For example, a PST might show a photo of puppies and asks, “These puppies all look slightly different, right?” Or she might confirm that the students understood what she just lectured by asking, “So now we know that miosis creates genetic diversity, right?” These questions were coded as passive questions because students neither needed to think of an answer nor verbally respond. The questions already include the expected response. After that, the total number of questions asked and the percentage of each type of question were calculated.

SRL practice

Three coding cycles were used to analyze the interviews: two rounds of a priori coding, followed by cross-case analysis. Initial rubrics with three code levels: maladaptive (1), partly adaptive (2), and adaptive (3) were developed based on previous research (Chi & Wylie, 2014; Peters-Burton & Botov, 2017; Peters-Burton et al., 2020; Smith, 2020). The rubrics also included sample responses for the adaptive codes that show what an expert would attempt while accomplishing the tasks (Peters-Burton et al., 2020). A researcher used the rubrics to code all the interviews while simultaneously revising and adding codes to the rubrics. The process ensured the codes adequately represented the meanings in the participants’ responses, which resulted in final rubrics with five code levels: missing (1), maladaptive (2), partly adaptive (3), adaptive (4), fully adaptive (5). Table 3 shows the rubrics. The five-level rubrics were used for the second a priori coding, which was conducted

by two researchers. After that, cross-case analysis was conducted to find themes that cut across cases and themes that are specific to individual cases (Miles et al., 2014).

Reaction to coaching

Content analysis and inductive thematic analysis were used to analyze observation notes, planning interviews, and enacting interviews for the salient characteristics of the PSTs' reaction to coaching (Miles et al., 2014). While coding the reactions, we also used classroom materials and recordings of the teaching to triangulate the findings (Maxwell, 2012).

Table 3

Rubrics for Coding the Quality of Adapting SRL Processes (Goal Setting, Self-Monitoring, Self-Evaluation) to Regulate Planning and Enacting Classroom Questions

Code	Score	Code description	Exemplar quote
Missing	1	Did not do it	"Um, be honest, no. Um, again, I think the questions just kind of took a back burner in my head, like, I just kind of put them aside and forgot about them until after the observation had ended. And then I went, Oh, I could have done that better." (Low case, first teaching interview, self-monitoring)
Maladaptive	2	Aimed to do it but did another SRL process	"Um sort of, …, through an outside source, I asked her [mentor teacher] if those [questions] were good or not. So I did it that way." (Intermediate case, first planning interview, self-evaluation)
Partly adaptive	3	Did the process but no effective	"Yes, I did. Um, it kind of went into how I was disappointed about how the lesson went. And I

		strategies or tactics were mentioned in the participant's response	felt like I didn't accomplish the goal, that the questions were a big part of that. So that was definitely a focal point of my self-reflection that I mentioned that I did in second period" (Low case, third teaching interview, self-evaluation) (Notes: even though the participant disappointed about how her lesson went, she did not mention how she would do better for the next period that had the same lesson).
Adaptive	4	At least one goal/strategy/tactic was mentioned but without clear explanation for how the participant did so or without justification for why they chose the strategy	"I had the first set of questions in my PowerPoint. So the kids were able to hear it from me and look at the question at the same time. And that was the whole class discussion. And then so I kept track of that that way, like which slides I was going through. And then the second set of questioning, I had a printed-out piece of paper with the questions on it. So as easily able to see like, what my questions were, and which one was I was asking per group. And then the last set of questions were printed out on the back of a worksheet, and they were just answering those independently. So yeah, each one had a different, or each section had a different way, I was keeping track of it. But for all the sections, it was

			written out somewhere, and I knew exactly what was going to be asked." (Intermediate case, third teaching interview, self-monitoring) (Notes: the way the participant monitored her questioning was good, but there was no link with the goals of the questioning. This is why the score for this response is 4, not 5).
Fully adaptive	5	At least one goal/strategy was discussed with specific explanation for how the participant did so or justification for why they chose the strategy and alignment with the goals	"So I wanted to tackle different misconceptions with each question, but also really dive deep and see what they know about natural selection" (High case, second planning interview, goal setting) "Yes. I think through a process of asking so many questions to these students, I'm getting answers that I have expected. And that I haven't expected, I've been more able to think about everything that I should ask in advance. So there's a question that says, Do you think? Do you think that solar powered cars will be widespread? In the next 20 years? Why or why not? And I can already kind of anticipate maybe 25% of students just giving a yes or no answer to that question and not answering the why or why not? And so I think in evaluating that, one thing that we have to do when

			presenting that information, both for tomorrow and the next day, because this will be over the course of the next two days, is be sure we're hitting on those questions, be sure we're talking about them. And then tomorrow, since it's a race day, being ready to answer questions related to how students need to start the race. So do we need to push the thing or tap the thing? Or should we just let it go? Those are all questions that we need to ask. And tomorrow very well might again, be too cloudy to race these cars. So we're bringing in batteries to power them if the solar energy don't doesn't work, and then we have to tie that back into the content. Well, solar power didn't work again. So this time we brought batteries, why is that a good thing? Why is that a bad thing? So that's required a lot of evaluation of our questions to make sure that we know what we should be talking about at different terms." (High case, third planning interview, self-evaluation)

This section includes the themes across the three cases (high, intermediate, and low self-regulated teacher). We first present two themes regarding teacher questioning, three themes regarding SRL practice, and then present a theme about the PSTs' reaction to coaching.

Teacher Questioning

Theme 1: The higher self-regulated teachers asked a greater number of higher-level cognitive questions

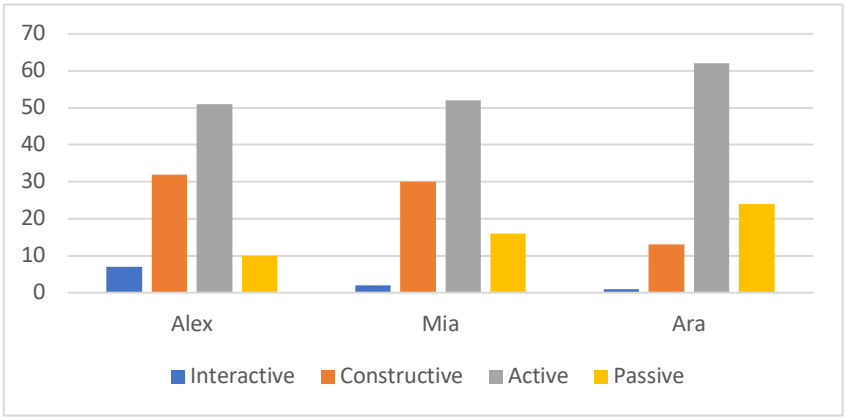
The average numbers of questions asked per minute by the PSTs were similar. All the PSTs asked about one question per minute (regardless of the question types). Alex, the high self-regulated teacher, faced no difficulty in asking his planned questions in the classroom. In contrast, Mia, the intermediate self-regulated teacher, had to consciously focus on questioning to ask her planned questions. To avoid forgetting the questions she intended to ask, Mia wrote her questions on a note card, "we [Mia and the mentor teacher] had a note card with the questions on them at the front and we would kind of glance at them if we forgotten" (Mia, first teaching interview). Ara, the low self-regulated teacher, tended to turn her planned questions into explanations. For example, Ara did not ask the questions she planned for the first observation lesson; and in the first teaching interview, she said, "I was not thinking about the questions [while teaching]".

Figure 3 presents the percentage of each type of teacher questions compared to the total number of questions asked in the three lessons. Each question was coded as either interactive, constructive, active, or passive question. The major difference between the three PSTs was that Alex asked a greater number of higher-level cognitive questions than Mia, and she in turn asked more higher-level cognitive questions than Ara. More than 30% of the questions Alex and Mia asked in the classroom were interactive or constructive. Whereas only 14% of the questions Ara asked were interactive or constructive. Noticeably, compared

to Mia and Ara, Alex asked more interactive questions, which means Alex gave students more opportunities to exchange ideas with their peers that went beyond what they were taught.

Figure 3

Percentage of the PSTs' Question Types in the Three Lessons



In general, Alex's questions were more integrated throughout his lessons compared to Mia and Ara. Alex was also better than Mia and Ara in terms of building his classroom questions on one another. He asked many more follow-up questions, which led to constructive questions or prompted students to elaborate further to be able to answer the initial constructive question. Mia aimed to embed her questions into classroom activities, including whole-class discussions and small-group discussions. Ara tended to ask questions at the beginning of the lessons as a form of formative assessment of previous lessons or asked after a brief lecture to check whether students could follow the facts or concepts presented within the lecture.

The PSTs asked a large percentage of active questions (more than 50%), which were primarily used to assess student understanding of facts that had been previously presented to them or were provided on learning materials (e.g., readings, worksheets). Most of the time, the PSTs moved on after receiving the answer to the active questions without trying to ask follow-up questions that require higher-level cognitive thinking. Passive questions were also

used often (10% or more), especially for Ara (24%). It is not a bad thing to ask passive questions, but when PSTs ask so many passive questions, they lose opportunities to ask meaningful questions that support knowledge construction. In Ara's case, she reworded some of her planned questions (constructive or active questions) into passive questions, leaving fewer opportunities to ask constructive questions.

Theme 2: All three PSTs aimed for more student engagement in answering classroom questions, and the higher self-regulated teachers got more students to do so

All three PSTs aimed to get more students to answer their questions. Data from our classroom observation notes revealed that Alex had more students volunteer to answer his questions. Alex self-regulated while teaching to decide whom to call to answer certain questions. Specifically, he consciously thought about whom he would call on to answer particular questions based on how he felt it might support the student's learning as well as other students in the classroom. The excerpt below is an example of Alex's thoughts regarding the decision on which student to call on.

> "So one thing I have to think about when I am teaching a lesson is 'am I going to call on a student who I think gets it or a student who I think doesn't get it?' Because if you call on a student who gets it, they can explain it in student terms that hopefully other students relate to. But if you call on a student who you expect not to get it, you can work through that with them. And the added pressure of them having to think about it in the low stakes environment, I think helps them come naturally to some answers… That was a big point of self-regulation and the most consistent point of self-regulation through my lesson" (Alex, first teaching interview).

Mia's decision regarding whom to call on to answer her classroom questions is less complex than Alex's decision. Mia was less selective and simply aimed for as many students to engage in answering her questions as she could; Mia said, "I evaluated when I should use

those [constructive questions], and I came to the conclusion that those will be better in a small group setting because I really wanted to get multiple kids to answer" (Mia, second teaching interview). Similar to Mia, Ara wanted to have all students aiming to answer her questions. And she was happy when she got more students to do so.

> "I think so. Um, because that group of students that you saw, are usually not that lively. And they're usually not that eager to, like, give ideas out. So um, like, for example, I had like, a lot of people volunteering to talk about like, their animal and later they're like, assigned organism, and like, they're, like, like, method of meeting, or something like and stuff like that. And, you know, when I was up there asking, like people to tell me about their animals. Um, and I felt like if the goal if I'm purely looking at the goal of to engage them while learning, I think I really succeeded because I felt like that group of kids is usually not that lively or interested, especially not on a Monday. That that was also something I was worried about, is you coming in on Monday morning, but it ended up not being so bad. And also the the depth of like, answers that I was getting from the students were pretty on pair with what I was, like, wanting them to get at" (Ara, second teaching interview).

Despite the convergence across cases regarding aiming for more students to engage in answering classroom questions, the three cases diverged in terms of the ability to engage more students. Data from classroom observations and classroom recordings show Alex and Mia did better than Ara in engaging more students with answering questions. Alex did so by constantly paying attention to calling different students when he asked questions. Mia did so by calling volunteer students to answer whole-class discussion questions, then having at least one question to ask each student in small-group discussion.

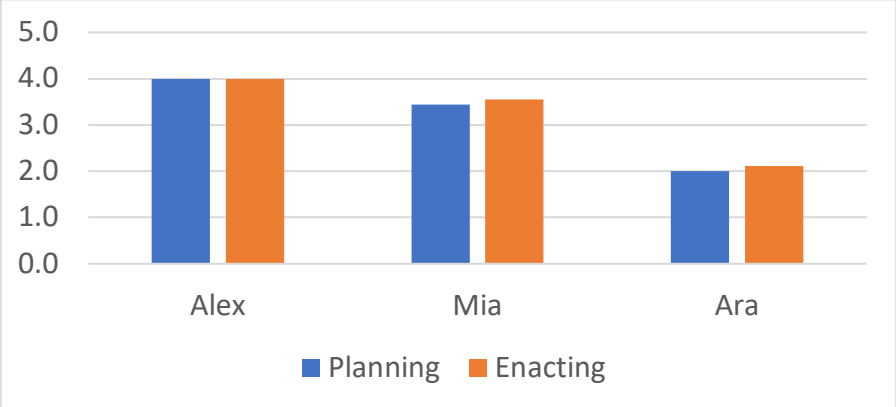
SRL Practice

Theme 1: The PSTs who were better at self-regulating planning questions were also better at self-regulating enacting questions

Figure 4 presents the PSTs' average scores of self-regulating planning questions and self-regulating enacting questions. The average scores of self-regulating planning questions were calculated from scores of goal setting, self-monitoring, and self-evaluation regarding planning questions for three lessons. The average scores of self-regulating enacting questions were calculated the same way but for the implementation of classroom questions. The results show that the PSTs' ability to self-regulate planning and self-regulate enacting was not very different. Alex, the high self-regulated teacher, had the highest scores for both planning and enacting questions. Mia's scores were a little lower than Alex's scores while Ara's scores were substantially lower. Thus, there were differences among the PSTs, especially for Ara; however, within each case, the planning question scores and the enacting question scores were similar.

Figure 4

Average Scores for Self-Regulation of Planning and Self-Regulation of Teaching



In the interviews with the three PSTs, one common theme emerged: the PSTs paid a little more attention to enacting than planning questions, especially for self-evaluating. The PSTs valued self-evaluation of their classroom questions after the teaching more than self-evaluation after planning them. One reason for this is that the PSTs wanted to see students'

reactions to the questions and use the reactions as one standard for evaluating classroom questions. An extreme example of this is Ara's response to the question, "Did you evaluate your performance in planning the questions?" during the third planning interview. She said,

> "Um, I guess not really, because in my opinion, the only way to really evaluate its effectiveness is to do it. So, um, what I've been kind of doing is using these observations as like an opportunity to try out like some, maybe ideas that I'm playing around with. And a lot of the times I like, I've never done something quite like this before. And so therefore, I think it's really hard to predict how it's going to go without actually doing the lesson and then getting that feedback in real-time. So I'd say no. And also, I don't think that trying to evaluate before you give the lesson is really an effective strategy."

Theme 2: The PSTs who asked a greater number of higher-level cognitive questions were better at SRL practice.

Overall, the average scores for goal setting, self-monitoring, and self-evaluation for Alex were the highest. Mia was also quite good at those SRL processes. Ara's scores, especially for self-monitoring and self-evaluation, were lower (see Figure 5). These findings make sense in terms of how we selected the cases and the quality of the PSTs' classroom questions. The PSTs who did better at self-regulating planning and enacting questions asked more higher-level cognitive questions in the classrooms.

Figure 5

Average Scores for Goal Setting, Self-Monitoring, and Self-Evaluation

Theme 3: The low self-regulated teacher who asked fewer higher-level cognitive questions was not good at self-monitoring and self-evaluation

While Alex and Mia's skills for the SRL processes (goal setting, self-monitoring, and self-evaluation) were higher and nearly uniform, Ara's SRL skills were lower and somewhat uneven (see Figure 5). Ara's ability to self-monitor and self-evaluate was much lower than her ability to set goals. Ara's average score for self-monitoring (calculated from three planning interviews and three teaching interviews) was 1.5 on a 5-point scale, which means she did not really self-monitor her process of planning questions and enacting classroom questions. In other words, at the beginning of student teaching, Ara did not self-monitor and then aimed to self-monitor but could not do it effectively. She struggled with self-monitoring her classroom questioning. Ara said,

> "I did not ask as many questions as I intended on. Um, I think the only reason for that is purely just I wasn't thinking about it. I was thinking about so many things. I think that the asking questions kind of like took a backburner… I ended up just explaining it without trying the questioning" (First teaching interview).

So, at the beginning of her teaching internship, Ara could not ask all her planned questions. That means Ara was not good at self-monitoring to enact what she planned. This resulted in her spending less time planning questions. She said,

> "I don't feel like it's useful to me to plan the questions in advance. So, the act of like writing down the questions and sending them to you, I only do that for your observations. I don't do that normally… Once I made that list and sent it to you, I never looked at it again, never even thought of it. Um, I went up there and tried to accomplish my goal of getting my questions to relate to all the content, but it as for the specific ones that I sent you, those were not in my head at all, they went completely out the window" (Third teaching interview).

Ara's thought that planning classroom questions was not helpful, so she planned classroom questions for only the observed lessons (not the other lessons), which means Ara did not practice planning questions. And this was another reason why the quality of Ara's classroom questions was lower compared to Alex's and Mia's. Ara knew that asking questions was necessary, so she tried to ask questions that were relevant to the content. Nonetheless, she did not use her planned questions; she tried to come up with questions while teaching. And Ara did realize it was not easy to come up with good questions while teaching; she said, "I noticed that I had a hard time thinking of those questions [constructive questions] in the moment [in the classroom]" (Second planning interview). The fact that Ara did not ask her planned questions and could not come up with good questions while teaching showed that she did not self-monitor well in enacting questions.

After failing to ask questions in the classroom a few times, Ara began to value planning questions. In the third teaching interview, she said, "I had initially thought it [asking questions] was more natural just part of teaching that you just do automatically. And then I learned after failing at it a few times that no, you need to plan it out". It sounded like after the

interview, Ara would put more time and effort into planning questions and aim to monitor enacting the questions. But the third teaching interview was the last activity of the study's data collection; thus, we do not know whether there were improvements after the interview.

Ara's average score for self-evaluation was 1.7, which means she did not really self-evaluate her planned questions or classroom questions. Later in her student teaching, Ara tried to self-evaluate her questions and her way of self-monitoring asking questions; but the evaluations were not well aligned with her goals, and no effective strategies or tactics for improvement were mentioned in her responses. The excerpt below is an example that shows Ara did not mention how she would do better the next time she planned questions or asked classroom questions.

> "It kind of went into how I was disappointed about how the lesson went. And I felt like I didn't accomplish the goal, that the questions were a big part of that. So that was definitely a focal point of my self-reflection." (Ara, third teaching interview)

In short, Ara's goal-setting skills were quite good. She linked her goals for teacher questioning with the learning objectives of her lessons and wanted to ask questions that stimulate student thinking. However, Ara's low ability to self-monitor caused her to doubt the value of planning questions which led to not putting time and effort into the work. In addition, Ara's ineffective self-evaluation could not help her to come up with a solution or implement the suggested solutions provided to her. Both the low self-monitoring ability and unproductive self-evaluation contributed to her failure to achieve her goals of asking higher-level cognitive questions.

Reaction to Coaching

Theme 1: The PSTs' reactions to coaching differed across cases in terms of their willingness to apply what they had learned from professional learning and coaching.

The higher self-regulated teachers were more willing to apply what they had learned. Without further prompts, Alex applied principles of high-quality science lessons, which he learned from professional learning, into his teaching. He said, “It [the coaching] required me to call back on knowledge from block one [the courses] a lot and make sure that my lessons and lesson plans are rooted in some sort of research-based pedagogy” (Alex, third teaching interview). Mia did not automatedly link student teaching with concepts in professional learning, but she learned from the coaching and applied the strategies. Mia said, “… It [the coaching] helped me to think and apply my SRL to questioning specifically.” Whereas Ara needed to be convinced to try out SRL strategies (one way to do so was to provide rationales for the activities) and needed more specific suggestions regarding action plans for the next steps. One example which shows Ara’s hesitance to apply what she has learned is about planning classroom questions. Professional learning and coaching emphasized that it is important for PSTs to plan their classroom questions before teaching. However, Ara did not plan questions for her lessons (except the observed lessons). She only learned the value of planning questions after failing a few times at asking questions in the classroom. Ara said,

> “I had initially thought it [asking questions] was more natural just part of teaching that you just do automatically. And then I learned after failing at it a few times that no, you need to plan it out. And although it won't come out the exact way that you've planned it, the act of planning really helps you do it like more naturally” (Ara, third teaching interview).

Discussion

Teacher Questioning

According to (Crawley & Krockover, 1979; Timmins, 1998) the ideal proportion of question types is a balance between lower and higher-level questions. Overall, less than half of the classroom questions asked by the participants of this study were higher-level cognitive

questions. Thus, further improvement is needed. All the PSTs asked about one question per minute (regardless of the question types), which is a little lower than the average number of questions per minute the two inservice science teachers in Morris and Chi's study (2020) asked, but the number of questions was reasonable. Some studies showed the number of questions asked by student teachers during practicum is low, and the quality of these questions is poor (e.g., Ahtee et al. 2011; Eshach et al. 2013). Therefore, compared to other studies, the PSTs in this study asked a reasonable number of questions, but there was room for them to improve the quality of their questions.

One essential feature of productive classroom interactions is the cognitive purpose of the talk, which focuses on building students' ability to think and reason (Alexander, 2006). Interactive and constructive questions promote students' thinking and reasoning. Another important feature of classroom questions is to enhance interactions between teachers and students. While constructive questions lead to interactions between students and the teacher, interactive questions promote interactions between both students with the teachers and interactions among students. Morris and Chi's study (2020) shows that it is not easy to ask interactive questions. Compared to Mia and Ara, Alex asked more interactive questions. Since Alex was better than Mia and Ara in terms of self-regulation of teaching, it stands to reason that improving PSTs' self-regulation of teaching may be an effective way to support them in asking more interactive questions.

SRL Practice

Findings from this study show that PSTs who were better at self-regulating planning questions were also better at self-regulating enacting questions. So, optimizing teachers' SRL practice in planning questions might improve their SRL practice in enacting questions. The PSTs paid more attention to self-evaluating their questioning after the teaching than after planning their questions. This view is not productive. A more effective way for the PSTs is to

see planning and enacting classroom questions as different steps of the process of teaching and be able to handle them somewhat separately even though the steps serve the same ultimate goals. The PSTs would use the learning objectives of the lesson and the ICAP framework to self-evaluate their planned questions and feel more confident about the questions before asking them in the classroom.

The PSTs who were better at SRL practice asked a greater number of higher-level cognitive questions. This finding suggests that fostering PSTs' SRL skills has a high potential to improve their questioning skills. Moreover, since the metacognitive aspect of SRL is transferable (Schuster et al., 2020), fostering teachers' SRL skills will likely work for other teaching competencies as well.

The combination of low self-monitoring skills and non-effective self-evaluation prevented Ara from achieving her goals for classroom questioning. According to Pashler (1998), to succeed at school, students must develop their ability to engage their attention selectively and divide their attention between different essential elements of learning contexts. We think the statement is also applicable to teachers. To succeed in their teaching, teachers need to be able to divide their attention between a few crucial elements at the same time. And Ara could not do so. She focused on delivering the content correctly and could not pay more attention to asking classroom questions. Kaufman (2010) states it is self-monitoring capacity that puts the *meta* in metacognition and all other metacognitive executive functions are arguably dependent on the ability to monitor what one is doing in real-time. We understand that it is not easy to improve one's self-monitoring skills. However, one's capacity for selective attention enables the filtering out of the multitude of stimuli competing for notice, which allows the person to focus on only important things; and one's goal-directed attention skill keeps them focused on things they deem to be of value (Kaufman, 2010). Ara did not prioritize asking higher-level cognitive questions, so her selective attention was not

for teacher questioning. Furthermore, if one is aware of the quality of their focus and thinking as they work, they can tweak their cognition and environment to improve their functioning at the moment. Self-evaluation can help here. If Ara would effectively self-evaluate the performance of her planning and enacting questions, she could find a way to be better at self-monitoring the next time she planned or enacted classroom questions.

Reaction to Coaching

The findings suggest that PSTs' initial SRL skills affect how they react to and benefit from coaching. Ara set quite clear goals for her teacher questioning, which means she understood what good teacher questioning looks like. However, she was unable to effectively self-monitor to achieve her goals which took away her motivation for self-evaluation. And since Ara was not willing to enact what she had learned, she did not benefit much from the coaching, which in turn did not motivate her to try out suggested strategies. In addition, our findings show that not all PSTs remembered and applied what they had learned in professional learning. So, university supervisors and mentor teachers should differentiate coaching to PSTs based on their initial SRL skills. The findings also show that Ara did not prioritize asking higher-level cognitive questions as Alex and Mia did. Thus, task value might be another factor that affects the PSTs' reaction to coaching. Future research should further examine the relationship between those two constructs (i.e., PSTs' task value to asking higher-level cognitive questions and their reactions to coaching).

Implications for Teacher Education

Findings from this study show PSTs' SRL skills in planning and enacting classroom questions contribute to the quality of their questioning. Thus, fostering PSTs' SRL skills should help improve their questioning competency. Secondly, integrating SRL in professional learning and coaching suggests a new approach to optimize PSTs' questioning skills. Such an approach is possible within current teacher education programs as most secondary science

teacher preparation programs include coursework in advance of student teaching where PSTs could receive feedback from a supervisor on their teaching. Since the metacognitive aspect of SRL is transferable (Schuster et al., 2020), the approach will likely work for other teaching competencies. Thirdly, teachers asking higher-cognitive level questions supports students' cognitive engagement (Chi et al., 2018). Higher-cognitive level questions enhance students active and constructive participation in their learning which aligns with the Next Generation Science Standards. Finally, another suggestion from the findings is the need to differentiate coaching during student teaching based on PSTs' initial SRL skills and task value. Even though in most teacher preparation programs, university supervisors give student teachers individual feedback, there is a lack of research on how to optimize the effectiveness of the feedback. Thus, some adjustments within the current structure of university supervision could give the institutions more control over the quality and better prepare teacher candidates for the profession.

Limitations of the Study

First, future research needs to select participants from a larger and more diverse sample of PSTs. Our study selected three cases from a group of 18 PSTs. Second, the participants' perspectives on the role of SRL and the role of teacher questioning might affect the quality of their SRL practice and their questioning. This study did not examine the participants' perspectives. Finally, we cannot draw causal inferences regarding the relationship between the PSTs' SRL practice and their questioning quality. Despite the limitations, the findings of this study support the idea that PSTs' SRL practice contributes to their ability to ask higher-level cognitive questions.

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CHAPTER 4

PROFESSIONAL LEARNING FOR PRESERVICE SCIENCE TEACHERS: SHIFTS IN TEACHERS' SELF-REGULATED LEARNING PRACTICE AND QUESTIONING SKILLS

To be submitted to the *Journal of Research in Science Teaching*

Abstract

This multi-case study investigated preservice science teachers' (PSTs) self-regulation of teaching. The participants were three PSTs representing low, intermediate, and high self-regulated PSTs in a certification program for teaching secondary science. Data came from classroom materials, semi-structured interviews about planning classroom questions, classroom observations, classroom audio recordings, and semi-structured interviews about enacting questions. Findings show that even though the changes that happened in each case had some unique characteristics, the quality of their self-regulated learning (SRL) practice and teacher questioning all increased. The analysis elicits PSTs' SRL practice in the context of planning and enacting classroom questions. The research suggests ways to optimize PSTs' questioning skills by integrating SRL into teacher preparation and offers a window into how PSTs' SRL skills can be better developed.

Keywords: Self-regulated learning practice, student teaching, preservice science teachers, self-regulation of teaching, teacher questioning

Introduction

One of the changes in recent reform standards for science instruction is the focus on knowledge construction rather than memorization of facts (NRC, 2012; NGSS Lead States, 2013). In reform-based instruction, teachers provide opportunities for students to engage in deep thinking and meaningful exchanges of ideas (Windschitl & Stroupe, 2017). One way to meet the expectation of engaging students in knowledge construction is to ask questions that stimulate student thinking and enhance meaningful discussions (Lee & Kinzie, 2012; Morris & Chi, 2020; Resnick et al., 2010). However, research has reported that science teachers do not often ask questions that require students to go beyond recalling facts they were taught (Banilower et al., 2013; Benedict-Chambers et al., 2017; Eshach et al., 2014). Thus, there is a

lack of alignment between science teachers' questioning practice and the standards. Given the misalignment, it is of vital importance to find effective ways to design professional learning for science teachers that increases the quality of their classroom questions.

Scholars agree that question asking plays an essential role in teaching (Chin, C., 2008; Morris & Chi, 2020; Otto & Schuck, 1983), but the use of fact-recalling questions is often not productive for student learning (Benedict-Chambers et al., 2017; Shields & Edwards, 2005). Researchers who study teacher questioning suggest that support is needed to alter classroom discourse patterns (Burns & Myhill, 2004; Skidmore et al., 2003; Townsend & Pace, 2005). Prior research has examined different aspects of teacher questioning (Chen et al., 2017; Lee & Kinzie, 2012); however, few studies have explored the most effective ways to support teachers in how to ask effective questions (Morris & Chi, 2020). We attribute this situation to a lack of an effective means of supporting teachers in asking higher-level cognitive questions. To develop questioning skills, teachers need professional learning opportunities and need to be supported in learning from the act of teaching. A systematic literature review on professional learning regarding self-regulated learning (SRL) for science teachers (Capps et al., 2021) shows that SRL improves both science teachers' learning and teaching, but there is a lack of learning opportunities for teachers that leverage SRL practices to optimize teacher questioning. Therefore, we propose a novel approach to increase the number of higher-level cognitive questions preservice science teachers (PSTs) ask during student teaching. In the context of implementing the approach, which integrates SRL into professional learning and coaching, we aim to answer the following research questions:

4. How does the quality of PSTs' SRL practice in planning and enacting classroom questions improve during student teaching?
5. How do the percentages of PSTs' question types change during student teaching?

This study distinguishes itself from previous studies because it focuses on understanding the process of change over time in PSTs' SRL practice and questioning. We acknowledge that higher-level cognitive questions are not the only type of questions PSTs should ask during instruction. Science teachers should ask diverse classroom questions. Nonetheless, given the lack of thought-provoking questions in science classrooms, fostering PSTs' competency to ask higher-level cognitive questions is a good place to start aligning science teachers' questioning practice and the science education standards.

Self-Regulated Learning

SRL concerns the application of regulation and self-regulation to issues of learning, particularly academic learning that takes place in classroom contexts (Pintrich, 2000). According to Zimmerman (1986), SRL is a goal-directed process in which learners are metacognitively, motivationally, and behaviorally active participants in their learning. SRL does not mean students learn by themselves; students still need help from teachers. SRL can be considered a broad term that includes different variables that influence learning, such as goal orientation, metacognition, strategic thinking and action, motivation, and emotion. In other words, "SRL is a complex and multifaceted phenomenon that is linked to goal orientation" (Pintrich, 2000, p. 485). And SRL has been viewed as both a process that facilitates students' effective performance in academic settings and as a valuable outcome of schooling.

SRL is critical for success in learning in academic life and beyond (Boekaerts, 1999; Cleary & Zimmerman, 2004; Perry, Nancy & VandeKamp, 2000; Pintrich, 1999). Highly self-regulated learners often feel empowered because they believe that success largely depends on one's skill in effectively using and adjusting strategies (Cleary & Zimmerman, 2004). According to Peters-Burton (2015), in this fast-changing world, knowledge continues to grow in an exponential way and technology fortifies the progress; students graduating from

high school must have the knowledge and skills to be independent learners. Many theorists argue that SRL is teachable; several studies have also supported the premise (Cleary & Platten, 2013). SRL is one of the educational goals in several national educational policies (Dalland & Klette, 2016). Despite the importance of SRL, a large number of students do not use the skills to serve their learning (Pintrich & Zusho, 2002; Zimmerman, 2008). One reason for this situation is that many students are not taught strategies that could help them regulate their learning. Another reason is that students are not given sufficient opportunities to regulate their own learning in the classroom to develop SRL skills (Buzza & Allinotte, 2013).

Kramarski and Heaysman (2021) distinguished three areas of SRL for teachers: self-regulation of learning, self-regulation of teaching, and promoting students' SRL. This study focuses on PSTs' self-regulation of learning from one's own teaching and self-regulation of teaching. Teachers should learn from their teaching experiences because teaching competencies can hardly be fully obtained before or apart from practice (Randi, J., 2004). In addition, teachers work in rapidly changing environments and need to update their teaching skills often (Randi, Judi et al., 2011). Furthermore, instead of waiting until ineffective instructional strategies have been adopted, researchers recommend starting SRL promotion in teacher preparation programs (Kramarski & Michalsky, 2009; Perry, N. E., 1998; Randi, J., 2004). The existing literature shows SRL has positive effects on several aspects of student teachers' learning and teaching, such as student-centered teaching beliefs, problem-solving skills, and design of lesson plans (Delfino et al., 2010; Dembo, 2001; Kramarski & Michalsky, 2009; Perry, Nancy E. et al., 2008; Randi, Judi & Corno, 2000).

Teacher Questioning in Science Classrooms

Changes in the Next Generation Science Standards (NGSS) have increased the expectations for active learning during science instruction (NRC, 2012; NGSS Lead States, 2013). Instead of classrooms in which science teachers are primarily content providers, the

current standards highlight instructions in which teachers ask questions to engage students in knowledge building (Schwarz et al., 2017). In traditional lessons, the primary purpose of teacher questions is to evaluate what students know. Whereas, in lessons that engage students in knowledge building, teacher questions are to prompt student thinking, elicit student thought process, and encourage students to exchange their ideas (Dalvi et al., 2021; Kawasaki & Sandoval, 2020; McNeill et al., 2017). In addition, flexibility is needed when asking questions in the classroom to accommodate student contributions; and responses to student thinking should be in neutral ways rather than evaluative manner (Chin, Christine, 2006).

Thinking with evidence and reasoning is at the heart of scientific literacy (Osborne et al., 2004). Instructional approaches that teach students how to think with evidence and reasoning give students opportunities to construct knowledge actively and make personal meaning from their shared experience via drawing on prior knowledge and via interacting with each other and with the teacher (Driver et al., 1994; Nystrand et al., 1997). Because students come to understand scientific concepts and scientific thinking as they are constructed in conversation (Driver et al., 1994; Mercer et al., 2004), Alexander (2006) argues that classroom discourse is the foundation of all learning and that the quality of student learning is closely linked to the quality of classroom talk. However, research indicates that it is not easy for teachers to create productive classroom talk (Harris et al., 2012; Pimentel & McNeill, 2013). Hackling et al. (Hackling, Mark et al., 2011; 2010) argue that in order to achieve sustainable improvements in students' science learning, there is a need to improve teachers' competency in creating and sustaining productive classroom discourse. Asking questions is a way for teachers to create and sustain classroom discourse.

To engage students in knowledge construction processes, science teachers should ask diverse classroom questions. For example, science teachers should ask open-ended or divergent questions which students can answer in multiple ways (Ash & Kluger-Bell, 1999;

Carin et al., 2005; Cliatt & Shaw, 1985; Colburn, 2000; Erdogan & Campbell, 2008). Connecting questions that require students to link the concept they are learning to their prior knowledge is also productive for knowledge construction (Worth & Grollman, 2003). Two other effective question types are probing questions and metacognitive questions. Probing questions request students to expand, clarify or justify their answers (Chiappetta et al., 2002). Metacognitive questions help students to be more aware of their learning process (Chin, Christine, 2007; Graesser et al., 2005). Teachers should also ask questions with the pronoun you to encourage students to focus on their reasoning instead of trying to provide the right answer (Carin et al., 2005). Since research shows most teachers' questions are fact-recalling questions, a necessary step toward asking diverse classroom questions is to support science teachers with asking higher-level cognitive questions.

In short, teacher questioning plays a crucial role in achieving the vision of science education reform. The standards require students to actively engage in constructing their knowledge, and the first step is that science teachers should ask more higher-level cognitive questions in the classroom. Higher-level cognitive questions stimulate student thinking, extend students' ideas, increase critical awareness, and encourage students to discover. The primary goal of classroom questioning is to facilitate students constructing their knowledge. SRL processes might help science teachers improve their questioning skills and shift from using questions as a tool for formative assessment to using questions as a way to facilitate students' knowledge construction.

Teacher Questioning Professional Learning for Science Teachers

Since asking good questions is the starting point for promoting classroom discourse that engages students in scientific thinking, it seems evident that science teachers should have the competence to ask good questions. However, according to Gall (1970), "research spanning more than a half-century indicates that teachers' questions have emphasized facts",

and “studies conducted in the last several years indicated that teachers’ questioning practices are essentially unchanged” (p. 712). The findings in research on teachers’ questioning practices are fairly consistent: about 60% of teachers’ questions require students to recall facts, 20% are about procedural, and 20% require students to think (Gall, 1970; Morris & Chi, 2020). Teachers spend most of their time asking low-level cognitive questions that do not help students acquire a deep, elaborate understanding of the subject matter (Wilen, 1991).

One of the reasons teachers emphasize factual questions is the lack of effective teacher preparation programs (Gall, 1970). Probably, teachers did not often encounter good teacher questions when they were students themselves; and they were not taught systematically how to ask productive questions in the course of their teacher preparation program (Corden, 2004). Gall (1970) emphasizes the need for effective teacher professional learning programs to implement desired questioning strategies in the classrooms. And some teacher preparation programs have included questioning as one of the generic instructional skills that graduates should develop during their preservice experiences (Ralph, 1999). Findings from Dos et al.’s study (2016) reveal that teacher questioning competence must be considered more important in preservice education, and teachers must be supported with professional development programs. Regarding how to use questions in teacher training programs, Gall (1970) stated that teachers could not be expected to learn new pedagogies if they are presented to them in vague, general, undefined terms; they can be expected to learn new methods if the methods are presented, at least in part, as sets of specific types of questions asked in specific classroom situations.

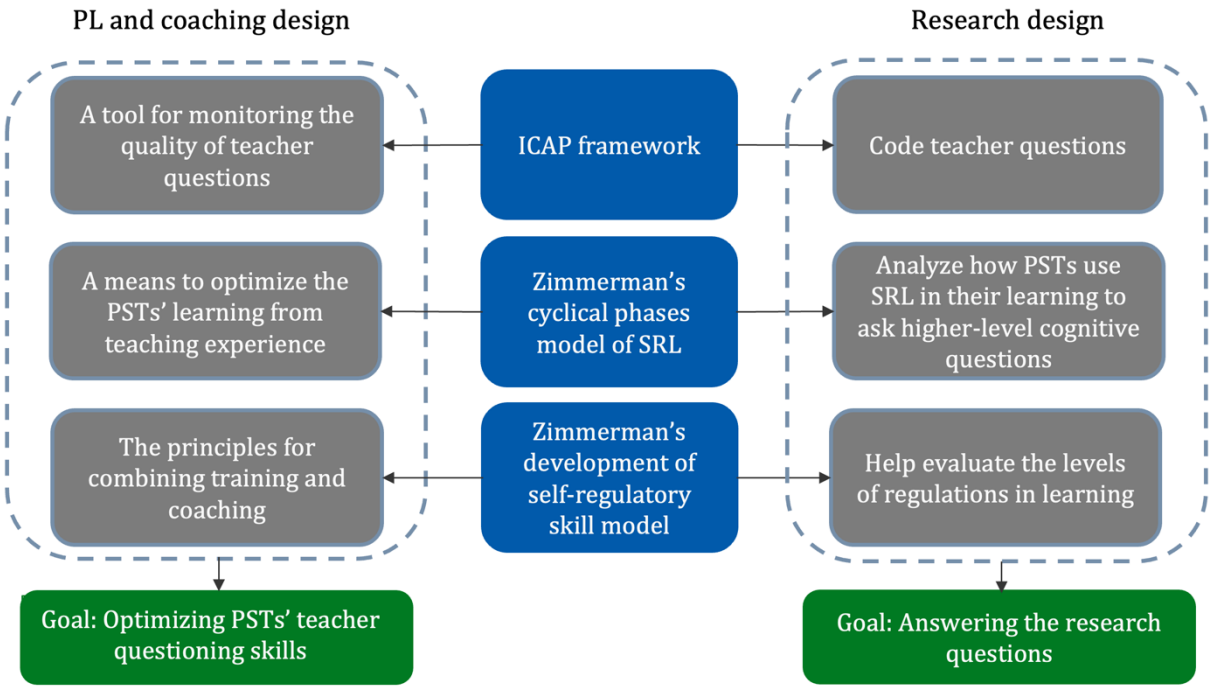
Theoretical Framework

This study is framed by three theoretical frameworks: the Interactive, Constructive, Active, and Passive (ICAP) framework of cognitive engagement (Chi & Wylie, 2014),

Zimmerman's cyclical phases model of SRL (Zimmerman, 2000; Zimmerman & Moylan, 2009), and Zimmerman's development of self-regulatory skill model (Zimmerman, 2002). The frameworks inform both the professional learning and coaching design as well as the research design of the study (Figure 1).

Figure 1

Theoretical Frameworks that Inform this Study



Interactive, Constructive, Active, and Passive (ICAP) Framework of Cognitive Engagement

The ICAP framework describes a continuum of four modes of learning with progressively more cognitive engagement: passive, active, constructive, and interactive (Chi & Wylie, 2014). Passive engagement leads to storing new information in an isolated way, and then students can only recall the facts. The active mode of engagement helps students integrate new information with activated prior knowledge, leading to the ability to apply the knowledge in similar situations. Constructive engagement supports the inference of new knowledge from activated and integrated knowledge. The learning outcomes of constructive engagement allow students to extend what they have learned to new contexts. Engaging

interactively in the learning activities fosters students' ability to co-create when working with peers.

There are four types of questions that align with the four modes of engagement. Passive questions are those that do not expect learners to verbalize an answer, or the answer was provided in the question itself; for example, “So… where’s the gene? It’s on the chromosome, right?” Active questions ask learners to recall information from background knowledge or previous lessons; for example, “Who remembers what we talked about yesterday with predator and prey, about the relationship between predator and prey?” Constructive questions ask learners to go beyond the presented materials; for example, “What will happen to the mice that have the mutation described in the text?” (Morris & Chi, 2020, p. 7-8). Interactive questions are those that require students to exchange their constructive ideas with a partner(s) (Chi & Wylie, 2014). One example of interactive questions is when students are asked to mutually exchange ideas with another student on “What real-world applications are there for Phylogenetic tree?”. Thus, asking constructive questions and interactive questions are preferred in terms of stimulating student thinking. This framework is introduced to PSTs as a tool for monitoring the quality of their questions because the defining characteristics of constructive and interactive questions in ICAP are easier for teachers to utilize compared to other question typologies (Morris & Chi, 2020, p. 3). The framework will also be used to develop a coding scheme to analyze teacher questions.

Zimmerman’s Cyclical Phases Model of SRL

The Zimmerman’s cyclical phases model of SRL (Zimmerman, 2000; Zimmerman & Moylan, 2009) is grounded in social cognitive theory. The model consists of three phases: forethought, performance, and self-reflection, with an emphasis on goal orientation. Each phase comprises different processes; the forethought phase also comprises motivational constructs. In the forethought phase, learners analyze learning tasks, set goals, and

strategically plan to achieve the goals. Learners' self-motivation beliefs affect the goals learners set for their learning. During the performance phase, learners aim to monitor their learning process. The self-reflection phase is when learners evaluate the results of their work and identify possible causes of their performance. Learners' attribution of their success or failure affects their motivation and learning behaviors in the next learning cycle (Zimmerman & Moylan, 2009). This framework was included in the SRL professional learning for PSTs, and was used to analyze data from reflective writings, and semi-structured interviews.

Figure 3

Zimmerman's Cyclical Phases Model of SRL (Zimmerman & Moylan, 2009)

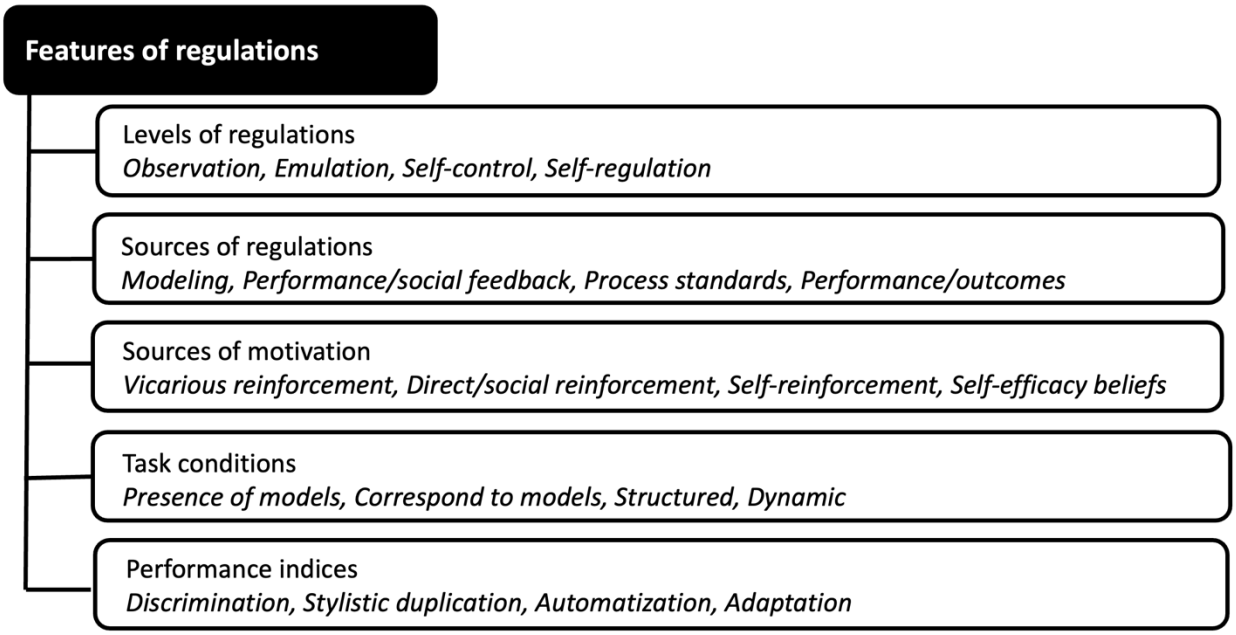
Zimmerman's Development of Self-Regulatory Skill Model (Zimmerman, 2002)

Zimmerman's development of self-regulatory skill model (Zimmerman, 2002) includes four levels: observation, emulation, self-control, and self-regulation (Figure 3). At the observational level, learners need the presence of models and vicarious reinforcement. The emulation level of regulation is attained when learners approximately duplicate the general form or style of a model on a similar task. That is, learners primarily emulate the strategic features and blend them in their own way. Learners' accuracy and motivation to emulate are enhanced if they receive guidance, feedback, and social reinforcement (Zimmerman, 2002). To acquire the self-controlled level, learners must practice what they

have learned in structured settings outside the presence of models. At this level, learners who focus on fundamental processes or techniques rather than on learning outcomes are more successful in achieving automaticity (Zimmerman & Kitsantas, 1997). To accomplish the self-regulated level, learners should practice in unstructured settings. At this level, learners can practice with minimal process monitoring so their attention can be shifted toward performance outcomes without detrimental consequences. The self-regulated level is acquired when learners can adapt their performance to changing situations (Zimmerman, 2002). The existing study's approach, which includes both professional learning and coaching, was based on this theoretical framework. The professional learning targeted observation and emulation level of regulation for teacher questioning. The coaching focused on emulation and self-control level of regulation with the goal that at the end of the program, the PSTs could move to the self-control or self-regulated level. We also used this framework to analyze interviews and to evaluate the level of regulation in planning and enacting classroom questions the PSTs have reached at the end of the coaching.

Figure 3

Social and Self-Sources of Regulation



Method

This research is a multi-case study (Yin & Campbell, 2018) using multiple analysis methods. The research method was chosen for this study because it allows investigating in depth and with real-world context (Yin, 2018). The analyses focused on changes in SRL practice and teacher questioning within each case over time.

Participants

To represent variance among PSTs, three participants were purposefully selected from 18 PSTs enrolled in a certification program for teaching secondary science. The participants represent low, intermediate, and high self-regulated PSTs. Appendix 1 shows the rubrics for participant selection.

Context

SRL lessons and teacher questioning lessons were embedded into a teacher preparation program for secondary PSTs. Those lessons provided participants with the foundations of SRL and teacher questioning, both theoretically and practically. For example, the two teacher questioning lessons discussed the roles of higher-level cognitive questions in science classrooms based on the ICAP framework and the current science education standards . Then, participants used the ICAP framework to classify sample classroom questions. Appendix 2 summarizes five lessons that happened during the Fall of 2021. The primary aim of coaching was to facilitate participants' learning from the act of teaching to be better at SRL practice and asking higher-level cognitive questions. Coaching occurred in Spring 2022 during student teaching (Appendix 3).

Data Sources

Research data were collected from multiple sources (Appendix 4) as part of the effort to minimize bias in the study.

Teacher Questioning Data

Data for teacher questioning were primarily collected via classroom materials and audio recordings. Classroom materials (lesson plans, slides, worksheets, etc.) of the first, middle and last lesson of student teaching were collected and examined before a researcher observed the PSTs teaching the lessons. Those materials and other data sources helped determine whether the content was explicitly provided to the students; this information was necessary to code the types of questions the PSTs asked. Audio recordings of the teaching were also collected.

SRL Practice Data

The primary data sources regarding SRL practice were interviews and classroom observations. Semi-structured interviews about planning lessons were conducted to gather data about how the PSTs used SRL processes while planning questions for the lesson. These interviews were conducted after the PSTs completed their lesson plans (before the teaching). Classroom observations helped researchers get a sense of the context of the classroom and what the teaching entailed. During classroom observations, the researcher took notes of the discourse and activities in the classroom. Within 24 hours after the lesson, the researcher conducted interviews with the PSTs to understand what they thought about the questions they asked during the instruction, why they asked the questions, and how they used SRL processes while teaching. Interviews followed Patton's (1990) recommendations for standardized, semi-structured interviews. During the interviews, the researcher's responses to the PST were a combination of non-leading leads and low-inference paraphrasing (Carspecken, 2013). After each interview, the researcher typed an interim case summary as the first attempt to drive a coherent, overall account of the case.

Data Analysis

Classroom recordings were transcribed using Otter.ai. Once transcribed, the questions were coded as either interactive, constructive, active, or passive according to a coding scheme

developed based on the ICAP framework (Chi & Wylie, 2014). After that, the total number of questions and the percentage of each type of questions was calculated.

Three coding cycles were used to analyze the interviews: two rounds of a priori coding, followed by pattern coding. Initial rubrics with three code levels: maladaptive (1), partly adaptive (2), and adaptive (3) were developed based on existing research (Chi & Wylie, 2014; Peters-Burton & Botov, 2017; Peters-Burton et al., 2020; Smith, 2020). The rubrics also included sample responses for the adaptive codes that show what an expert would attempt while accomplishing the tasks (Peters-Burton et al., 2020). A researcher used the rubrics to code all the interviews while simultaneously revising and adding codes to the rubrics. The process ensured the codes adequately represented the meanings in the participants' responses, which resulted in final rubrics with five code levels: missing (1), maladaptive (2), partly adaptive (3), adaptive (4), and fully adaptive (5). The five-level rubrics were used for the second round of a priori coding. Since there were no differences in the quality of PSTs' self-regulation of planning questions and self-regulation of enacting questions, the score for each SRL process was calculated by averaging the planning score and the enacting score. After that, pattern coding was conducted to understand how changes within each case happened over time. Findings from the pattern coding were then mapped to the four levels of regulations in Zimmerman's development of self-regulatory skill model (Zimmerman, 2002) to better see the growth in the participants' SRL practice. Two researchers independently coded the data, all discrepancies were then discussed until a consensus for final codes and themes was reached.

Finding

The findings will be presented by case (high, intermediate, and low self-regulated teacher). Within each case, we will explain the trends over time in SRL practice (goal setting,

self-monitoring, and self-evaluation) and in teacher questioning. The changes that happened in each case had some unique characteristics, such as the initial quality, the level of improvement, and the pattern of growth (i.e., the specific aspect of SRL and teacher questioning in which the PSTs improved most).

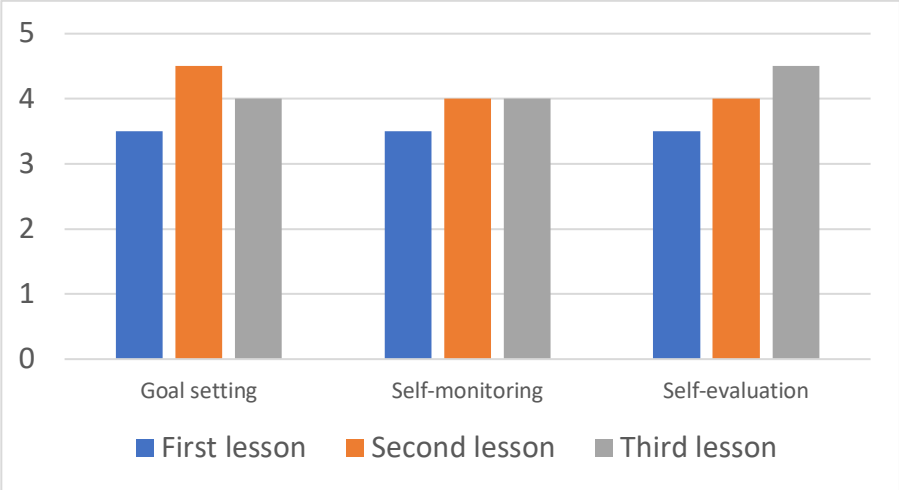
High Self-Regulated Teacher Case

SRL Practice

Figure 4 shows changes in Alex's average scores for goal setting, self-monitoring, and self-evaluation over time.

Figure 4

Changes in the Quality of Alex's SRL Practice Over Time



Goal Setting: Alex's scores for goal setting markedly increased from the first to the second observed lesson and decreased slightly from the second to the third lesson. The score started at three and a half, meaning Alex set goals for planning and enacting questions with justifications on why he set the goals, but the goals were not really clear. Below is an excerpt that shows Alex's response touched on goals, but the main point of what he discussed was more about how to come up with good questions to ask than what he wanted to achieve with

the questioning. In other words, the response was more about how to plan questions than what the goals of the questioning were.

> "I think that I kind of work backwards. When I think about questioning, I think about what the answer is that I'm looking for, or what the what the right answer is, I guess. And then thinking about a really specific question that would get to that answer. And then think about a larger question that would lead you to that question and kind of work outwards from there… Because as someone who knows the answers that I'm looking for, it's really easy for me to think about an active-level question, I guess that would immediately spark the answer from this, where they could just regurgitate something from their notes. But if I think about a question that would lead to that question, or a line of thinking that would lead to that question that gets them that answer. I think the backwards approach method has worked best for me, and it's definitely how I modeled all of my questioning the lessons" (first planning interview).

In the second planning interview, Alex had goals for his planned questions, which were clearer than his goals for the questions in his first lesson plan. The goals were to prompt student thinking, address student misconceptions, and assess students' understanding. He said,

> "I think if they can identify something that's wrong with a lab, that means that they understand the concept of the lab behind it very well... But even if that's not the case, then they should be able to explain how that's different from natural selection or why it's not supported by natural selection, or why it's the same to natural selection... So I wanted to tackle different misconceptions with each question, but also really dive deep and see what they know about natural selection" (second planning interview).

Alex's goals for planning and enacting questions in the third observed lesson received slightly lower scores compared to the second lesson. Alex wanted to connect the lesson to previous lessons and make the lab relevant to environmental science as well as the standards. From Alex's clarification, the lesson plan, and classroom observation, we can say the goal focused more on recalling than on student thinking. The percentages of different types of questions in Alex's questioning (see the next section) also reflect this goal. Alex said,

> "So in order to make it a good summarizer of the last three units, we have to think of questions that tie one little solar-powered car back to three units of content in order to be productive… in order to make it relevant to environmental science, and the environmental science standards" (third planning interview).

For the second lesson, Alex had the freedom to choose what to do and how to do it. He came up with the ideas and designed the lesson by himself, so he knew the lesson well: "The other thing that I learned was how beneficial it is to know your lesson inside and out. I could have answered any question about that lab, asked by anybody in the world" (second teaching interview). It was not Alex's choice to design the third lesson. The mentor teacher handed Alex some available materials, and Alex had a week to design a project which used the materials and linked with previous lessons of the class. The last-minute change was not something Alex was happy with. Designing a lesson that fit the available supplies was also not something he wanted to do; he wanted to start with the concept that need to be learned. Thus, the changes seemed to affect Alex's goals for the lesson. He said,

> "And so my mentor teacher gave us all the supplies and just kind of said, 'you do what you think would be good with this,'… which is typically not what I would hope to do, I would typically rather have the idea for a lesson, and then be and then have to go out and find the supplies for that and make it happen" (third planning interview).

Self-Monitoring: Alex's scores for self-monitoring started quite high, slightly increased from the first to the second observed lesson, then stayed the same. While planning the first lesson, Alex self-monitored to ensure his questions covered different concepts of the topics: "I wanted to make sure that I was hitting on all the topics that I wanted to hit on" (first planning interview). In the third lesson, Alex did a little better with self-monitoring. He kept track of planning questions that addressed student needs or misconceptions: "I tried to prepare a good number of questions based on the struggles that students were having either struggle that they were having building their cars or just misconceptions about the idea of building a car" (third planning interview).

Self-Evaluating: Alex's scores for self-evaluation constantly increased over time. While reflecting on teaching the first observed lesson, Alex evaluated whether he asked all his planned questions and how he would have done better. The following excerpt shows the point:

> "I looked back at my notes and checked how many questions I hit out of the ones I wanted to hit. And I believe I hit all or close to all of them. I think that there were some rabbit holes that I could have gone down that I didn't go down, some pathways where I started with a constructive question and worked towards the answer with probing questions. And there are opportunities that I could have done that and missed out on, but in general, the big-ticket questions that I wanted to ask, I asked, and I felt like I got reasonable answers out of them" (first teaching interview).

While self-evaluating his enactment of classroom questions in the third lesson, Alex evaluated not only how he enacted his planned questions but also whether the questions prepared his students for the next lesson. He said, "I think that reflecting on questions today made me anxious that they've been in this mode of building without knowing many

consequences for too long. And I thought about if the questions I asked fully prepared them for tomorrow" (third teaching interview).

Teacher Questioning

From the beginning of student teaching, Alex wanted to implement different instructional approaches (see Table 1). Even though Alex did well in his first observation, at the end of the first teaching interview, he said,

> "I hope to have different styles of lessons in the future. This was a pretty chill day as far as it was a lot of notetaking and working just in partners, nothing exceptionally exciting, but as far as like standard day and class would go, I think this is definitely good practice."

In the first lesson, Alex lectured most of the time. The second observed lesson was about data collection outside of the classroom. For the third lesson, students developed models of solar-powered cars and Alex circulated the classroom to ensure students were on task and asked questions to guide the work. The different settings made it harder for him to ask questions, but it helped him learn more about asking questions in different classroom settings. The excerpt below is an example of how Alex thought about asking questions while students collected data outside the classroom. The classroom setting was more dynamic, and Alex needed to be more adaptive while enacting his planned questions compared to the first observed lesson. Since Alex was not used to asking questions in such dynamic setting, he thought he was not as good as he hoped to be.

> "I think so because it was an environment that's different from what I'm used to asking questions in. And it was a challenge because I was not in a classroom where I could talk to one group of students or every group of students all at once. So I think

that it gave me a little practice towards those more student-centered lessons and how you can still be a good teacher and use good teacher questions during those. I think that I was not as good as I would hope to be. But the lesson was as good as I hoped it would be. So, it's helping me to see what the teacher needs to do in addition to just prepare a good strong lesson, but how they can execute that and make it even better" (second teaching interview).

Table 1

Percentage of the PSTs' Question Types in the Three Lessons

	Alex			Mia			Ara		
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Lesson type*	L	DC	DM	L	L	L & DM	L	L	L
Questions per min	1.3	1.3	0.9	0.9	1.6	1	0.4	1.4	1.5
Interactive (%)	1	7	14	0	0	6	0	1	1
Constructive (%)	55	28	2	10	33	43	13	12	14
Active (%)	38	51	72	63	51	43	44	63	65
Passive (%)	6	14	12	27	16	8	43	24	20

* L = lecture, DC = data collection, DM = developing models

From the first observed lesson, Alex did well with teacher questioning. He asked many questions during the lesson, and more than half of the questions (56%) were interactive

or constructive (Table 1). After the first observation, Alex wanted to ask more interactive questions that made students exchange ideas. Reflecting on his second observed lesson, he said, “There were some missed opportunities for good discussion, too. And I think part of that is timing related. But also part of it is because I was I made up this lesson, and I was doing it for the first time” (second teaching interview). Alex did ask more interactive questions in the second lesson. However, the percentage of constructive questions decreased significantly, and the percentage of active and passive questions increased significantly. Similarly, in the third lesson, Alex focused more on asking interactive questions, he doubled the percentage of this type of question. However, he asked fewer constructive questions and more active questions.

It is worth noticing that in the third lesson when Alex asked many interactive questions, the questions per minute rate decreased. This makes sense because teachers need to give students time to discuss after asking interactive questions. Thus, the more interactive questions asked, the more classroom time is needed for small group discussions and less time for additional questioning.

Overall, there were mixed changes in Alex’s questioning. The positive shift was the increase in the number of interactive questions. Since asking interactive questions is not easy, the improvement was important. The negative shift was the decrease of constructive questions and increase of active questions. Besides the quality of Alex’s self-regulation in planning and enacting classroom questions, the lesson type might affect the shifts.

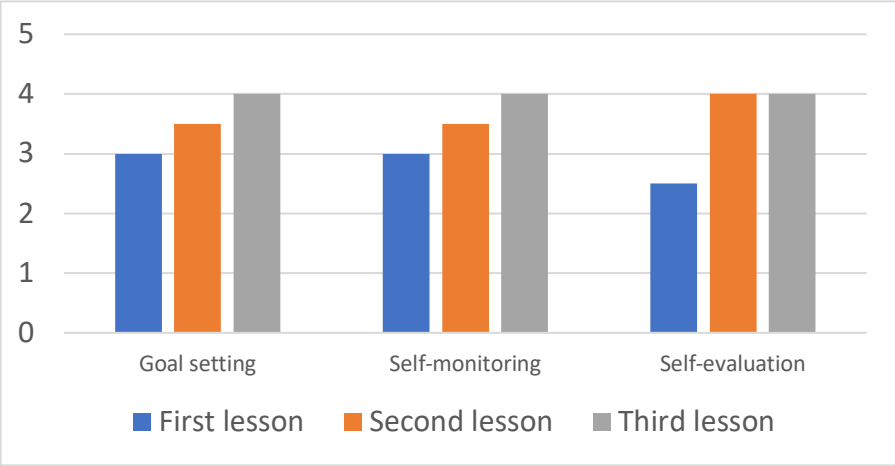
Intermediate Self-Regulated Teacher Case

SRL Practice

Figure 5 shows changes over time in Mia's average scores for goal setting, self-monitoring, and self-evaluation.

Figure 5

Changes in the Quality of Mia's SRL Practice Over Time



Goal Setting: Mia's scores for goal setting consistently increased from the first to the third observed lesson. The score increased from three, which means Mia set goals for planning and enacting questions, but no justification for the goals was mentioned, to four, which means Mia knew why she set the goals, but the justification was not clear. Over time, Mia set clearer and higher goals for questioning. In the first interview about planning the lesson, Mia said, "Um, yes, I would say I specifically didn't want to ask any yes or no questions. I wanted to have like some more abstract questions, I guess like, DOK [depth of knowledge] level three, I think that's more abstract." Mia knew that she wanted to ask some abstract questions, but she was not sure what types of questions she should ask. More importantly, Mia did not mention what she aimed to achieve via asking the questions (e.g., stimulate student thinking, check for misconceptions). Responding to the same question in the third planning interview, Mia said:

> "Well, I wanted to have specific questions for different sections of the lesson… I wanted some of it to be like a class discussion, some of it to be like, a small group

> discussion, and some of it to be independent... And so my goal was to not only see where we were as a class, but to see if there were any misconceptions."

At that time, Mia's goals for teacher questioning were clearer (but not necessarily higher). She wanted to use classroom questioning as a formative assessment. And Mia also had goals for not only what questions to ask but also when and in what context to ask the questions. During the last teaching interview, Mia said, "I think I was able to make more clear goals and like purposeful goals, and understand why I was making those goals, not just making goals for the heck of it." The response shows Mia was aware of her improvement.

Self-Monitoring: The pattern of changes in Mia's quality of self-monitoring planning and enacting questions was the same as the changes in her goal-setting quality. There was constant improvement over time. In the first planning interview, Mia could not distinguish self-monitoring from self-evaluation. She said, "Um, I don't know if this is self-monitoring or not. But I definitely reread the questions multiple times to make sure they make sense after I wrote them." Mia also did not use her goals, which is to ask more abstract questions, to monitor her process of planning questions. But she learned quickly, and in the second planning interview, she said:

> "I kept track of what type of question I was asking… And I also kept track of which objective of the lesson I was actually addressing with my questions… So I really tried to evenly spread out my questions across the learning objectives for the lesson."

During the first observation, Mia did not ask all her planned questions. Then, after teaching the lesson, she learned that the students were capable of answering higher-level cognitive questions. "I learned that they responded well, to like higher level thinking. I was a little nervous that they were just gonna be like, I don't know. So, I learned that they were capable of answering higher-level questions" (first teaching interview). At this time, Mia was still not confident in her ability to monitor asking her planned questions, but she wanted to

have more questions to choose from while teaching; she said, “I want to have more quantity of questions to choose from, even if I don't hit all of them. I wouldn't. I want to think I want to focus on having like more.” While preparing lesson plans for the third observed lesson, Mia monitored to organize when to ask specific questions. She said, “I tried to develop my questioning and like, organizing the way I was thinking about when I'm going to ask them and not just kind of putting them down and waiting to see what happens” (last planning interview). Mia used her goal, which is “I wanted to have specific questions for different sections of the lesson”, to monitor the process of planning questions, “A thing I did differently for this lesson was I like broke them into different sections and like correlated it with the sections of the lesson.”

Self-Evaluating: From the first to the second observed lesson, there was remarkable improvement in the way Mia self-evaluated her planning and enacting questions. At the beginning of coaching, self-evaluation was Mia’s weakest SRL process. Mia did not self-evaluate her planned questions for the first observation. She did not know whether her questions were good or not, so she asked her mentor teacher to evaluate her questions: “I asked her [mentor teacher] if those [questions] were good or not. So I did it that way.” Even though Mia mentioned DOK level three, she could not use it as a standard to self-evaluate her planned questions. Five weeks later, Mia self-evaluated her questions after typing them. She said, “I went over kind of made sure there were no yes or no questions and see if they were worded in a weird way. And also, I went back and kind of said, ‘Okay, what are some possible answers?’”

Mia moved from “when I first started, it was like, ‘I think that's good enough’, like I don't want to do anymore,” to “I put more effort into it in the revision part of it” and “I made myself go back and actually, like, reread it and check for my goals more than usual.” Since

the quality of Mia's self-evaluating was lower than setting goals and self-monitoring, it was good that she put more effort into it. The reason behind the change was that Mia started seeing the role of reflection; in other words, "learning from mistakes and learning about the consequences that happen when you don't reflect and like what that looks like," she added,

> "I think I started to see what happens when I don't self-reflect on it. So, when I wasn't like, reflecting on lessons, I kind of found out that those are more of my days that like, I don't get as much accomplished as I want to in the lesson. And I don't hit the learning objectives as well. And I feel a little less prepared when I'm actually teaching it" (third planning interview).

Mia also found another way to evaluate her planned questions: "And then I reflected kind of in the eyes of a student like what they might say about it. And I haven't done that before. So that was definitely a new part of my reflection for this lesson" (third planning interview). Moreover, Mia saw the effect of the forethought–performance–reflection cycle of SRL; thus, she used her reflection to inform her next cycle of teaching and paid attention to what she needed to do better. She said,

> "Throughout the study, I've realized like how important it is to be specific with your reflection and how you can kind of adapt the way you set your goals for the next lesson based on the reflection of the past one and really focus on things you need to improve on" (third teaching interview).

In short, Mia did improve a lot regarding self-evaluation and adaptation, and she was aware of her progress. The two quotes below show her awareness.

> "I definitely feel like I made a huge improvement in the way that I plan my questioning and the way that I organize it. And then the way that I actually implement

> it in the classroom and have a plan for it" and "I've also kind of learned more about like, where their challenges lie, like what types of questions really challenged them" (third teaching interview).

Teacher Questioning

Mia did not purposefully implement different instructional approaches, but she did pay attention to diversifying classroom activities such as taking notes, reading, watching videos, completing worksheets, and having small group discussions. Mia cared about the hands-on aspect of classroom activities and used them to get students interested in the lesson topic. The first priority was not about using the activity to help students better understand the scientific concept. She mostly lectured during the first two lessons. In the third lesson, besides lecturing, Mia gave students 12 minutes to develop models of moths (Each student created their own model of moths by cutting and coloring. The students aimed to have their moths hide best in the classroom). Then, Mia linked the moths activity with the concept of camouflage.

Mia asked many more questions in the second lesson than in the first one (see Table 1). As described in the SRL practice finding, the second lesson was when Mia paid more attention to teacher questioning and knew better how to regulate the work. Similar to Alex, in the third lesson where Mia asked more interactive questions, the number of questions per min was lower. At this time, Mia understood better different types of questions and knew better how to integrate classroom questions into different classroom activities.

Table 1 shows the percentage of each type of questions Mia asked in the three observed lessons. Broadly, there was a positive shift in the quality of Mia's classroom questions. Compared to the first lesson, Mia asked many more constructive questions, fewer active and passive questions during the second lesson. In the third lesson, Mia asked three

interactive questions (6%) that required students to exchange their constructive thoughts; she also asked more constructive questions, fewer active and passive questions. Most of Mia's constructive and interactive questions started with "why" or "what if."

Low Self-Regulated Teacher Case

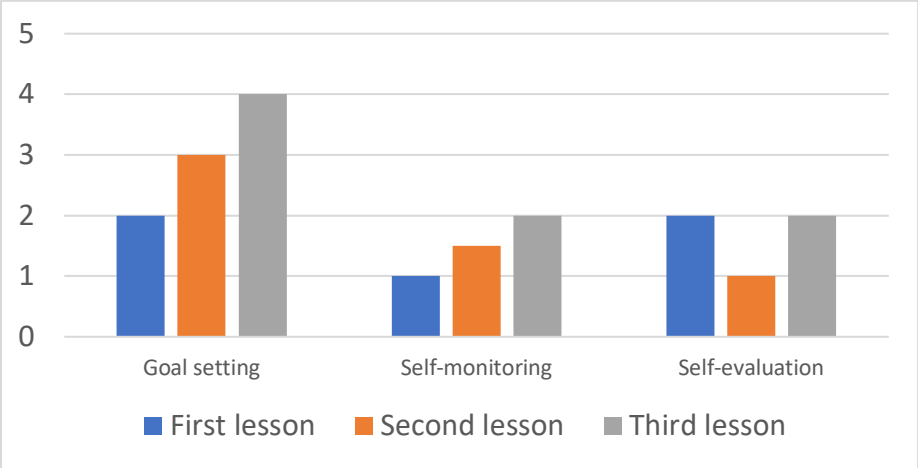
SRL Practice

Goal Setting: There was constant improvement in the quality of Ara's goal setting (Figure 6), which means over time Ara did learn what good questioning looks like. In the first planning interview, Ara did not have a clear goal for her planned questions. It seems like Ara wanted classroom questions to help students learn the content of the lesson, but the goal was not explicit. She said, "I would read a PowerPoint slide, go, 'oh, what's the thing to take away from this?' And then design a question around it... I'm more on the fly when I'm up with the board." Relatedly, at the beginning of student teaching, Ara believed her style of teacher questioning was to come up with questions while teaching.

In the second planning interview, Ara had a clearer and higher goal for her questions. Ara was also aware that she needed to work more on her questioning skills. These were shown in her response: "I attempted to ask more thought-provoking questions, like questions that have more complex answers… I admit that I need a lot of work on the questions." However, Ara's goal for enacting her planned questions did not align with the original goal that she set while planning the questions. Ara changed her goal to focus on active engagement instead of constructive engagement, which requires higher-level thinking. She said, "I wanted to more engage the students that typically tend to not pay so much attention during class, only to make the lesson interesting enough to capture their attention" (second teaching interview).

Figure 6

Changes in the Quality of Ara's SRL Practice Over Time



Self-Monitoring: There were slight improvements in Ara's self-monitoring scores over time. Nonetheless, the initial score was really low; the improvement did not lead to the desired result. At the beginning of student teaching, Ara did not self-monitor her process of planning questions; she said, "Truthfully, no, I feel like I just kind of wrote questions that I thought would be good and expected that if I thought of anything else while it was up there, I would say it. So no, I apologize" (first planning interview). Similarly, Ara did not self-monitor enacting classroom questions while teaching; she said, "The questions just kind of took a back burner in my head, I just kind of put them aside and forgot about them until after the observation had ended. And then I went, 'Oh, I could have done that better'" (first teaching interview). Ara's response revealed why she did not pay attention to or did not prioritize questioning; she said, "My main thought processes when I was up there was like, 'Okay, make sure I get the content, right, like, Okay, make sure like, don't mess up, don't mess up, don't mess up'" (first teaching interview). So, Ara's worries about delivering the content right took all her working memory as she said, "I'm not sure there was like that much room for other thoughts" (first teaching interview).

Near the end of student teaching, Ara learned that she should monitor her work while designing lesson plans and while teaching. So, Ara aimed to do so. However, the quality of her self-monitoring was low. In responding to the question “Did you self-monitor during the time you planned your questions” Ara said, “I guess I kept track of like, what the main ideas of the unit were. If that counts as something to keep track of, like I hopefully didn't leave out any major things that we talked about” (third planning interview). The way Ara monitored was more for the content of the lesson in general (making sure the lesson covered the main concepts that would appear in the test the week after), not specifically for teacher questioning. This way of monitoring might help with the content of questions (what concepts to ask) but does not guide choosing the types of questions to ask. Regarding self-monitoring enacting classroom questions, the PowerPoint slides helped remind Ara to ask questions, but she did not purposefully use the slides as a tool to keep track of her questions. This is shown in the following except.

> “So seeing the slide kind of reminded me a lot of like, Oh, I was going to ask this question, um, that being said, it was not as purposeful, as maybe you're thinking it was because again, when I'm in the process of teaching, I'm hyper focused on the teaching, and I don't really have room in my brain to be thinking about, like, keeping track of a lot of different questions” (third teaching interview).

Even though Ara did not monitor the types of questions, she paid attention to the wording of her questions. While teaching, Ara focused on communication (saying things that make sense to students): “Making sure that what I am saying makes logical sense… I'm more focused on making sure I'm communicating it clearly. And in a way that would make sense to someone who's never seen it before” (third teaching interview). In addition, Ara paid attention to student reactions to her questions. She said, “and then also keeping track of their

reactions to it" (third teaching interview). Ara was aware of her low self-monitoring skills. She said,

> "I don't really have the space to mentally check myself as I'm going. So oftentimes, I find myself planning out stuff really well. And then doing it's all just kind of a blur. And then afterward, I spend a good amount of time self-reflecting, but the performance phase, I think, is where my brain is the most turned off, and I tuned out to the whole SRL process" (third teaching interview).

It was correct that Ara planned her questions better than enacting the questions. It was also true that self-monitoring is where Ara needed to work on more than the other two SRL processes because the failure to enact what she planned lowered Ara's motivation to put more effort into self-regulating her work. Nevertheless, Ara did not spend a good amount of time on self-reflection. The next section will provide evidence for Ara's ineffective self-evaluation, which is a sub-process of self-reflection.

Self-Evaluating: Ara's scores for self-evaluation started at two, which means maladaptive, decreased to one (i.e., no self-evaluation on teacher questioning), and returned to two. In the first planning interview, Ara said, "I basically did a round of 'okay, I want this to be a shorter list. Let's cut out all the weaker ones'". To cut out some questions, Ara might somewhat evaluate the question list. However, she could not elaborate on how she decided which questions to remove. Ara said she cut out some weaker questions, but she did not have a standard for evaluating the strength of the questions. She just used her feeling and felt like she did not closely evaluate her questions.

Ara did not self-evaluate her questions for the second observed lesson. One of the reasons was that she did not have a framework to facilitate evaluating the questions. Ara said,

“Um, I guess I didn't closely evaluate them. I'll admit, I just kind of like, ‘Okay, that looks good’” (second planning interview). Another reason is that Ara needed to see students’ reactions to the questions to evaluate her questions. She continued, “which I guess is the best I can do without actually seeing the response I get from students” (second planning interview). Even though Ara said she needed to see her students’ reactions to evaluate the questions, she did not evaluate after seeing her students’ reactions to the questions (after teaching the lesson), as she said, “I looked at the lesson as a whole, but I don't really think I honestly put that much thought into the questions after the lesson was over” (second teaching interview). Here Ara also admitted that she did not know how to self-evaluate her teacher questioning productively; she added, “that's something that I have been struggling with a little bit. So, I guess now is when I'm reflecting on them more” (second teaching interview). Using the interview as a chance to evaluate her teacher questioning, Ara thought it would be better for student learning if she asked all her planned questions; she continued,

> “I definitely hit some of the questions that I wanted to. But as you mentioned, I totally did forget some of them, which is kind of disappointing because I had carefully crafted them to be like, for the lesson. So, anything that I forgot to mention, I feel like it's like lost knowledge to my students. Um, so yeah, um, I'm gonna say three or four, because the ones that I did ask I felt went pretty well” (second teaching interview).

Part of Ara’s responses in the third planning interview revealed a reason for her low ability in self-monitoring and self-evaluation. Ara thought it was not effective to evaluate her questions before enacting them.

> “I don't think that trying to evaluate before you give the lesson is really an effective strategy… So again, same answer as before, I don't really believe that it's that

constructive to try and evaluate my work before I actually get to see the effect that it has on my students" (third planning interview).

Instead of having a goal and a standard to self-evaluate her questions before asking them, Ara wanted to use student reactions to evaluate, which she did not really do. Since Ara believed that evaluating classroom questions before enacting them was ineffective, she did not invest time and effort in doing so. Without the evaluation, Ara was not sure whether her planned questions were good. Thus, she did not commit to asking the questions. This lowered Ara's motivation to find a more effective way to keep track of her questioning. Ara's strong belief also prevented her from trying the suggested techniques she received from the coaching. In general, Ara was not willing to change the way she worked. One reason Ara did not consider changing her approach is that she was happy with how she taught: "I'm going to give it a four [out of five]. Because, well, I think it's a pretty good lesson… generally, I'm pretty happy with it" (third teaching interview).

Teacher Questioning

Overall, the primary instructional approach that Ara implemented during the three observed lessons was lecture (see Table 1). Ara used a few videos, worksheets, and small group discussions. However, those activities were short (one to 10 minutes) and served to demonstrate or review some of her points in the lectures. Similarly, Ara used classroom questions as a way to remind students what they had learned in the previous lessons or as formative assessments to check whether students understood the concepts in the lessons. In the first observed lesson, Ara did not ask many questions; she ended up turning some of her planned questions into explanations without asking the questions. In the next two observed lessons, Ara asked many more questions.

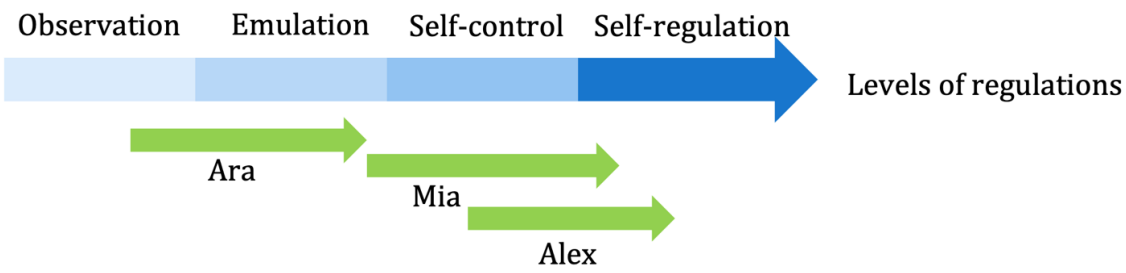
Table 1 shows the percentage of each type of questions Ara asked in the three observed lessons. Broadly, there was a positive shift in terms of more active questions and less passive questions. Nonetheless, the percentages of interactive and constructive questions were almost constant. In other words, the changes in Ara's questioning were mostly about quantity, not quality. In the first lesson, Ara asked a high percentage of passive questions that did not really require students to verbalize an answer. In the next two lessons, the percentage of passive questions dropped significantly, Ara asked many more active questions.

Overall Changes in the Levels of Regulations of the PSTs Over Time

Based on the Zimmerman's development of self-regulatory skill model (Zimmerman, 2002) and the above findings, there were positive shifts in the level of regulations of the three cases over time (Figure 7). Ara's self-regulation level moved from the observation level, where she needed the researcher to tell her whether what she did was SRL or not, to the emulation level, where she aimed to duplicate the strategic features of setting clear goals for teacher questioning. Mia moved from the emulation to the self-regulation level, which means she could self-regulate to ask higher-level cognitive questions in quite dynamic teaching environments. Alex moved from the self-control level, where he did well with teacher questioning in structured teaching environments, to the self-regulation level.

Figure 7

Changes in the Level of Regulations of the PSTs Over Time



Discussion

The levels of improvement in SRL practice were not uniform across cases. The differences in the growth appeared to relate to the participants' initial SRL skills and task value. The findings suggest that university supervisors and cooperating teachers should differentiate their coaching to PSTs. While high self-regulated PSTs benefit from practicing teacher questioning in dynamic teaching environments, PSTs with lower initial SRL skills might need (1) to be convinced to try out different strategies (one way to do so is to provide rationales for the activities) and (2) more specific suggestions regarding action plans for the next steps. This finding corroborates Zimmerman's development of self-regulatory skill model (Zimmerman, 2002), which is useful for teacher education but has not been used often.

An equal number of lower-level and higher-level cognitive questions proved best at eliciting students' thinking and enhancing student achievement (Lamb, 1976). The study's findings show that the percentages of the PSTs' question types need to be improved. In addition, the ICAP framework shows that the interactive mode of engagement can enhance learning more than the constructive mode, which is better than the active mode, which in turn is better than the passive mode (Chi & Wylie, 2014). Thus, the PSTs should ask more higher-level cognitive questions. In general, although the PSTs of this study exhibited gain quality in SRL practice and teacher questioning, to be able to ask higher-level cognitive questions in dynamic teaching environments, the high and intermediate cases still need further practice, while the low case needs additional coaching. Despite the need for further coaching or practice, the PSTs' growths in teacher questioning indicate that the integration of SRL into the teacher preparation program increased PSTs' questioning competence. The positive shifts over time in the PSTs' questioning quality show their questioning practice was better aligned with the NGSS.

High Self-Regulated Teacher Case

According to Zimmerman (2002), to accomplish the self-regulated level, learners should practice in unstructured settings. Alex did so. Alex practiced planning classroom questions for different types of lesson, such as primarily lecture, data collection, and developing models. The dynamic learning environments challenged Alex's questioning at some points, but also helped him to be aware of the flexibility characteristic of questioning. Even though Alex's initial skills for SRL practice and questioning were quite good, he benefited from the professional learning and coaching and could ask more interactive questions over time. The gain was important because research shows that it is difficult for science teachers to ask interactive questions (Morris & Chi, 2020).

Intermediate Self-Regulated Teacher Case

In the first observation, Mia did not ask all her planned questions. Research has shown that student teachers often eliminate some of the more challenging questions while teaching (Davis et al., 2016). The positive shifts in Mia's SRL practice and questioning align well with the goal of the study. Additionally, it appeared that the changes in Mia's SRL practice contributed to her improvement in teacher questioning. Furthermore, the largest gain in Mia's SRL practice was self-evaluation. At the beginning of student teaching, Mia did not pay much attention to self-evaluation. The coaching helped her see the value of the SRL process, so she put more time and effort into it. The quick improvement in Mia's self-evaluation quality suggests that Mia entered the study with the skills to some extent already; she just did not value the process much at the beginning.

Low Self-Regulated Teacher Case

According to Kaufman (2010), the clearer the goals, the more likely they are to be achieved. At the beginning of student teaching, Ara's goals for teacher questioning were

unclear. Thus, it makes sense that she could not ask many questions in the classroom, and the quality of her asked questions was low. Then, Ara could set clearer and higher goals for her questions showing that she learned from the coaching and her teaching experience. This means Ara benefited from the coaching. However, she was inconsistent with her goals. Ara lowered her goals which might mean she was not confident in her students' ability to answer higher-level cognitive questions. Or she was just not confident in her teaching and focused on student active engagement in which the effect of the teaching was more observable. Additionally, setting goals alone does not guarantee success. Plans and strategies for achieving the goals need to be selected or developed. And the ability to follow plans and strategies plays an essential role in determining whether people achieve their goals (Kaufman, 2010). In Ara's case, she could not hold her plans and strategies in working memory, and she did not note them down somewhere to follow.

Ara's low quality of self-monitoring can be explained by constraints of selective attention. People have a narrow focus of awareness and miss anything outside that focus (Cowan, 1988). Ara focused on not messing up rather than on success. In addition, it seems like Ara had anxiety that led to fear of failure ("My main thought processes when I was up there was like, 'Okay, make sure I get the content right, like, Okay, make sure like, don't mess up, don't mess up, don't mess up'" (first teaching interview). Control-value theory suggests that the environment influences people's control and value appraisals (i.e., self-related and situational beliefs regarding perceived control and value), which then trigger emotional responses that impact performance (Pekrun et al., 2006). In Ara's situation, her anxiety was teaching anxiety. Moreover, it was hard for Ara to focus on the process instead of the end goal. She should use her end goal to set specific goals for planning lessons and then use the specific goals to monitor and evaluate for planning (before doing so for

teaching). According to Zimmerman (2002), at the emulation level of regulation, Ara should focus on process, not outcomes.

Even though Ara said she needed to see her students' reactions to evaluate the questions, she did not evaluate her questions after seeing her students' reactions to them (after teaching the lesson) (as she said, "I looked at the lesson as a whole, but I don't really think I honestly put that much thought into the questions after the lesson was over" (second teaching interview)). The finding shows Ara did not self-evaluate and did not know how to self-evaluate her questioning. It seems like the lack of a tool or standard to evaluate is a cause of this. Ara also admitted that she did not know how to self-evaluate her teacher questioning productively ("that's something that I have been struggling with a little bit. So, I guess now [during the interview] is when I'm reflecting on them more" (second teaching interview)). The interview gave Ara a chance to reflect on her questioning. This is important because reflection might contribute to improvement in the next learning/teaching cycle.

Most notably, Ara did not practice planning and enacting questions; she did the work only for the observations. Students need "skill" and "will" to self-regulate learning (Liu et al., 2014). Ara's initial SRL skills were not high, and she lacked a will. Since Ara did not practice, she did not leverage the suggestions she received from the coaching as well as her ideas from reflections to do better with questioning. To acquire the self-controlled level, learners must practice what they have learned in structured settings outside the presence of models (Zimmerman, 2002). These reasons explain why Ara could not move to the self-control level at the end of the coaching. Furthermore, Ara was happy with her teaching, including questioning. A reason for that is Ara did not implement other instructional approaches, such as data practices or developing models, so she was not aware of the challenges of asking questions in dynamic classrooms.

Implication, Limitation, and Future Research

Findings from this study elicit PSTs' SRL practice in the context of planning and enacting classroom questions. The findings contribute to our understanding of teachers' self-regulation of teaching. Secondly, it appears that PSTs' SRL practice contributes to the quality of their questioning. To ask more higher-level cognitive questions in science classrooms, PSTs first need to set clear and high goals for their questions. Then, PSTs need to be able to monitor to enact their planned questions. Self-evaluation is also important to the growth of PSTs' questioning skills because the process facilitates PSTs to come up with ideas on how to do better in their next teaching. Finally, before reaching the self-regulation level (i.e., at the emulation level or self-control level), PSTs need to pay attention to the process, not only the outcome. One example of this is to somewhat separate self-evaluation of planning questions from enacting questions. With a clear goal and a question classification system (like the ICAP framework), PSTs can self-evaluate their classroom questions before enacting them.

The limitations of this study include the scope of teacher questioning, SRL processes, and participant population. First, our study focused on PSTs' ability to ask higher-level cognitive questions without looking at the quality of students' answers to those questions. Further studies should follow PSTs to their first year of teaching and aim for the next step, which is to support PSTs with promoting high quality student responses. From the findings of this study and Zimmerman's development of self-regulatory skill model (Zimmerman, 2002, we think high self-regulated PSTs are ready to focus on student response when they start their first year of teaching; intermediate self-regulated PSTs need a few months to learn to ask higher-level cognitive questions in dynamic teaching environments before focusing on student responses; and low self-regulated PSTs even need more time because those PSTs first need support with asking more higher-level cognitive questions in structured teaching environments. Secondly, the existing study focused on three SRL processes (i.e., goal setting, self-monitoring, and self-evaluating). For the low self-regulated PST, the findings show that

task value (which belongs to self-motivation beliefs) and causal attribution (which is another SRL process) would also help explain the limited improvement in her SRL practice and questioning. Finally, the three cases were selected from 18 PSTs in a secondary science certification program. Future studies should select participants from larger and more diverse groups of PSTs. Despite these limitations, our findings elicit the process of positive shifts in PSTs' SRL practice and questioning and suggest implications to optimize PSTs' questioning skills.

There are three major directions for future research. First, future research on teacher questioning can extend these findings by modifying the approach with an emphasis on (1) convincing low self-regulated PSTs of the crucial roles of practicing teaching strategies they have learned (to increase task value) and (2) encouraging low self-regulated PSTs to enact different instructional approaches so they are aware of the challenges of asking classroom questions in dynamic teaching environments. Second, we hypothesize that the PSTs (at least the high and intermediate cases) will apply SRL processes while doing other teaching tasks. Future studies can follow their participants into their first year of teaching to examine how PSTs transfer their SRL skills to do different teaching tasks other than teacher questioning. Third, there are research opportunities to examine the effect of SRL practice on other teaching competencies, such as the implementation of science and engineering practices or the enactment of equity-centered approaches.

Appendices

Appendix 1

Rubrics for Participant Selection

	High self-regulated learner	Intermediate self-regulated learner	Low self-regulated learner
Survey score	25% upper See themselves as a good self-regulated learner	50% in the middle - See themselves as an average self-regulated learner - Or good at one aspect of SRL but not the other - Or try to self-regulate their learning sometime, but not often very effective	25% lower Do not see themselves as a good self-regulated learner
Reflection writing			
Observation	- Do not submit their assignments late (except for special circumstances) - The quality of their work is high most of the times - If they get feedback on improving something, they will	- Submit their assignment late once or twice - The quality of their work depends on the topic (good or quite good), but it is always higher than average. - Improve most of the points they get feedback on	- Submit their assignment late more than twice during the semester without special reasons - Their work often does not meet all the requirements

	significantly improve it the next time	- Do not improve their work's quality much after getting feedback

Appendix 2

Summary of the Professional Learning During the Fall 2021 Semester

Time	Lesson
Sep 10th (3 hours)	How to become a self-regulated learner - The definition of SRL - Why promote SRL - Zimmerman's cyclical phases model of SRL - Self-questioning strategies for each SRL process and subprocesses - Characteristics of self-regulated learners
Oct 1st (2.5 hours)	Teacher questioning - The roles of teacher questions in science teaching - The ICAP framework on questioning - Other types of questions - Teacher question construction - Analyzing teacher questions in the science classroom
Oct 11th (1 hour)	Teacher questions in the context of implementing data practices - Introduction to data practices - Teacher questions for each data practice
Nov 5th (3 hours)	How to foster SRL skills in students

	- Why science teachers need to position students as active agents in knowledge construction - Zimmerman's development of self-regulatory skill model - Strategies to foster SRL skills in students - Teacher questioning as a strategy to foster students' SRL skills - Lesson plan analysis on strategies for fostering SRL skills in students - Classroom video analysis on strategies for fostering SRL skills in students
Nov 15th (1 hour)	Teacher questions in the context of implementing computational thinking practices - Introduction to computational thinking practices - Applying SRL to learn about computational thinking practices - Teacher questions for each computational thinking practice

Appendix 3

Summary of the Coaching During Spring 2022 Semester

Time	Coaching
First, third, and last observation	- Before observation, examine lesson plans and classroom materials, and give feedback/suggestions if needed - After observation, have a short meeting (5 to 20 minutes) with the participant to discuss and give immediate feedback on the teaching - During interview, the majority of interview questions are SRL microanalysis questions regarding planning or enacting questions (Author et al., 2013) that are useful in eliciting learning processes

	for the participant and provide opportunities for reflecting on SRL practice (Peters-Burton et al., 2020) - By the end of most interviews, talk with the participant about their understandings of SRL and teacher questioning and provide suggestions for what and how they could be improved - After interview, send written feedback to the participant and the mentor teacher via email (the average length of the written feedback was a page)
Second and fourth observation	- Before observation, examine lesson plans and classroom materials, and give feedback/suggestions if needed - Right after observation, have a short meeting (5 to 20 minutes) with the participant to discuss and give immediate feedback on the teaching and questioning - After observation, send written feedback to the participant and the mentor teacher via email (the average length of the written feedback was a page)

Appendix 4

Timeline for Data Collection

Data types	Data sources	Timeline (Spring, 2022)		
		Jan	Feb	Mar
Teacher questioning	Classroom artifacts	—	—	—
	Audio recordings of the teaching	—	—	—
Teacher questioning and SRL practice	Interviews about planning questions	—	—	—
	Classroom observations	—	—	—

Interviews about enacting questions	— — —

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CHAPTER 5

CONCLUSION

In chapter two, I presented a literature review of SRL professional learning (PL) programs for science teachers. Findings from the review revealed that there have been a relatively small number of studies (n = 14) that have focused on SRL PL over the past three decades. The studies reviewed show that SRL supports science teachers' learning (e.g., learning new science concepts, enhancing knowledge transfer, and fostering constructivist beliefs) and teaching (e.g., arrangement of SRL environments, increasing lesson-designing skills, and developing the ability to implement SRL processes). Teacher questioning is an important aspect of science teaching because teacher questions affect different aspects of learning outcomes. However, none of the studies leveraged SRL to improve science teachers' questioning skills. This lack of attention provided the rationale for the design of the PL and coaching of this study, which integrated SRL into professional learning and coaching during student teaching for PSTs.

In chapter three, I examined ways in which using SRL processes in coaching PSTs during student teaching contributed to their growth in asking questions. The findings suggest that coaching contributed to the PSTs' improvement in several different aspects of asking questions including: (1) enhancing PSTs' understanding and application of strategies they had learned from the PL, (2) supporting PSTs in realizing that asking good questions requires planning, (3) facilitating PSTs in becoming more purposeful in asking questions, (4) increasing PSTs' confidence in asking questions, and (5) enhancing PSTs' questioning skills. One key implication from the findings is that since not all PSTs remembered and applied what they had learned from PL, coaching is needed to enhance their understanding and application. Moreover, differentiation based on PSTs' SRL skills is needed. And Zimmeman's (2002) development of self-regulatory skill model provided a useful framework for differentiating coaching preservice teachers in the field. Another implication from the findings is the need to provide PSTs with descriptions of a question classification system that

is more elaborated, easy to remember, and grounded in a learning theory. Furthermore, even though in most teacher preparation programs, university supervisors give student teachers individual feedback, there is a lack of research on how to optimize the effectiveness of the feedback. This study shows that using SRL processes to give feedback to PSTs can be an effective approach to better support teacher candidates in learning specific skills, like questioning, that will better prepare them to enhance the learning environment for students.

In chapter four, I conducted a comparative case study to compare and contrast across cases (Bartlett & Vavrus, 2017). I found three key cross-case patterns: (1) the PSTs who were better at self-regulating planning questions were also better at self-regulating enacting questions, (2) the higher self-regulated PSTs asked a greater number of higher-level cognitive questions, and (3) the higher self-regulated PSTs were more willing to apply what they had learned from professional learning and coaching. Findings from this chapter show PSTs' SRL skills in planning and enacting classroom questions contribute to the quality of their questioning. Thus, fostering PSTs' SRL skills should help improve their questioning competency.

In the fifth chapter, I investigated shifts in PSTs' SRL practice and questioning skills over time. The changes that happened in each case had some unique characteristics, such as the initial quality, the level of improvement, and the pattern of growth (i.e., the specific aspect of SRL and teacher questioning in which the PSTs improved most). Overall, the quality of PSTs' SRL practice and asking questions increased during student teaching. Findings from this chapter elicit PSTs' SRL practice in the context of planning and enacting classroom questions. Secondly, it appears that PSTs' SRL practice contributes to the quality of their questioning. To ask more higher-level cognitive questions in science classrooms, PSTs first need to set clear and high goals for their questions. Then, PSTs need to be able to monitor to enact their planned questions. Self-evaluation is also important to the growth of

PSTs' questioning skills because the process facilitates PSTs to come up with ideas on how to do better in their next teaching. Finally, before reaching the self-regulation level (i.e., at the emulation level or self-control level), PSTs need to pay attention to the process, not only the outcome. One example of this is to somewhat separate self-evaluation of planning questions from enacting questions. With a clear goal and a question classification system (like the ICAP framework), PSTs can self-evaluate their classroom questions before enacting them.

The limitations of this study include the scope of teacher questioning, SRL processes, and participant population. First, the study focused on PSTs' ability to ask higher-level cognitive questions without looking at the quality of students' answers to those questions. Further studies should follow PSTs into their first year of teaching and aim for the next step, which is to support PSTs with promoting high quality student responses. From the findings of this study and Zimmerman's development of self-regulatory skill model (Zimmerman, 2002), we think high self-regulated PSTs are ready to focus on student response when they start their first year of teaching; intermediate self-regulated PSTs need a few months to learn to ask higher-level cognitive questions in dynamic teaching environments before focusing on student responses; and low self-regulated PSTs even need more time because those PSTs first need support with asking more higher-level cognitive questions in structured teaching environments. Secondly, the existing study focused on three SRL processes (i.e., goal setting, self-monitoring, and self-evaluating). For the low self-regulated PST, the findings show that task value (which belongs to self-motivation beliefs) and causal attribution (which is another SRL process) would also help explain the limited improvement in her SRL practice and questioning. Finally, the three cases were selected from 18 PSTs in a secondary science certification program. Future studies should select participants from larger and more diverse groups of PSTs.

There are three major directions for future research. First, future research on teacher questioning can extend these findings by modifying the approach with an emphasis on (1) convincing low self-regulated PSTs of the crucial roles of practicing teaching strategies they have learned (to increase task value) and (2) encouraging low self-regulated PSTs to enact different instructional approaches so they are aware of the challenges of asking classroom questions in dynamic teaching environments. Second, we hypothesize that the PSTs (at least the high and intermediate cases) will apply SRL processes while doing other teaching tasks. Future studies can follow participants into their first year of teaching to examine how PSTs transfer their SRL skills to do different teaching tasks other than teacher questioning. Third, there are research opportunities to examine the effect of SRL practice on other teaching competencies, such as the implementation of science and engineering practices or the enactment of equity-centered approaches.