ESOL Strategies in STEM Content Classroom Teaching

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This paper aims to introduce and discuss ways to incorporate various language scaffolding and instructional strategies in secondary science, technology, engineering and mathematics (STEM) content classrooms. The paper is based on a research study conducted on English for Speakers of Other Languages (ESOL)-trained STEM teachers' teaching effectiveness. The focus of the study was on describing how ESOL-trained STEM teachers utilized various language scaffolding and sheltered instruction (SI) strategies in their classroom instruction, and compared them with those who have not received any substantial training in ESOL. The participating teachers' teaching effectiveness was measured based on a set of established sheltered instruction evaluation criteria. It was revealed that the ESOL-trained STEM teachers, when compared to those with no such training, incorporated more explicit instruction of academic language, more explicit language and literacy integration in content instruction, activation of background knowledge, partner and small-group work to increase student talk time. Their instruction was also more balanced in terms of classroom interaction types and was not heavily dependent on teacher talk. This paper concludes with a summary of the ESOL strategies commonly adopted by ESOL-trained STEM teachers and implications of ESOL professional development for effective STEM content instruction for secondary English language learners (ELLs).

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The contents of this paper were in part developed under a grant from the U.S. Department of Education. However, those contents do not necessarily represent the policy of the U.S. Department of Education, and you should not assume endorsement by the Federal Government.

Sheltered instruction (SI) is an instructional model used in K–12 content subject teaching to facilitate English language learners' (ELLs) understanding and learning of concepts introduced in content subject lessons (Peregoy & Boyle, 2012). ELLs are students from non-English-speaking families and do not yet possess grade-level English language proficiency. ELLs in K–12 content subject lessons face dual challenges: they need to learn and understand the concepts introduced in the content lessons while trying to learn the language of instruction itself. As they move up in grade levels, the content gets increasingly more challenging and the language required to learn and understand the concepts becomes more complicated. Therefore, lack of grade-level English language proficiency likely results in achievement gaps, particularly at the secondary level, unless the content lessons are taught and scaffolded in a way that ELLs can comprehend and follow the instructions.

ELLs are in need of language accommodations in order to understand content in subject-area classes, and most often receive specialized English language instruction in their schools for the purpose of improving proficiency in English. SI, originally modeled after content-based instruction (CBI), uses the target language (English) while applying various language modifications and scaffolding strategies. When implemented effectively and utilized by content teachers, SI has been shown to significantly enhance ELLs' understanding of content subject concepts and vocabulary (Echevarria & Short, 2010).

Therefore, it is important for content-subject teachers of ELLs, especially at the secondary level, to be prepared to address ELLs' needs. Indeed, academic language proficiency is one of the most determining factors for ELLs to succeed in secondary schools, as discussed by Short and Boyson (2012). Despite the recognition that we need trained professionals, the reality is that many secondary-level teachers, particularly teachers of science, technology, engineering and math (STEM) subjects are still not adequately equipped to address ELLs' needs (Hart & Lee, 2003). Thus, the goal of the present study was to compare secondary STEM teachers who have and have not received training in (English for Speakers of Other Languages) ESOL in an attempt to demonstrate how all levels of teachers, regardless of their subject area specialization, must be well prepared to teach ELLs in their classroom.

In order to achieve this goal, the following research questions were put forward:

1. In what ways are ESOL-trained STEM teachers similar or different in classroom instruction when compared to non-ESOL-trained STEM teachers in ESOL?
2. What language scaffolding and ESOL strategies are commonly observed among ESOL-trained STEM teachers' classroom teaching?
3. What types of ESOL strategies appear to be most prevalent in STEM content instruction?

Review of Sheltered Instruction Strategies

In the US K–12 education system, the major SI models adopted for content-based English language instruction include Sheltered Instruction and Observation Protocols (SIOP), Guided Language Acquisition Design (GLAD), Specially Designed Academic Instruction in English (SDAIE), and Systematic English Language Development (ELD) (Be GLAD, n.d.; Echevarria, & Graves, 2011; Echevarria, Vogt, & Short, 2009; Echevarria, Vogt, & Short, 2016; Peregoy, & Boyle, 2012; Short, Vogt, & Echevarria, 2011; SIOP, n.d.; Systematic ELD, n.d.).

Although each SI model has unique features, there are a number of overlapping strategies. These models are intended to enhance students' understanding of academic content concepts and language proficiency by employing many of the effective language teaching strategies known to enhance content subject teaching (Peregoy & Boyle, 2012). The review of these major SI models revealed ten commonly observed strategies:

1. Identification and Review of Content Lesson Objectives

Most SI models emphasize the importance of the teacher's role in identifying and reviewing the lessons' objectives. This is typically done via visible display, accompanied by the teacher's and the students' oral review of the learning objectives. Learning effectiveness will be enhanced when the students are clearly informed of what will be taught to them in the lesson.

2. Identification and Review of Language Objectives

In SI, each lesson comes with a clear set of language objectives that correspond to and correlate with the content learning objectives. Teachers clearly identify key content vocabulary that will be introduced and explicitly taught in their lesson, along with linguistic structures and functions that are covered in their content instruction. These language objectives are also clearly visible in the classroom and reviewed with students.

3. Activation of Background Knowledge

ELLs' learning will be much more effective if they can make a clear connection between what they previously learned and what they will learn. It is important to use various teaching strategies and teacher guidance to help to help students relate to and understand new concepts by making a clear connection with what they already know.

4. Modeling

In many SI models, the role of the teacher in providing modeling is greatly emphasized. Through modeling, the teacher's expectation can be clearly communicated, particularly when ELLs have difficulty understanding all the verbal directions given to them in class. As a result, ELLs will better understand and engage in the learning activities.

5. Scaffolding of Key Academic Concepts

Scaffolding is important in any learning process, but it is particularly critical for ELLs. It is very important that key academic concepts crucial for understanding and following the instruction are explicitly covered and scaffolded to ELLs. To provide a scaffold, teachers are encouraged to use visual illustrations of the concepts using concept webs, maps, or flow charts. Explicit instruction, illustration, and explanation of key concepts also contribute to and facilitate ELLs' learning.

6. Multi-faceted Vocabulary Instruction

ELLs, particularly those in secondary-level content instruction, need academic vocabulary in their content subject classes. For this, teachers must provide ample opportunities to learn key content vocabulary words through rich and varied language experiences. This is facilitated through the development of word-learning strategies and through pre-teaching of academic vocabulary words in every content lesson.

7. Explicit Instruction of Academic Language

In addition to vocabulary, ELLs need to understand sentence and discourse patterns pertaining to a particular academic discipline. Sentence frames and sentence starters are frequently used to prompt ELLs to use proper sentence patterns and to help them engage in academic discourse using appropriate language structures. Teachers should also be prepared to rephrase complex sentences using simpler structures in order to scaffold the concepts and help ELLs.

8. Visual Aids (Diagrams, Charts, Graphic Organizers), Realia, Manipulatives

ELLs learn content concepts better when they are able to make a clear connection between what they learn and what they see or experience in real-life situations. It is also helpful if they are provided with visual images, real objects, or manipulatives that they can see and use to learn academic concepts.

9. Partner and Small-group Work, Cooperative Learning

ELLs should be given ample opportunities to practice language during classroom instruction by engaging in collaborative activities (e.g., partner or small-group work). This reduces the pressure associated with talking in front of the whole class. It also provides good opportunities to interact with peers and to receive peer support in accomplishing learning tasks.

10. Positive Learning Environment, Motivation

For all types of learning, creating a positive learning environment contributes to enhanced learning outcomes. It is particularly important for ELLs to learn in an environment where they can feel encouraged and motivated. ELLs will be motivated and learn better if they are not afraid of taking risks or making mistakes in using English. The teacher's positive feedback plays an important role in promoting a good learning environment.

To date, research studies have discussed the effectiveness of these SI instructional strategies in enhancing ELLs' academic learning. Echevarria, Vogt, and Short (2016) showed how ELLs taught by teachers who had been trained in SI strategies outperformed ELLs whose teachers had not received such training. More recently, Short, Fidelman, and Louguit (2012) found that ELLs with teachers trained in SIOP achieved greater academic gains than those taught by teachers with no such training. Although there are researchers who question the effectiveness of SI in closing the achievement gap between ELLs and non-ELLs, it is generally agreed among educators and researchers that ELLs need additional instructional support to make the instruction meaningful and productive (Goldenberg, 2013). Therefore, it is important to investigate how well teachers are prepared to implement the SI instructional strategies in their classroom teaching for ELLs and to examine whether teachers' professional development in ESOL increases their use of various SI instructional strategies.

The Study

The Context of the ELSTEM Project

The ESOL for STEM Educators (ELSTEM*)* project is currently in progress at Pacific University Oregon and is a federally funded professional development program. This program aims to design and implement a new ESOL teacher preparation curriculum that integrates teacher training in the STEM fields and an endorsement in ESOL. The goal is to increase middle and high school STEM teachers' ability to meet ELLs' instructional needs, thereby maximizing ELLs' achievement in STEM subjects.

The ELSTEM project is a yearlong graduate-level program that leads to an Oregon ESOL endorsement. The curriculum of the ELSTEM program follows the Oregon Teacher Standards and Practice Commission's competency guidelines for ESOL endorsement. The curriculum consists of courses that are specifically tailored to prepare secondary STEM teachers to teach ELLs effectively in their content subject teaching. These courses include training on STEM literacy and teaching methodology, linguistics for STEM teachers, cultural and linguistic diversity existing among secondary ELLs, and language policy relevant to ELL education. A special focus is given to prepare secondary STEM teachers to utilize various language scaffolding and ESOL teaching strategies introduced in many SI models.

Participants

There were a total of nine participants in this study. Five of the participants were ESOL-trained STEM teachers and had completed the first year of the federally funded ELSTEM project. The other four participants had not had any substantial training in ESOL (as declared in a self-reported survey), and were in-service STEM teachers recruited from the same school districts where the project cohort participants were teaching. These four teachers applied to for the study by responding to a call for participation. The participants were teaching in the school districts where over 10% of the students were identified as ELLs.

The ESOL-trained STEM teachers had an average teaching experience of 6 years, ranging from 2 to 11 years. The non-ESOL-trained STEM teachers had an average teaching experience of 12 years, ranging from 8 years to 20 years. In terms of classroom teaching experience, the non-ESOL-trained STEM teachers had approximately twice as much teaching experience as the ESOL-trained STEM teachers.

Instruments and Procedures

The ESOL-trained STEM participants were observed twice by three ESOL specialists (university supervisors) using an established set of criteria intended to measure ELL teaching effectiveness before and after the ELSTEM project participation. The non-ESOL-trained STEM teachers were observed once using the same criteria. The observation criteria included dimensions pertaining to ESOL and SI teaching strategies. Table 1 presents these strategies along with specific observation criteria used by the university supervisors.

Table 1. *Observation and Evaluation Criteria*

Commonly Observed ESOL Strategies in SI Models	Observation Criteria Used in this Study
Identification and review of content lesson objectives	The learning objectives clearly evident
Identification and review of language objectives	The language objectives clearly evident
Activation of background knowledge	Teacher's activation of students' background knowledge
Modeling	Teacher's modeling before having students engage in group or partner work
Scaffolding of key academic concepts	Scaffolding Thematic or cross-disciplinary units Explicit instruction in how to read and use math/science syntax and symbols
Multi-faceted vocabulary instruction	Vocabulary instruction varied and multi-faceted
Explicit instruction of academic language	Incorporation of explicit instruction of academic language STEM literacy integrated into the instruction
Visual aids, realia, manipulatives	Graphic organizers Realia (real-life objects or photos of real-life objects) Manipulatives (blocks, tiles, beans, models) Images and sketches
Partner and small-group work, cooperative learning	Partner work Small-group work Cooperative learning Ask students to explain how they solved a math/science word problem
Positive learning environment, motivation	Have students work in teams to solve math/science problems Inquiry-based methods to teach math and science concepts

The observation data were gathered through videotaping of the teachers' classroom instruction. Each observation lasted approximately 55 minutes (middle school lesson) and 75 minutes (high school lesson). The data were collected following the Institutional Review Board procedure for human subject research. The videotaped classroom instruction segments were then separately evaluated and rated by three ESOL specialists using the established observation templates. The observation template is designed to evaluate ESOL teaching effectiveness and rate the STEM teachers' overall teaching effectiveness for ELLs on a 5-point Likert scale (0–4 where 0 is for not effective at all and 4 is for exemplary). All three ESOL specialists had extensive experience in teaching and supervising pre-service and in-service teachers who were working towards their certification in ESOL. They had a minimum of eight years of experience in supervising teacher candidates in ESOL, and were very familiar with the observation criteria before evaluating and rating the teachers' ESOL teaching effectiveness. In an attempt to increase inter-rater reliability, they went through a series of training sessions during which they reviewed sample STEM-ESOL classroom instruction videotapes and discussed how to conduct evaluations using the observation template. The completed observation reports were reviewed and analyzed by the researcher as well as a program evaluation team to determine the effectiveness of the ELSTEM program (Autio & Lasley, 2014).

Findings

In the following section, the findings pertaining to the three research questions are presented.

Similarities and Differences Between ESOL-trained and Non-ESOL-trained STEM Teachers

The data analysis showed that, overall, the ESOL-trained STEM teachers shifted towards using more supportive language interventions near the end of their yearlong participation in the ELSTEM program. Specifically, the observers' overall rating of lessons for the ELSTEM program participants' teaching effectiveness improved: on a four-point scale, it increased from 2.8 before participation to 3.5 toward the end of their participation. On the other hand, the overall rating of lessons for the non-ESOL-trained STEM teachers was 2.75, which was about the same as the ELSTEM project participants' rating before their participation in the program.

Some similarities between the two groups were identified. For instance, both groups included content and language objectives in their instruction. However, only 50% of the non-ESOL- trained STEM teachers covered specific language forms (linguistic features) and functions during their classroom instruction, and none of them explicitly integrated STEM literacy and content instruction. Conversely, all of the ESOL-trained STEM teachers explicitly covered the intended language forms and functions in their instruction, and 60% of them also integrated STEM literacy in their classroom instruction.

Further, compared to the ESOL-trained STEM teachers, few non-ESOL-trained STEM teachers successfully demonstrated the activation of ELLs' background knowledge. Also, few made use of various scaffolding strategies to improve ELLs' language proficiency to learn STEM content. Although these teachers used at least one language scaffolding strategy during their instruction, it was scarcely used, unlike the ESOL-trained teachers. They did not, however, differ much from the ESOL-trained STEM teachers in terms of using classroom materials. Only one teacher relied heavily on textbooks; others used various instructional materials such as tools and props, models, and teacher-made materials, including a word wall that contained key concept vocabulary.

Language Scaffolding and ESOL Strategies Commonly Observed Among the ESOL-trained STEM Teachers

The findings revealed that the ESOL-trained STEM teachers incorporated more explicit language instruction into their STEM content lessons. At the end of their ELSTEM program participation (post-ELSTEM), all of their lessons included clear lesson and language objectives and incorporated explicit, planned language instruction. Also, 60% of their lessons demonstrated clear integration of STEM literacy and content instruction. Figure 1 shows these findings.

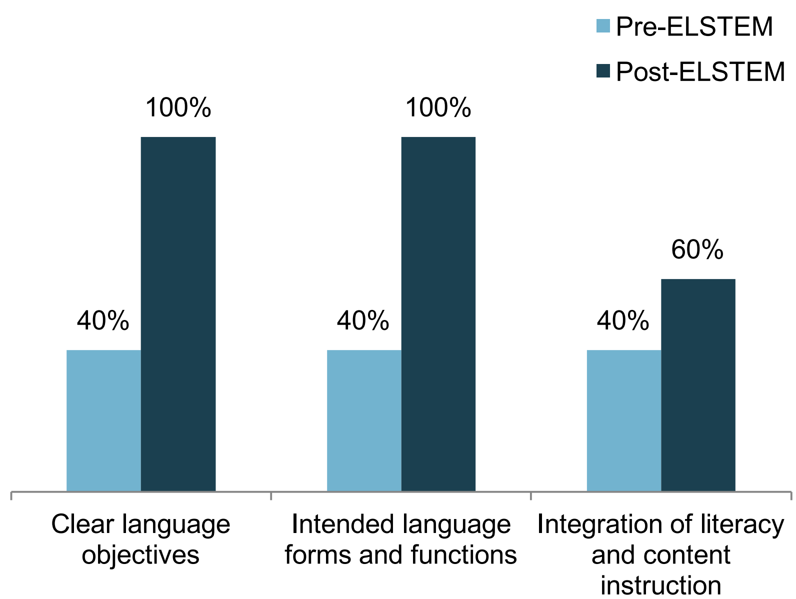

Figure 1. Language incorporation into STEM content lessons among ESOL-trained teachers.

There was also substantial growth in the activation of ELLs' background knowledge that applied to a given lesson topic. Before participation in the program, activation of background knowledge was never observed; however, toward the end of the program, it was seen in 100% of the lessons. By the end of the ELSTEM program, 40% of the participants' lessons explicitly incorporated ELLs' background knowledge into STEM instruction, in contrast to 20% prior to the program.

As Figure 2 shows, the participants also shifted in their use of instructional materials. For instance, they relied less heavily on textbooks, which were seen in just 20% of classrooms (compared to 80% before participation). Further, they began to use manipulatives—physical objects (i.e., blocks, tiles, beans, or models) that aid in learning—which were found in 40% of the lessons.

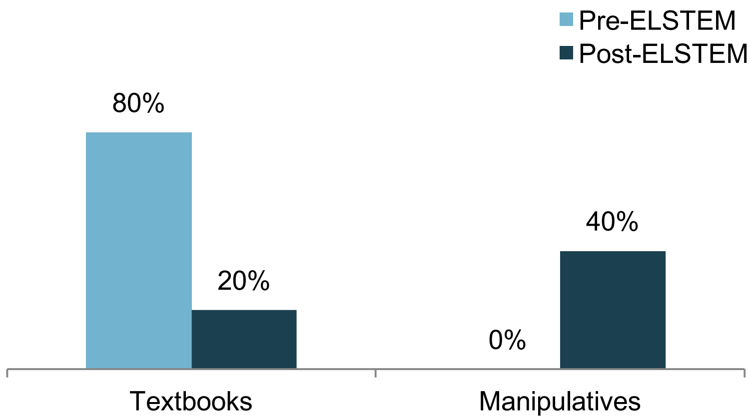

Figure 2. Use of materials among ESOL-trained teachers.

In addition, there were many changes in how teachers and students interacted with each other after the ELSTEM project participation (see Figure 3). The length of teacher-talk time calculated for an entire lesson period was reduced (53% to 37% of lesson time) while the duration of student talk time as measured by the length of student-to-student interaction increased (30% to 39% of lesson time). Also, the teachers used cooperative learning approaches in 40% of lessons (compared to none before participation). Their students worked with partners in 100% of lessons (compared to 40% before participation). In addition, their students worked in teams to solve math problems (in 60% of lessons) and were asked to explain how they solved word problems (in 60% of lessons), which was minimally seen before participation. Finally, a few observed lessons (20%) used inquiry-based methods: asking questions, planning and conducting investigations, using appropriate tools and techniques to gather data, thinking critically about relationships between evidence and explanation, and constructing and analyzing alternative explanations.

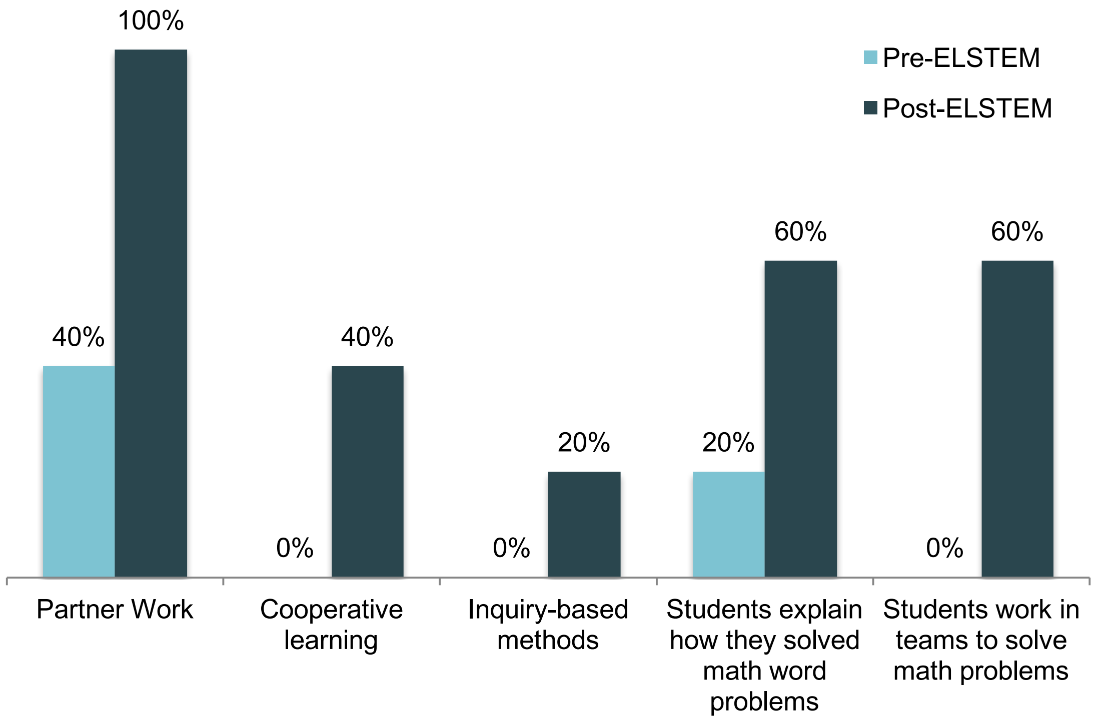

Figure 3. Changes in teacher/student interaction.

Most Prevalent ESOL Strategies in STEM Content Instruction

In this study, there were three ESOL strategies most commonly observed in the ESOL-trained participants' STEM content instruction. First, all of the participants (both the ESOL-trained and the non-ESOL-trained STEM teachers) included clear lesson and language objectives in their instruction. Moreover, all ESOL-trained STEM teachers went beyond including these objectives and further demonstrated clear incorporation of explicit, planned language instruction into their content instruction. Further, all of the ESOL-trained STEM teachers were shown to activate students' background knowledge that applied to a lesson topic. Finally, increase in student talk time and balance in classroom interaction types were also identified as the most commonly observed strategies used by the ESOL-trained STEM teachers. In particular, 100% of the ESOL-trained STEM teachers incorporated partner work toward the end of the ELSTEM participation. In summary, the findings showed that the ESOL-trained STEM teachers incorporated more explicit instructional interventions and strategies in their classroom instruction. Further, the ESOL-trained STEM teachers, when compared to the non-ESOL-trained STEM teachers, incorporated more explicit integration of the STEM content and language instruction. Finally, all of the ESOL-trained STEM teachers demonstrated clear and explicit incorporation of language learning objectives and instruction in the STEM instruction, activation of students' background knowledge, and greater allocation for collaborative work to increase student talk time.

Discussion

In this study, two groups of STEM teachers (ESOL-trained STEM teachers and non-ESOL-trained STEM teachers) were observed to address three research questions. With respect to the first research question, results show that the ESOL-trained STEM teachers demonstrated a number of language scaffolding and SI strategies to support ELLs' academic content learning. After the yearlong participation in the ELSTEM project, they incorporated more explicit instruction of academic language and literacy into their content instruction.

Compared to the ESOL-trained STEM teachers, the non-ESOL-trained STEM teachers did not demonstrate a wide array of explicit instructional intervention for ELL's language proficiency or ESOL strategies to support ELLs' content learning. Although these non-ESOL-trained teachers included lesson and language objectives in their STEM lessons, none of them clearly and successfully integrated language aspects in their actual classroom teaching. This finding demonstrates a need for teachers' professional development in ESOL, and also clearly shows that only the teachers with substantial training in ESOL actually implement language-related instructional intervention for ELLs. Thus, explicit instructional intervention strategies do not appear to be adopted without a substantial amount of ESOL training.

The findings pertaining to the second research question show that the ESOL-trained STEM teachers, after the yearlong training in ESOL, demonstrated substantial growth in activating ELLs' background knowledge, in using more explicit STEM language and literacy integration in content subject instruction, and in employing partner and small-group work to increase student talk time. They also relied less heavily on textbooks and began to use more manipulatives to enhance students' learning. On the other hand, the non-ESOL-trained STEM teachers did not integrate literacy and content instruction at all. In general, they scarcely incorporated explicit language instruction in their content subject teaching. This further supports the claim that ESOL training for content subject teachers is necessary and beneficial since language scaffolding and ESOL strategies are not gained without specific teacher training in these areas.

The third research question, regarding the types of ESOL strategies that appear to be most prevalent in STEM content instruction, was answered as well. All of the ESOL-trained STEM teachers were effective in activating and building on students' background knowledge, using explicit language and content integration, and providing ample opportunities for student talk and engagement in content instruction. All of them clearly addressed the language forms and functions intended to be covered during their STEM content instruction. These findings suggest that an ESOL professional development (PD) program intended to enhance classroom teachers' effectiveness, such as the ELSTEM program, leads to substantial growth in using many of the ESOL strategies. Also, it was notable that the length of teachers' teaching experience did not necessarily correlate with their teaching effectiveness. This implies that ELL teaching effectiveness and incorporation of explicit language instruction are not achieved just because content teachers gain more experience. It appears that classroom teachers need substantial PD experience in ESOL in order to improve their effectiveness for ELL teaching (US Department of Education, 2015). These findings are also in line with Hart and Lee (2003) who examined the impacts of an ESOL PD intervention on teachers' beliefs and practices in teaching science to ELLs. The study showed that teachers require continuous and sustained PD activities to promote the science and literacy achievement of ELLs. It appears that improved teaching practice for ELLs is only gained through substantial and sustained PD in ESOL.

In conclusion, this study showed and discussed the findings from a federally funded ESOL PD program offered to a group of secondary STEM content teachers and compared their teaching effectiveness with that of the teachers with no such PD experience in ESOL. Although this study is limited in terms of number of participants and scope of research questions, the findings clearly suggest that PD has a positive impact on teachers' ELL teaching practice. It is very important that teachers, particularly secondary content teachers, are well prepared to address ELLs' needs in their classroom instruction. It is hoped that future research studies will investigate further how the ESOL strategies demonstrated by the ESOL-trained STEM teachers are sustained and maintained in their content instruction, and that any long-term effects of improved ELL teaching effectiveness on ELL learning outcomes will be identified.

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