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Does Teaching Experience Matter? The Beliefs and Practices of Beginning and Experienced Physics Teachers

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Abstract This study utilized multiple data sources to examine the beliefs about learning and teaching physics and the instructional practices of five beginning teachers and seven experienced teachers from Singapore. Our study was implemented in the unique context of teachers teaching the topic of electricity to students grouped according to academic abilities. The topic of electricity is one of the most difficult physics topics for students to understand and for teachers to teach. It was found that the experienced teachers, compared to the beginning teachers, tended to have beliefs about teaching and learning physics that are closer to constructivist views. The majority of the teachers, particularly the beginning teachers, espoused beliefs about learning physics that were incongruent with their beliefs about teaching physics. Although transmission-oriented and teacher-directed practices dominated the classroom lessons of both groups of teachers, more elements of constructivist instruction were found in the classroom lessons of the experienced teachers. It was also found that the classroom practices of the teachers, especially those in their inductive years of teaching, were more aligned with their beliefs about learning physics than their beliefs about teaching physics.

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Introduction

Various research efforts have been carried out to describe the trajectory of teachers' professional development, with many of them focusing on teachers' beliefs and practices (e.g., Mansour 2013; Savasci and Berlin 2012). One of the prime goals of this research movement is to explicate ways to direct teachers' beliefs and practices toward constructivist orientations. Constructivist instruction, which underscores learners' active construction of knowledge and student-centered approaches, is often cited as the centerpiece of contemporary reform efforts in science education (Lew 2010). The elements of constructivist instruction are also consistent with the recent goal of promoting inquiry-based learning in science education (Gillies and Nichols 2015), which is central to the national science curriculum of Singapore (Ministry of Education [MOE] 2013)—the context of this study.

A few researchers have found evidence upholding the notion that longer teaching experience of teachers translates to more reform-oriented teaching beliefs and/or practices (e.g., Clermont et al. 1994; Levitt 2002; Lim and Chai 2008), but others have reported evidence to the contrary (e.g., Drechsler and Van Driel 2008; Feyzioğlu 2012; Sandholtz 2011). The conundrum arising from these conflicting reports becomes more complex when considering indications from earlier studies (e.g., Boulton-Lewis et al. 2001; Zhu and Geelan 2013) that teacher beliefs about learning may be asynchronous with their beliefs about teaching and classroom actions. An integrative investigation of this conundrum is needed to help generate a better understanding of the interplay among teachers' beliefs, teaching practices, and teaching experience. Unfortunately, limited studies have addressed this multifaceted conundrum, especially in relation to science education.

To address the stated gap in the extant literature, the current study aimed to unpack teachers' beliefs about learning and teaching science (in this study, physics), ascertain the alignment between these sets of beliefs, and then identify the relation between each of these sets of beliefs and the length of teachers' teaching experience and actual classroom practices. Teachers' beliefs and teaching practices form a reciprocal relationship; teacher beliefs may serve not only as the causes but also as the outcomes of teaching practices (Kagan 1992; Levitt 2002). In examining the beliefs and practices of *beginning* (i.e., with teaching experience of 3 years or less) and *experienced* teachers' (i.e., with more than 3 years of teaching experience), we can identify key areas that did or did not exhibit substantial development after extensive experience in science instruction and pre-service teacher training. Extracting information at different points in teachers' developmental pathways can help school administrators, teacher educators, and policymakers to form appropriate expectations of teachers at various stages in their teaching career (Wilcox-Herzog 2002). These ideas have also been deemed important by scholars who aim to promote excellence in science teaching (Clermont et al. 1994; Kagan 1992; Wilcox-Herzog 2002) and envision alignment of classroom instruction with reform-based approaches (Mansour 2009).

We have also noted how the existing literature contains scant information on domain-specific or topic-specific beliefs (Fang 1996; Van Driel et al. 2007) and their relationship with teacher's classroom teaching, although many teachers have recognized that teacher beliefs and/or practices are influenced by the nature of learning domain (Boulton-Lewis et al. 2001; Kagan

1992; Markic et al. 2008) and topic complexity (Gunstone et al. 2009). To enrich the existing knowledge base linking teacher beliefs and practice, we chose the topic of electricity—a key area in physics from the primary to the tertiary level (Mulhall et al. 2001)—as the focus of our investigation. Electricity is regarded as one of the most difficult physics topics for students to learn and for teachers to teach as it features a multitude of abstract concepts (Mulhall et al. 2001) and dynamic systems that are often microscopic (Jaakola et al. 2011). Previous research (Mulhall et al. 2001; Gunstone et al. 2009) has shown that teachers consider the teaching of electricity as a formidable challenge. Noting that beliefs are regarded as key components of the coping mechanisms teachers use to navigate through teaching realities (Pajares 1992), we deemed that framing the present study in relation to a challenging topic, such as electricity, can provide focused insights that can facilitate the adoption of adaptive and effective teaching, the assimilation of reform principles into teachers' beliefs, and the translation of such principles into practice.

Theoretical Background

Models of Teaching and Learning

The present research on teachers' beliefs and practices aims to examine and categorize teacher beliefs about teaching and learning using a framework underpinned by the constructivist models of learning and teaching, which has served as the foundation of many current reform initiatives in science education. These models have a pedigree that can be traced back to the seminal works of Bruner (1966), Ausubel (1968), Piaget (1973), von Glasersfeld (2001), and Vygotsky (1986). Although these scholars may have conceived different models or forms of constructivism (see Matthews 2002), their views tend to cohere into one key point: Knowledge is actively constructed by learners, either individually (Prawat and Floden 1994) or collaboratively (Staver 1998). Learning, for many supporters of constructivism, is learner-centered (or student-centered), with the learning process starting from learners' ideas and initiatives (Markic et al. 2008; Richardson 2003). In other words, the learning process is driven by learners' goals. Learning also involves the learners' activation of a knowledge base appropriate to making sense of new knowledge, with the possibility of integrating the former into the latter (Mayer 2004).

There are a variety of perspectives in translating constructivist views of learning into constructivist pedagogy. Nevertheless, many researchers and scholars converge on some aspects that define constructivist teaching. They tend to agree that a teacher's main role in constructivist-oriented teaching is to be a facilitator, guide, or diagnostician (Levitt 2002); to encourage learners to make their own interpretations of issues (Tsai 2002); to design tools and environments to support learners in making these interpretations and in constructing their own ideas (Jonassen 1991); and to provide learners with opportunities to determine, challenge, or change their existing ideas (Richardson 2003). Constructivist-oriented instruction involves teachers' identification of students' existing conceptions and guiding students to link new ideas with existing knowledge (Koballa et al. 2000; Tsai 2002) or to relate canonical ideas to real-world experiences (Poncy et al. 2010). Teaching anchored in constructivism features interactions between learners and learning materials, between learners and teachers (Koballa et al. 2000; Tsai 2002), and among learners (Mansour 2013) to help learners construct, share, and negotiate meaning (Richardson 2003).

The "absorptionist" (Mulhall and Gunstone 2012; Prawat 1992) or "reproductive" (Koballa et al. 2000) model of learning is consistent with the key tenet of ontological realism (Maxwell 2012), which regards reality as independent of knowers and their perceptions, and of scientific realism, which considers scientific knowledge as a representation of reality (Van Fraassen 1980). In line with this model, students are considered as passive recipients of knowledge (Kang and Wallace 2004; Mansour 2013) who are not expected to make interpretations of events on their own; it is the teacher who makes the interpretation for the learners (Jonassen 1991). The learning process involves acquiring, gaining, or reproducing ready-made knowledge (Markic et al. 2008; Osborne 1996) from external sources, such as teachers or textbooks (Tsai 2002).

The transmissionist model of teaching is consistent with the absorptionist model of learning—these models are often labeled as "traditional" by researchers in science education (Al-Amoush et al. 2011; Feyzioğlu 2012). Transmissionist instruction, as the term implies, involves unproblematic transfer of established knowledge (Tsai 2002; Koballa et al. 2000; Osborne 1996) from sources to the learner. It is primarily teacher-controlled, textbook-oriented, and exam-oriented (Mansour 2013) where learners are "told about the world and are expected to replicate its content and structure in their thinking" (Jonassen 1991, p. 10). As it emphasizes giving clear definitions and accurate explanations (Tsai 2002), the questions that teachers ask tend to be close-ended and task-oriented (Erdogan and Campbell 2008). The teacher primarily provides explanations, sometimes with demonstrations, to help learners grasp the concepts (Berg and Brouwer 1991). When students have conceptions that do not match established knowledge, the teacher just presents the "correct" scientific ideas (Berg and Brouwer 1991).

Recently, a number of studies have recognized the existence of a category that falls in the middle of the constructivist-transmissionist continuum. This category usually comes under the label "transitional" (Levitt 2002; Savasci and Berlin 2012; Simmons et al. 1999) or "mixed" model (Belo et al. 2014). Teachers with transitional or mixed beliefs express some elements of both the constructivist and transmissionist models (Feyzioğlu 2012).

In view of the above and following the lead of earlier researchers who examined science teachers' beliefs and/or practices (Belo et al. 2014; Levitt 2002; Mansour 2013), this study adopted a three-pronged categorization (i.e., transmissionist/absorptionist, constructivist, and mixed) of teachers' beliefs and practices. In using this approach, the present study hoped to generate a more nuanced understanding of teacher beliefs and classroom behavior than the dichotomous approach applied in earlier studies.

Beliefs of Beginning and Experienced Teachers

Teacher beliefs, which are sometimes equated with teacher "views" (Mansour 2009; Prawat 1992; Mulhall and Gunstone 2012) or "conceptions" (Tsai 2002; Lotter et al. 2007; Koballa et al. 2000), refer to "all mental representations that teachers or student-teachers hold (consciously and unconsciously) in their minds that influence, to a certain extent, their (potential) behaviour as teachers of science" (Markic et al. 2008, p. 111). Teachers form an overarching belief system (Rokeach 1968; Fives and Buehl 2014) that subsumes various belief systems or substructures, each formed by distinct yet related beliefs (Schommer-Aikins 2004). These belief systems need not be in consensus (Abelson 1979). Within a belief system, some beliefs may be in conflict and some may be coherent: Beliefs that are coherent form a cluster or "nest" (Chen 2008; Bryan 2003). Individuals may hold conflicting beliefs simultaneously without realizing the conflict as long as they hold these contradictory beliefs in separate nests and avoid comparing them (Chen 2008). For a given belief system, beliefs that are more central tend to receive more attention and are ascribed more power (Rokeach 1968) thereby having greater tendency to influence an individual's action (Pajares 1992; Rokeach 1968). Situated within teachers' larger belief system are their beliefs about teaching and learning, along with their views of students, content, and context (Fang 1996).

Teachers' beliefs about learning refer to their beliefs about the role that students have in their own learning and perceived attributes of "good" learning; teachers' beliefs about teaching correspond to their notions of their own role as a teacher and the nature of effective teaching (based on Samuelowicz and Bain 2001). The literature upholding close relationships between teachers' views of teaching and students' learning (Samuelowich and Bain 1992) is perhaps the reason why researchers (for example, Chan and Elliot 2004; Levitt 2002) do not usually segregate teachers' beliefs about teaching from beliefs about learning.

The few empirical studies that have explored teachers' beliefs about teaching and learning as distinct beliefs have revealed different patterns. One group of studies have shown consistent constructivist-oriented beliefs about the teaching and learning of science. One of these studies focused on trainee teachers from Spain (Mellado 1998) and another involved experienced teachers from Turkey (Feyzioğlu 2012). Moreover, consistent traditional beliefs about teaching and learning science were documented among the majority of experienced science teachers who participated in studies conducted in Taiwan (Tsai 2002), Canada (Laplante 1997), and Egypt (Mansour 2013). A similar pattern of results was described by Al-Amoush et al. (2011) concerning the beliefs of both beginning and experienced chemistry teachers in Jordan. The lack of intensive reform-oriented pre-service and in-service training (Al-Amoush et al. 2011), limited science knowledge base (Laplante 1997), and previous school and life experiences (Mansour 2013) have been cited as common antecedents of the nested beliefs of teachers with predominantly traditional orientations.

Some studies, however, paint a more complex picture of the link between teachers' views about teaching and learning. In Chai's (2010) study, involving mostly experienced Singapore primary school teachers, students' learning was generally viewed as a meaning-making and discovery process, but teaching was perceived as a process of imparting knowledge. In Wallace and Kang's (2004) study, the experienced science teachers who participated in an inquiry-based workshop generally espoused reform-based beliefs about science learning, but their perceptions of their roles as teachers in students' education—helping students to prepare for examinations and covering the curriculum—were found to be context-bound. These results may suggest that the teachers' beliefs about teaching and learning reside in different nests within their belief systems.

The systems-based nature of teachers' beliefs is exemplified in two studies. Bryan's (2003) research described a beginning science teacher espousing opposing nests of beliefs while holding coherent beliefs about science teaching and learning in each nest. One nest of beliefs comprised a reproductive view of students' learning and a transmissionist view of teaching; the other nest consisted of views consistent with an active learning process and constructivist instruction. Similarly, Belo et al. (2014) reported that a large sample of Dutch physics teachers (N = 126) held competing belief clusters: They valued both student-directed and teacher-directed learning, as well as both transmission- and constructivist-oriented teaching. The authors noted that such results could be attributed to the teachers' awareness of the complexity of physics topics and the diversity in students' abilities, as well as the two-decade implementation of curriculum reforms in the Netherlands. Holding multiple belief nests or mixed beliefs can be a manifestation of the teachers' "pedagogical sensitivity," which pertains to the careful consideration of contextual factors (e.g., students' attributes, content of the curriculum, goals of the lessons, and language-related issues) in making instructional decisions (Belo et al. 2014, p. 98).

The foregoing review indicates that both beginning and experienced teachers' beliefs about teaching and learning cannot be assumed to be always congruent and that greater teaching experience does not necessarily translate to more coherent belief systems. Unpacking beliefs about teaching and learning when studying their association with other factors, such as length of immersion in the teaching practice, and exploring the degree of their coherence at various stages in teachers' teaching trajectory are important in generating a more accurate picture.

Relationship Between the Beliefs and Practices of Beginning and Experienced Teachers

Researchers have also been concerned about how teachers' beliefs are translated into instructional practices and about how instructional practices can influence teachers' beliefs. Expectations for a strong beliefs-practice linkage emanate from the notion that teachers' beliefs serve as key drivers of classroom actions (Pajares 1992; Nespor 1987; Markic et al. 2008) and as filters for selecting and organizing information, choosing instructional approaches, and identifying priority areas (e.g., Cho and Huang 2014). Other researchers (Guskey 1985; Levitt 2002; Waters-Adams 2006) have also suggested ways in which the classroom can serve as a test bed for teachers' ideas and beliefs, and how changes in teachers' classroom behavior can lead to changes in their beliefs. These assertions, which allude to a reciprocal link between teachers' beliefs and practices, conform to the claims of a few researchers that the length of teachers' immersion in classroom instruction is a key determinant in the development of teachers' beliefs systems. For example, Kagan (1992) concluded from a review of multiple studies focusing on teacher beliefs that when teachers have longer experience in classroom teaching, they tend to develop more coherent belief systems, which, in turn, may serve as a stronger force to shape their instructional decisions and actions. This claim implies that extensive teaching experience is likely to render greater alignment of teachers' beliefs and practices.

Studies focusing on the relation between teachers' beliefs and their instructional practices have yielded two clusters of results. The first cluster, which appears to be more prevalent, has shown a concomitance of transmissionist/absorptionist beliefs with didactic teaching. These findings were reported in the studies of Laplante (1997) and Mansour (2013), both of which focused on experienced science teachers. In contrast, Levitt (2002) categorized both the beliefs and pedagogical approaches used by a sample of experienced science teachers as constructivists. These teachers had ample experience in enacting reform-based practices or exposure to reform-oriented ideas during teacher training. A combination of the stated beliefs-practice profiles among physics teachers with unspecified years of teaching experience was identified by Mulhall and Gunstone (2012). In this study, teachers with constructivist beliefs and practices also viewed physics ideas as more challenging to learn than the teachers associated with traditional beliefs and practices did.

Another cluster of studies has shown inconsistencies between what teachers believe and what they actually do in the classrooms. For example, primary school teachers from Singapore, regardless of their teaching experience, generally held constructivist-oriented teaching and learning views but reported teaching practices that remained focused on frontal teaching (Lim and Chai 2008). Similar beliefs-practice patterns were reported by beginning (Mellado 1998) and experienced science teachers (Chai 2010; Savasci and Berlin 2012), and physics teachers with varied years of teaching experience (Qhobela and Kolitsoe-Moru 2014). The incongruence between the teachers' beliefs and practices is often attributed to ecological factors, such as time constraints, assessment-based educational systems, students' abilities and attitudes (Chai 2010; Lim and Chai 2008; Mansour 2013; Qhobela and Kolitsoe-Moru 2014; Savasci and Berlin 2012; Zhu and Geelan 2013), and challenges faced by both students and teachers in relation to the language of instruction (Oyoo 2012).

In the context of teaching physics, Gunstone et al. (2009) suggested weak connections among teachers' perceived complexity of concepts to be taught, pedagogical beliefs, and instructional practices. With experienced secondary students as respondents, they found that most of those who adopted traditional approaches in teaching electricity, when compared to those who adopted teaching approaches that were closer to the constructivist model of instruction, tended to perceive the concepts of electricity as hard for the students to understand, learning of such concepts being linear, and teaching being straightforward. They also mentioned that the teachers who had a more elaborate view of the process involved in learning and deeper understanding of physics concepts, especially those that are abstract in nature, were more likely to have a better sense of the challenges associated with the teaching of such concepts.

The studies reviewed above reveal only partial support to the notion that coherence between beliefs (within a belief system) and alignment between beliefs and practices tend to increase with teaching experience of teachers. In connection with this issue, it was also noted that limited studies have presented the perspectives of science teachers from Asian educational contexts.

The Present Study

In view of the gaps in the literature that were presented above, our study sought to compare the beliefs and practices of physics teachers, who were grouped according to their years of experience in teaching. We also framed the study within the context of teaching the topic of electricity to students who were grouped according to academic abilities (i.e., by their scores on a standardized achievement test), an aspect that is unique to the Singapore education. More specifically, we aimed to address the following research questions.

1. Are physics teachers' beliefs about learning consistent with their beliefs about teaching?
2. What are the similarities and differences in the beliefs that beginning and experienced physics teachers hold about teaching and learning electricity?
3. What are the similarities and differences in the instructional practices of beginning and experienced physics teachers?
4. How is the consistency between the beliefs and practices of physics teachers influenced by their teaching experience and contextual factors?

Methodology

Participants

Twelve physics teachers from four Singapore secondary schools volunteered and consented to take part in this study. Five of the participants were beginning teachers (with 1 to 2.5 years of experience in teaching physics), and seven were experienced teachers (with 6 to 14 years of experience in teaching physics). They belonged to the top third of the secondary students' population, which is one of the criteria for recruiting teachers in Singapore (Tan and Darling-Hammond 2011). All participants, except BT4, had completed a bachelors' degree (with BT3 also receiving a master's degree in physics) before undergoing a 1-year initial teacher education (ITE) program at the National Institute of Education (NIE)—the sole teacher-education institute in the city-state (see Table 1). This ITE program involved courses on education (i.e., learning theories and principles), pedagogy (i.e., how to teach two core academic subjects, one of which is physics, at the secondary level), and language skills enhancement and teaching practice (i.e., practicum = 10 weeks). BT4, right after completing junior college (Year 12), directly pursued a bachelor's degree in science education at NIE (specializing in secondary physics and another academic subject) for about four years. The ITE of other participants and of BT4 shared similar course components, although the course components of the ITE attended by BT4 were longer. The ITE of BT4 involved additional courses aimed at enhancing the trainee's content knowledge in physics and 11 more weeks of practicum. For all participants, the ITE courses focused on teaching approaches that promote collaboration, problem-based and inquiry-based learning, and teaching diverse learners (see Tan and Darling-Hammond 2011).

About two years prior to the time of the study, seven teachers had participated in at least four professional development (PD) programs concerning reform-based teaching practices (i.e., focused on fostering conceptual change, inquiry, or critical thinking) and eight teachers attended two PD programs focusing on physics content (see Table 1 for details). Both the beginning and experienced teachers had regular interactions with peers (about three times a month) to discuss how to teach physics and observe classroom teaching.

At the time of the study, all of the teacher participants were teaching in Singapore public schools. In these schools, students are grouped into different ability tracks—Express, Normal Academic (NA) and Normal Technical (NT)—based on their aggregate scores in the Primary School Leaving Examination (PSLE), which is a national test given at the end of primary education. Students who belong to the same academic track are taught using the same curriculum. Express students have higher aggregate scores and, thus, could be regarded as having higher academic ability than NA students. Express students take the General Certificate of Education (GCE) Ordinary Level examination (or "O" levels) and NA students take the GCE "N" level examinations (or "N" levels) at the end of Secondary Four (Year 10). Both NA and Express students cover the same core topics in electricity, but only the latter take practical examinations, which feature inquiry activities, at the end of Secondary Four. Students from the NA stream who do well in the "N" levels can take the "O" levels at the end of Secondary Five (Year 11). Both examinations assess students' understanding in electricity through a combination of conceptual questions and problem-solving questions in both multiple-choice and open-ended formats. Each participating teacher selected one of their physics classes consisting of Secondary Four students (with ages ranging from 15 to 17 years) to be the focus of our classroom observations and interviews. Four teachers were observed teaching students from the Normal Academic (NA)

Table 1 Name codes for participating teachers, years of teaching experience, classes observed and professional development (PD) program attended

Teacher	Highest degree attained before teacher training	Years of experience teaching physics at the time of the study	Stream of classes observed	Number of PD programs attended within 2 years before the study was conducted			
				Content	Inquiry	Critical thinking	Conceptual change
BT1	Bachelor's degree (Engineering)	2.5	Express	1	1	1	1
BT2	Bachelor's degree (Engineering)	1	Normal Academic	1	1	1	1
BT3	Master's degree (Physics)	2	Express	2	2	1	2
BT4	Bachelor's degree (Education)	2.5	Express	2	2	1	2
BT5	Bachelor's degree (Engineering)	2	Normal Academic	2	1	2	2
ET1	Bachelor's degree (Engineering)	14	Normal Academic	2	1	1	2
ET2	Bachelor's degree (Engineering)	10	Express	1	1	1	1
ET3	Bachelor's degree (Engineering)	12	Normal Academic	2	2	2	1
ET4	Bachelor's degree (Physics)	6	Express	1	1	1	1
ET5	Bachelor's degree (Engineering)	7	Express	2	1	1	1
ET6	BS Business Studies	6	Express	2	2	1	2
ET7	Bachelor's degree (Physics)	11	Express	2	1	2	2

BT beginning teacher, *ET* experienced teacher stream, and eight teachers were observed teaching students from the Express stream (see Table 1 for details). The physics classes that were selected were those that belonged to the stream representing the greater proportion of the students that the teachers were teaching during the time of the study. As it is in all subjects other than the Mother Tongue Language, the medium of instruction used by the teachers in this study was English. The students' proficiency in English can be assumed to be at least in the acceptable level, noting that all the students had to pass the English component (along with three other components) of the PSLE to qualify for Secondary One (Year 7) NA or Express stream and had to receive a passing grade in English language class in Secondary Two (Year 8) to be promoted to Secondary Three (Year 9).

Data Collection

This study used multiple data sources to ascertain the espoused beliefs about learning and teaching physics and the actual instructional practices of the participating teachers. These data sources included semi-structured interview transcripts (transcribed verbatim) as well as audio-video recordings and field notes of the classroom lessons. Data collection was carried out at the time the teachers covered the topic of electricity.

Semi-Structured Interviews Two sets of semi-structured interviews (about 30–45 minutes each) were conducted by the first author. The first set of interviews, which were implemented before the classroom observations, probed for the teachers' beliefs about the teaching and learning of electricity. The interview prompts included the following questions:

- What do you think is the role of the learner/teacher in an electricity lesson?
- How can the topic of electricity be best learned by students in secondary schools?
- How do you/can you help students develop a sound understanding of electricity ideas/concepts?
- Can your students explain electricity-related phenomena/formulate solutions to problems/conduct science investigations with minimal guidance? Please explain your answer.

The second set of interviews, which were carried out within a month after the teachers' last classroom lesson on electricity, focused on elucidating the factors that influenced the effects of teaching experience on the teachers' beliefs and classroom practices (based on Avraamidou and Zembal-Saul 2005). To draw insights more effectively from the teachers, noting the difference in their years of teaching experience, different questions were posed to each group: The experienced teachers were asked how their teaching experiences have changed them as teachers (Q1); the beginning teachers, in turn, were asked about areas to improve in the teaching of physics (Q2). These questions were meant primarily to elicit possible ways of supporting teachers' professional development. During the preliminary stages of the study, it appeared to us that Q1 was not relevant to the beginning teachers and that the question was not helpful in generating insights that could be utilized to answer our research questions.

Classroom Observations All classroom lessons (86 lessons, 56 hours of curriculum time) that involved the "current electricity" unit were video-recorded. At least seven classroom lessons were recorded for most of the teachers. However, only three lessons were observed for BT4 and ET2. BT4 allotted only three lessons (90 minutes in total) to cover all the core topics (current, electromotive force, potential difference, resistance, resistivity, and resistors in series and parallel) involved in this study. Almost all the topics mentioned, except *resistivity*, were covered in the three lessons (110 minutes in total) of ET2 that were observed. Unlike the rest of the participants, BT4 and ET2 quickly presented the definitions and formulas associated with each concept and allotted most of their lessons time on asking students to solve quantitative physics problems involving series and parallel circuits. While videotaping, research assistants took down field notes on attendance, student behavior, and other aspects of the lessons that were not clearly captured in the video (e.g., description of simulations carried out by the teachers).

Data Analysis

Analysis of Teacher Interviews

The interviews were transcribed verbatim and the transcripts were analyzed based on our framework (see "Theoretical Background" and Appendix Table 7). To construct the individual belief profile of the teachers, we borrowed approaches from Miles and Huberman's (1994) process of selecting, reducing, and organizing the data. The transcripts were read reiteratively in order to ascertain the teachers' beliefs and practices as reported by the teachers themselves. Further analysis entailed having relevant parts of the transcripts marked, with parts that fell into the same dimension of the teachers' beliefs pooled; these dimensions included (1) students' role during the learning process and how they learn and (2) teachers' role during instruction and preferred teaching approach. While being mapped with the indicators in our framework, the details of each dimension were recorded and tabulated, along with quotes from various aspects of the teacher transcript. We also noted relevant parts of the interview transcripts suggesting how teaching experience influenced the teachers' beliefs and classroom practices, as was described by Miles and Huberman (1994). This marked information was also added into the teachers' individual profiles. The first two authors likewise discussed their personal analysis of the reduced data set in order to come to a collective interpretation (Lincoln and Guba 1985) of this aspect of the analysis.

The first two authors used the details in the tabulated profiles to categorize each teacher's beliefs about learning into *predominantly constructivist*, *predominantly absorptionist*, or *mixed* paradigm. Concerning teachers' beliefs about teaching, similar categorizations were used except that the predominantly absorptionist category was replaced by *predominantly transmissionist*. When the authors' respective categorizations of the teachers' beliefs were compared, the agreement was found to be satisfactory (Cohen's $\kappa = .88, p < .0001$). After that, the differences and similarities in the beliefs of beginning and experienced teachers were examined.

To enrich our analysis, we conducted content analysis similar to the approach used by Clermont et al. (1994) to explore the details of the teachers' responses per dimension in their beliefs profile. We clustered meaningful categories that formed similar kinds of responses for each dimension. In identifying the categories, we focused on the *manifest content* (i.e., "elements that were physically present and countable") of each teacher's response (Berg and

Brouwer 1991, p. 292). We then determined the number of teachers whose responses fell in a particular category of responses and compared the major patterns of responses of beginning and experienced teachers across each dimension of beliefs.

We also carried out thematic analysis (Miles and Huberman 1994) on the transcripts of the second interview. While reading the transcripts reiteratively and alongside each other, we marked the parts that focused on the factors that influenced the teachers' enactment of their beliefs to practices, changes that accompanied experienced teachers' longer immersion in the teaching arena, and areas in which beginning teachers saw themselves as needing improvement. We constructed themes through a search for recurring regularities in words, phrases, meanings, relationships, and patterns.

Analysis of Research Lessons

The video recordings of the research lessons were transcribed and divided into 5-minute segments, totaling 314 (26 hours) and 354 (30 hours) for beginning and experienced teachers respectively. Viewing the video recording alongside the transcripts, the teaching strategies used by the teachers in each segment were coded using the modified Classroom Observation Protocol (COP) of Lawrenz et al. (2002) (see Appendix Table 7). In order to capture the subtleties in the teachers' classroom actions, we have made some modifications to the COP. First, we have identified variations in "lecturing" (which is predominantly teacher-directed) by specifying key components of teacher presentation such as the inclusion of students' input, teacher's use of analogy and/or demonstrations, and linking of scientific concepts to daily life. The different forms of "hands-on activities" and "collaboration" were differentiated by the degree of students' participation in the process. Lastly, the two forms of "seatwork" were differentiated by the type of guidance offered by the teachers to their students.

In coding each lesson segment, we examined the teachers' instructional strategy, role in the teaching process (e.g., facilitator of learning, dispenser of knowledge), and questions or prompts used. We also looked at students' classroom activities (e.g., note-taking, answering worksheet), role in the classroom activities (e.g., receiving knowledge, constructing/ discovering knowledge), questions posed, and responses to teachers' questions. We also examined the teacher-student interactions to be able to extract some clues on the teachers' intention behind their classroom actions, particularly in relation to the strategy that they applied. In using the foregoing approaches, our goal was to categorize, at the very least, the instructional approach that the teachers' intended to enact during a particular lesson segment.

During the initial coding stages of the teaching strategies, a research assistant and one of the authors discussed how the coding scheme would be applied in two lessons and then tried to resolve any disagreements in the coding. Afterward, they randomly selected six research lessons (45 segments, including lessons of BT2 and BT4) and then independently coded the teaching strategies used by the teachers in each segment. The agreement between the coders was found satisfactory (Cohen's $\kappa = .83$, $p < .001$). The rest of the lesson segments were coded by one coder. The next step was to count the number of lesson segments used by each teacher for a particular instructional strategy.

Using our framework (see Appendix Table 7), we also categorized each of the coded instructional strategies per lesson segment (with a particular focus on the role of the teacher and role of the students) into *transmissionist-oriented*, *constructivist-oriented*, or *mixed*. After categorizing the strategies, we determined the intercoder agreement: We randomly selected 12 lessons (one lesson per teacher, including ET2 and BT4, total = 93 segments), and each segment of the lessons was independently categorized by the first and second authors. Their intercoder agreement was found satisfactory (Cohen's κ = .89, $p < .0001$). To generate an overall categorization of the teachers' instructional practices, the proportion of the total class segments that each teacher devoted to constructivist-oriented (%CONS), transmissionist-oriented (%TRANS), and mixed (%MIXED) practices were determined. We categorized teachers' practices as follows: if %CONS or %TRANS was 60 or higher, the practice was coded as *predominantly constructivist teaching* or *predominantly transmissionist teaching*, respectively; otherwise, the practice was coded as *mixed teaching* (based on Mansour 2013).

Results and Discussion

Beginning and Experienced Physics Teachers' Beliefs About the Teaching and Learning of Electricity

We found that the beginning and experienced teachers differed in views about learning and teaching electricity. The beginning and experienced teachers diverged in their perceived role of students in the learning process (see Table 2) and the nature of students' learning. The beginning teachers' responses suggest a general perception of students as passive recipients of knowledge (e.g., listener, observer): Most of these teachers described students' learning as a process of receiving ready-made knowledge (i.e., definitions and formulas), and remembering and applying this knowledge in solving computational problems. These points are illustrated by the responses of BT2.

Interviewer: What do you think is the role of the learner, particularly when you are teaching electricity?

Table 2 Teachers' perceived role of students in the learning process

Role of students in learning	Beginning teachers (BTs) (n = 5)		Experienced teachers (ETs) (n = 7)	
	Count	%	Count	%
Pay attention/listen[a]	5	100	0	0
Know or memorize formulas/definitions of terms[a]	2	40	2	29
Copy[a]	2	40	0	0
Read textbook[a]	1	20	0	0
Observe[a]	0	0	2	29
Ask questions[b]	2	40	2	29
Relate lessons to everyday life[b]	3	60	0	0
Share ideas/reason out[c]	1	20	1	14
Use prior knowledge[c]	0	0	1	14
Take responsibility for their learning/discover or explore on their own[c]	0	0	4	57

Total could be greater than 100 % as some teachers stated more than one role of students

[a] Related to absorption-oriented belief

[b] Can be MIXED, or of different categorization

[c] Related to constructivist-oriented belief

BT2: Perhaps, first thing of course, when I start this topic, they [students] must listen and copy down the relevant [points]. Yeah, because if they do not even catch the beginning, it'd be very hard to carry on... Then, when there's a worked example, of course, if the first example is more difficult, I'll be going through with them. They can copy down the correct answer first. Then the second example, they must try first before I give them the correct solution.

The foregoing views of beginning teachers about the students' role in learning were perhaps associated with their concerns about language-related challenges in teaching and learning physics. All of the beginning teachers noted that students find the learning of electricity difficult because of the abstract nature of concepts associated with this topic, as well those being used in physics as a whole. Two beginning teachers (BT1 and BT4) also mentioned the inconsistencies between the everyday and physics meanings attached to these concepts as one of the reasons why they viewed the teaching of physics as difficult. The following interview excerpts uphold the stated points:

Interviewer: So do you expect them [students] also to make their own explanations?

BT1: No, because the everyday…I think ah, sometimes, the difficulty in teaching physics is that, sometimes, the everyday common terminologies used are not exactly the same as the… the physics understanding of the same word. So, a common example will be mass and weight… [E]lectricity is no different. So their [students'] prior understanding of current and voltage, actually most of them will think they are one and the same thing.

BT4: Make their [students] own explanations, for electricity? Not so much ah… Yes, because I mean, electricity a lot of the information is theoretical [e.g., current]. It cannot be seen.

Although the majority of experienced teachers also recognized the abstract nature of electricity concepts (ET1, ET2, ET4, ET6, and ET7), with some of them (ET4 and ET5) explicitly mentioning the counter-intuitive nature of these concepts, such perceptions did not seem to lead them toward viewing learners as passive; instead, the idea appears to have encouraged them to view learners as having more active roles in learning.

ET2: But the challenge would be to think of some abstract [concepts] because this is a chapter that they cannot see. So the ability to, the role would then to be able to visualize, to have the right mental models, to be able to conceptually categorize the differences between current, voltage and resistance; to be very clear from the definitions and then deriving from the first principles; and then to know from the observations, regarding the series and parallel circuits. These would be the key role of a learner.

ET5: No, they have a bit more problems [giving their own explanation to common phenomena associated with electricity]. They can explain but they link a lot of physics concepts as common sense. So once common sense comes in, they cut out the possibility to learn… the learning of concepts that requires explanations.

When asked about the role of learners in learning, ET5 mentioned: "I feel that the role of the learner is more to open the ideas, a free thinker and active contributor."

Overall, the experienced teachers indicated predominantly mixed beliefs about learning electricity: They acknowledged the students' active role in knowledge development and the importance of learning by discovery and collaboration, but they also upheld the need for students to receive and reproduce established knowledge (e.g., formulas that are needed to solve computational problems), especially for students with low language proficiency. These were implied when ET6 described the role of learners and teachers:

ET6: [E]ven though they [education leaders] talk about "teach less, learn more" I think there's still a part where we have to give them [students] the knowledge so that they can think.

Certain students can do that just by reading a textbook. They can understand but not all. Especially I think in our school, we have quite a lot of international students and language skills may not be that good. I think we are giving them the knowledge. I think that's the first role [of a teacher]. Then beyond that would be actually helping them [students] find the answer for [sic] themselves.

Although most of the experienced teachers expressed the belief that students can formulate explanations about electricity concepts and phenomena, a few of them expressed some reservations for the "academically weaker" students. These ideas were suggested in the following interview excerpts:

Interviewer: We are thinking of your Normal Academic students? Do you think your students can give meaningful explanations with minimal teaching from you?

ET3: So I would say, the better ones would be able to explain it in a good way. But I'd say, only the better ones. The average would struggle a bit. And then the weak ones ah would just.

ET6: Correct and I think it depends on the students that we have. Because I think with better caliber students for example, then you can do less teaching. But with students that are weaker, then I think you need to do more teaching.

In relation to teaching electricity, the beginning teachers perceived themselves as sources or providers of canonical ideas in electricity; half of them also viewed themselves as guides of students' learning (see Table 3). More diverse roles were expressed by the experienced teachers (e.g., source of knowledge, listener, coach, and motivator) than did the beginning teachers. The diversity of the pedagogical roles expressed by the experienced teachers could be due to their relatively greater opportunities to interact with students and gain familiarity with students' needs. Five experienced teachers (ET1, ET2, ET3, ET6, and ET7) indicated that their teaching experience as in-service teachers has enabled them to be more familiar with students' attributes and learning difficulties. ET6 mentioned: "I think over the years, I think it's more of able to see more from the students' point of view."

Table 3 Teachers' perceived roles during instruction

Role of teachers	Beginning teachers (BTs) (n = 5)		Experienced teachers (ETs) (n = 7)	
	Count	%	Count	%
Present definitions, formulas, theory, or explanations[a]	4	80	3	43
Help students pass examinations/ask recall questions[a]	2	40	3	43
Make topics easy to understand[b]	1	20	0	0
Build rapport/cultivate respect/develop habits of mind[b]	0	0	2	29
Ask guide questions/open ended[c]	2	40	2	29
Help or encourage students to find answers by themselves/discover/explore[c]	0	0	3	43
Guide/facilitate/listen[c]	3	60	4	60
Arouse/develop interest of students to learn/motivate[c]	0	0	2	29
Help students relate lessons to everyday life[c]	2	40	2	29

Total could be greater than 100 % as some teachers stated more than one role of teachers

[a] Related to transmission-oriented belief

[b] Can be MIXED, or of different categorization

[c] Related to constructivist-oriented belief

Furthermore, the preferred teaching approaches of the teachers also appeared to vary with the length of their teaching experience. Most of the beginning teachers endorsed transmissionist-oriented strategies (e.g., lecturing, drill, and practice) to teach electricity effectively (see Table 4). The experienced teachers had a wider repertoire of preferred teaching approaches; more of them endorsed constructivist-oriented strategies, which involved greater learner participation (e.g., peer teaching) and opportunities for discovery (e.g., student-designed hands-on activity). These results cohere with the findings of Chai (2010) and Mellado (1998). The professional development programs attended by the experienced teachers, as was suggested by ET5, could have helped them to gain exposure to reform-oriented strategies.

Specifically, beginning and experienced teachers also indicated some similarities and variations in their preferred teaching approaches in relation to addressing language-related challenges faced by both teachers and students in teaching and learning physics, respectively. To help students visualize the abstract and microscopic aspects of electricity, many of the teachers expressed the need to use simulations and/or demonstrations (beginning teachers = 80 %; experienced teachers = 57 %), with some of them also indicating preference for the use of analogies (beginning teachers = 40 %; experienced teachers = 43 %). To help students deal with their confusion between the everyday meanings and scientific meanings of physics concepts, three teachers underscored (BT3, ET4, and ET5) the need for the students to verbalize their own reasoning, with two of them (ET4 and ET5) also recognizing the importance of using hands-on activities and peer-coaching (i.e., asking students with more solid understanding to communicate their ideas to other students with problems in understanding electricity concepts).

Table 4 Strategies that teachers mentioned as important to be effective in teaching electricity

Preferred strategies by teachers	Beginning teachers (BTs) (n = 5)		Experienced teachers (ETs) (n = 7)	
	Count	%	Count	%
Lecturing/mostly teacher talk[a]	5	100	1	14
Drill and practice[a]	2	40	2	29
Problem modeling[a]	4	80	4	57
Simulation/demonstration (show-and-tell approach)[a]	4	80	4	57
Hands-on (teacher-structured)[a]	3	60	4	57
Analogy (unclear if deriving ideas from students)[b]	2	40	3	43
Relating lesson to everyday life (unclear if deriving ideas from students)[b]	3	60	2	29
Examples with increasing difficulty[b]	0	0	1	14
Hands-on (student-structured)[c]	0	0	3	43
Peer teaching/pair work[c]	1	20	4	57
Asking high-cognitive questions[c]	0	0	1	14
Predict-observe-explain[c]	0	0	1	14

Total could be greater than 100 % as some teachers stated more than one teaching strategy

[a] Related to transmission-oriented belief

[b] MIXED belief, or of different categorization

[c] Related to constructivist-oriented belief

Table 5 summarizes the nature of the beliefs about teaching and learning of beginning and experienced teachers. The beginning teachers' beliefs about learning were predominantly absorptionist, while those of the experienced teachers were predominantly mixed. More of the experienced teachers than the beginning teachers espoused constructivist views, but a significant proportion of both groups expressed mixed beliefs. The predominance of mixed beliefs about teaching for the participants, regardless of experience, and mixed beliefs about teaching for the experienced teachers coheres with the systems-based nature of beliefs that were evident in the findings of earlier researchers (e.g., Belo et al. 2014; Bryan 2003; Chen 2008; Fives and Buehl 2014).

Moreover, Table 5 suggests the incongruence between the beliefs about learning and teaching physics for 7 of the 12 teachers, especially for beginning teachers. In other words, there seems to be a tension between the present sample's conceptions of how they should teach and how students learn the topic of electricity. This finding contradicts the results of several studies (e.g., Feyzioğlu 2012; Laplante 1997; Mansour 2013; Mellado 1998; Tsai 2002) in which the majority of the subjects reported coherence between these beliefs. The discrepancy between our findings and those of earlier studies can be partly due to the difference in the domains on which the studies focused. These earlier studies examined science teachers' beliefs concerning the learning and teaching of science in general. The current study focused on physics teachers' beliefs about the learning and teaching of a specific science topic—electricity—which feature several "complex concepts" (i.e., concepts that are difficult to learn or grasp owing to their abstract nature and/or conflict between their physical and everyday meaning), such as potential difference, electromotive force, and current. Just like other physics teachers (Gunstone et al. 2009), many of the present sample of teachers (e.g., ET4, ET5, BT1, BT3, and

Table 5 Beliefs about teaching and learning and classroom practices of beginning teachers (BTs) and experienced teachers (ETs)

Teacher	Beliefs		Practice (actual)				
	Learning electricity	Teaching electricity	Overall categorization	%CONS	%TRANS	% MIXED	Total segments
BT1	ABS	MIXED	TRANS	0	74	28	72
BT2	ABS	MIXED	TRANS	0	65	35	65
BT3	ABS	MIXED	TRANS	2	61	37	59
BT4	ABS	MIXED	TRANS	0	72	28	15
BT5	ABS	MIXED	MIXED	14	47	39	64
All BTs				4	63	34	275
ET1	MIXED	MIXED	TRANS	0	67	33	54
ET2	MIXED	MIXED	MIXED	4	35	60	23
ET3	MIXED	CONS	MIXED	0	48	52	54
ET4	MIXED	MIXED	TRANS	5	76	18	38
ET5	MIXED	CONS	MIXED	36	24	39	66
ET6	MIXED	MIXED	MIXED	27	41	32	37
ET7	CONS	CONS	MIXED	31	21	48	62
All ETs				17	43	40	334

ABS predominantly absorptionist, *TRANS* predominantly transmissionist, *CONS* predominantly constructivist, *MIXED* combination of CONS and TRANS

BT5) explicitly emphasized their perceived difficulty in teaching and learning these complex concepts, especially in relation to those who were seen to be weaker in physics. Thus, the teachers' perceptions of students' ability might have amplified the otherwise nominal differences between teachers' beliefs about the nature of students' learning and the process of teaching (Yim and Cho 2016).

Upon further examination of Table 5, it can be noted that all of the beginning teachers held beliefs about effective teaching that were more sophisticated than their beliefs about students' learning. They endorsed the view that learning is a process of receiving and reproducing knowledge from external authority (e.g., teachers); however, when it comes to teaching, they have noted the value of providing guidance and support for students aside from providing knowledge. For example, BT2 suggested in connection with teaching students how to solve quantitative problems: "My usual practice is I normally teach first…Besides the basic teaching, I think, the rest of the time, it's more like, someone that go around giving them hints and advice." This finding counters the results of Chai (2010), which was also set in Singapore, but focused on teachers' beliefs about teaching and learning in general and involved experienced primary school teachers teaching varied subject domains (Malay, English, Social Studies, Mathematics, and/or Science) as participants. This author noted that most of the participating teachers held transmission-oriented pedagogical beliefs, but their beliefs about students' learning ranged from receiving to constructing knowledge. However, the findings for the present study cohere with the partial results of Boulton-Lewis et al. (2001), involving Australian secondary teachers of varied subject areas but with unspecified years of teaching experience. We suspect that the potential reasons for the varying patterns of results between earlier studies and the current study were the differences in the teaching experience, teaching domain, and grade level of students.

Beginning and Experienced Physics Teachers' Actual Teaching Practices

Table 6 shows the proportions of class segments used for transmissionist-oriented, constructivist–oriented, or mixed practices by beginning and experienced teachers. The experienced teachers utilized a greater portion of their class time on constructivist-oriented and mixed practices and less on transmissionist-oriented practices; the beginning teachers engaged primarily in transmissionist-oriented practices. The experienced teachers implemented a variety of hands-on activities, but the beginning teachers enacted mostly teacher-structured ones. Relating concepts learned to students' daily lives was observed only in the classroom lessons of three experienced teachers (ET1, ET3, and ET7), albeit only in very few lesson segments. For example, ET1 prompted his students to compare the resistivity of different conducting wires and then asked which would serve as a good conductor. He further asked the students how materials with high resistivity (e.g., nichrome wire) could be used in making items useful at home.

Notwithstanding that both beginning and experienced teachers acknowledged the language-related challenges faced by students, such as those pertaining to the abstract nature of electricity concepts and the disjunction between the everyday and physics meanings of words that are used in the topic of electricity, there were differences in the teachers' enacted practices that can be linked to these views. Table 6 shows that a greater proportion of the lesson segments observed for the beginning teachers (12 %) than for the experienced teachers (3 %) involved demonstrations (including simulations) delivered in show-and-tell manner. Activities that involved active negotiation of meaning, which includes clarification of terms used in

Table 6 Teaching strategies used by beginning teachers (BTs) and experienced teachers (ETs)

Teaching strategies	Percentage of classroom segments used by ETs								Percentage of classroom segments used by BTs					
	ET1	ET2	ET3	ET4	ET5	ET6	ET7	All	BT1	BT2	BT3	BT4	BT5	All
	$n = 55$	$n = 23$	$n = 57$	$n = 42$	$n = 74$	$n = 39$	$n = 67$	357	$n = 80$	$n = 72$	$n = 70$	$n = 17$	$n = 76$	315
1. Lecturing														
Teacher-directed[a]	18	24	17	45	14	9	6	17	23	22	26	33	18	23
With SSI[b]	15	26	16	5	14	10	15	14	4	11	7	6	16	9
With analogy[b]	6	0	4	5	2	3	2	3	6	0	3	11	3	3
With analogy and SSI[b]	2	0	0	0	3	0	0	1	0	1	1	0	0	1
With demos[a]	7	13	0	2	0	3	0	3	13	21	10	0	6	12
With demos and SSI[b]	5	9	0	0	0	0	6	3	0	0	14	0	1	3
With linking to daily life[b]	5	0	4	0	0	0	0	1	0	0	0	0	0	0
With linking to daily life SSI[b]	2	0	0	0	0	0	2	1	0	0	0	0	0	0
2. Active discussion[c]	0	4	0	5	32	13	18	12	0	0	1	6	2	1
3. Problem modeling														
Teacher-directed[a]	19	11	18	15	0	8	1	9	13	12	11	19	6	11
With SSI[b]	4	0	11	1	11	8	3	6	4	8	2	6	2	5
4. Seatwork														
With TG[a]	2	4	17	7	2	17	6	8	14	8	3	0	4	7
With CG[b]	0	4	9	0	0	0	1	2	6	7	1	0	5	5
5. Hands-on activities														
Teacher-structured[a]	11	0	0	0	9	8	10	6	6	0	0	0	0	2
Partly student-structured[b]	0	0	0	0	0	0	15	3	0	0	4	0	10	3
Student-designed[c]	0	0	0	0	0	13	10	3	1	0	0	0	0	3
6. Collaboration														
Pair work[c]	2	0	0	0	0	5	0	1	0	0	2	0	0	0

Table 6 (continued)

Teaching strategies	Percentage of classroom segments used by ETs								Percentage of classroom segments used by BTs					
	ET1	ET2	ET3	ET4	ET5	ET6	ET7	All	BT1	BT2	BT3	BT4	BT5	All
	$n = 55$	$n = 23$	$n = 57$	$n = 42$	$n = 74$	$n = 39$	$n = 67$	357	$n = 80$	$n = 72$	$n = 70$	$n = 17$	$n = 76$	315
Student presentation[b]	0	4	1	0	0	0	4	1	0	1	0	0	2	1
Student presentation with explanation[c]	0	0	0	0	2	0	0	0.5	0	0	0	0	0	0
7. Administrative	2	0	5	14	11	5	8	7	9	8	11	11	16	12

See also Appendix Table 7 for detailed description of the teaching strategies

SSI with some student input, *TG* teacher-directed guidance, *CG* constructivist-oriented guidance

[a] Transmisisonist-oriented practices

[b] MIXED practices

[c] Constructivist-oriented practices

science, and critiquing of ideas were observed only in a small proportion of the experienced teachers' classroom lessons (12 %); this occurrence was rarely observed in the lesson segments of beginning teachers (1 %). The field notes and classroom videos show that the students of some experienced teachers (e.g., ET3, ET5 and ET7) appeared to be comfortable and willing to stand and express their ideas during class lessons. The experienced teachers tended to encourage active participation of students by posing high-order questions; the beginning teachers tended to do most of the classroom talk and seldom elicited the students' ideas.

Although the enacted lessons of the experienced teachers provided some empirical evidence that constructivist-oriented practices can happen within an assessment-based school culture—one of the key attributes that are often cited in describing the Singapore education system (Chai 2010)—the classroom environment that the participating teachers forged remained predominantly teacher-controlled. This is not surprising noting that similar findings were reported in another Singapore-based study that involved beginning and experienced teachers from primary schools teaching multiple subjects (Lim and Chai 2008) and in other international studies involving experienced science teachers (e.g., Savasci and Berlin 2012).

Alignment Between the Beliefs and Practices of Beginning and Experienced Teachers

Mixed patterns on the linkage between the teachers' beliefs and practices were noted (see Table 5). For half of the current sample of teachers, their classroom practices tended to be more aligned with their views of students' learning than their views of teaching electricity (see Table 5). In particular, four beginning teachers who expressed absorptionist views of students' learning and mixed views of teaching were observed enacting predominantly transmissionist-oriented classroom practices (BT1, BT2, BT3, and BT4). Two experienced teachers (ET3 and ET5), who espoused constructivist-oriented beliefs about teaching and mixed beliefs about how students' learn, devoted similar proportions of their classroom lessons to the use of transmissionist- and constructivist-oriented strategies.

The beliefs, about both teaching and learning, and the actual classroom practice of two experienced teachers (ET2 and ET6) converged on the mixed category. Two other teachers (ET1 and ET4), who also expressed beliefs about teaching and learning that were both categorized as mixed, used mostly transmission-oriented strategies during the classroom lessons observed. One beginning teacher, BT5, held absorptionist beliefs about learning, but her beliefs about teaching and the instructional approaches that she used in the classroom fit in the mixed category.

What appears to be consistent between the results of the current and previous studies (Mansour 2013; Bryan 2003; Zhu and Geelan 2013) is that whenever inconsistencies between teachers' beliefs about teaching and beliefs about learning were noted, the teachers' practices, in most cases, were aligned with their less progressive beliefs (which was usually their beliefs about the students' learning). This pattern of results, however, is partly inconsistent with the findings of Boulton-Lewis et al. (2001): They reported a general consistency between the beliefs about teaching and the *reported* teaching practices of their teacher respondents, who were teaching varied subject areas. The lack of coherence in the results could be due to the nature of data sources used to examine the teachers' classroom practices: Our results and those of three other studies mentioned observed teachers' actual teaching practices, while Boulton-Lewis et al. (2001) used self-reported practices. Self-reported data involves retrieval of information from long-term memory, which may be incomplete, reconstructed, or even invented (Fang 1996, p. 58). Another point is that self-reported instructional practices may serve as manifestations only of teachers' espoused beliefs but not their enacted beliefs.

The alignment of the transmissionist-oriented classroom actions of six teachers with their predominantly absorptionist beliefs about students' -learning, rather than with their mixed beliefs about teaching, could suggest a *student-oriented* but not necessarily student-centered approach in the teaching of electricity. In our view, a student-oriented approach is applied when teachers modify their teaching strategies in accordance with their perceptions of students' processes of learning, ability to learn, and learning needs (see Wallace and Kang 2004). However, in relation to the foregoing fraction of the sample, their classroom activities remained largely teacher-controlled even if their actions appear to have been influenced by their views of how their students learn. These findings partly resonate with those of other researchers (Chai 2010; Mansour 2013; Bryan 2003) who reported congruence between science teachers views about students' learning and their instructional practices.

Contextual Factors that Influenced the Alignment between Physics Teachers' Beliefs and Practices

After examining the teachers' interview transcripts, we have identified a few contextual factors that seem to have substantially influenced the alignment between the teachers' beliefs and classroom actions. For some teachers, their perceptions of their students' abilities seem to have guided the translation of their beliefs into classroom instruction, as was also suggested in earlier studies (Zhu and Geelan 2013; Savasci and Berlin 2012; Yim and Cho 2016). This finding can be linked to the fact that Singapore adopts an academic streaming process, which could have made the difference in abilities among students even more explicit to the teachers and could have served as a major force or constraint in their choice of instructional strategies. For example, BT2 (beliefs about students' learning = absorptionist, beliefs about teaching = mixed, practice = mainly transmissionist) mentioned that "Express [students] can explore more on their own [but NA students cannot]." In teaching electricity to NA students, BT2 did not utilize discovery or hands-on activities and mostly used teacher–directed activities such as lecturing, and presentations of demonstrations and simulations, with minimal student participation (at least 60 % of classroom segments observed, see Table 6). ET7, who was the only teacher who expressed constructivist-oriented beliefs concerning both teaching and learning, said that he was likely to use a more teacher-directed and simplified approach in classes where students were relatively "weaker"; if his students were "from better classes," he tended to utilize more student-centered activities. In teaching Express students (who are considered stronger academically relative to the rest of the cohort), he allotted about 25 % of his lessons for student-structured hands-on activities (see Table 6).

Alongside teachers' beliefs about their students' academic ability, another factor that appears to influence the coherence between teachers' beliefs and classroom behavior is their perception of the language-related challenges encountered by students in learning the topic of electricity. For some teachers, the students' language proficiency shaped their perception of students' "caliber" (ET6), whether they would "do less teaching" or more (ET6), or whether they would elicit students' ideas or not. For example, ET6 expressed views about teaching and learning that were both mixed; however, he indicated his inclination to use transmissionist-oriented approaches (i.e., "giving them knowledge") for students whose "language skills may not be that good." BT4, who expressed a predominantly absorptionist view about students' learning and a mixed view about teaching electricity, noted that many electricity concepts are "theoretical" and "cannot be seen" and that his students "have difficulty if it requires explanations"; thus, he did not expect students to be able to make their own explanations of electrical phenomena or principles. Consistently, BT4's actual classroom practice was largely teacher-dominated, with minimal input coming from his students.

As the present sample of teachers modified their teaching practices to suit their students' needs, they also tended to contend with factors present in their instructional contexts. Similar to teachers situated in other educational systems that emphasize high-stakes testing (Lim and Chai 2008; Mansour 2013; Savasci and Berlin 2012 Zhu and Geelan 2013), teachers in Singapore are pressed for time to prepare their students for these types of examinations. Three experienced teachers noted how, after teaching for more than 10 years, they developed knowledge and dispositions that were aligned with an examination-oriented system. ET1 explained that "as an experienced teacher, you'll know what type of questions, what type of calculation questions that they [students] will be asked to solve for exam." This could have been the reason why ET1 used more examination-driven strategies: He seems to have narrowed down his pedagogical repertoire to transmission-oriented teaching practices and refrained from using constructivist-oriented activities (i.e., doing science investigation), noting that "they [national tests] don't have these types of questions." Indeed, the dilemma of employing reform-based pedagogical strategies when they run up against what teachers perceived as an exam- and content-driven science curriculum has also been noted in another study involving Singapore teachers (Tan and Nashon 2013).

Longer immersion in classroom teaching may also influence the experienced teachers' perspective toward teaching. The intent to cover the prescribed curriculum was the key reason mentioned by ET4 in enacting transmission-oriented practices, despite expressing support for progressive views (i.e., mixed beliefs) about teaching and learning.

ET4: You [referring to herself] should facilitate their learning, yeah, but most of the time, in reality, you are just teaching them the theory. You are not really facilitating… because we need to finish the syllabus.

ET1 said, "After teaching a few batches, you realize, eh, certain things work. Certain things you don't really have to elaborate, the students won't ask." This idea brings forth the notion of a more targeted pedagogy, which, for some teachers such as ET1, may connote the enactment of transmission-oriented practices. However, for some teachers, such as ET5 and ET7, the time freed up in using a more focused teaching approach may have been utilized to allow their students to have more opportunities to engage in constructivist-oriented activities, such as inquiry-based tasks. However, recognizing the tension between the demands of high-stakes tests and implementing reform-based approaches, both teachers settled with the enactment of mixed teaching approaches.

More of the experienced teachers used mixed teaching approaches, which coincided with mixed or constructivist-oriented beliefs about teaching. This may suggest their greater pedagogical sensitivity (Belo et al. 2014, p. 98) compared to the beginning teachers. These experienced teachers tended to draw upon a range of pedagogical approaches and consider a number of ecological and domain-related factors in making instructional choices. For example, ET3, who used mixed approaches for nearly half of the lessons observed, described how he modifies his lesson based on students' academic abilities, while seemingly assuming the role of knowledge provider:

ET3: [I] go to the class with different abilities. And within a class, there are different abilities among themselves, supposedly the same ability class [NA class]. I'd just go, I'd prepare a general lesson and I would go by the year. And if I be teaching in a better class, I notice you know, they seem to catch on fast. So the examples, the additional examples I would give. Straight away I would give, just want to make sure everyone is OK, on the same level, I'll give them a basic.

At some points during the interview, he also indicated how he intended to let students play a key role in their learning: "So I make it a point that, students sit in pairs, and I do actually allow them to discuss what I teach…After the initial example, and some plus examples, they can go off and work with one another."

Moreover, the beginning teachers' perceived complexity of many concepts involved in the electricity unit prescribed in the physics syllabus, and the need to cover these topics within a limited period, seems to have predisposed them toward the adoption of transmission-oriented practices. BT3, for instance, noted how he tended to quickly present analogies that he regarded as useful to help students understand complex electricity concepts and then focus more on the drill-and-practice approach to be able to cover the prescribed content. These ideas can be inferred from his responses when the interviewer asked why he allotted minimal time for students to answer questions and express their ideas, particularly when he introduced analogies in relation to the concepts of potential difference and current:

[This is] because, first, I was rushing the syllabus; number two, I mean, as you can see, I already took 12 lessons [to cover the unit of electricity]. It is a big chapter, deep concepts and concepts they [students] were not familiar with, so I…okay. So, to be honest, my usual strategy is to try to get them to appreciate the theory as fast as possible and drill on questions. So, I mean, the way I learn physics is just do a lot of questions…So I wanted to, as quickly as possible, deliver the analogy, 'cause, in a way, the analogy is not in the syllabus. So to me, speed was key.

This result seems to be in harmony with the assertion of Mulhall et al. (2001) that didactic approaches tend to be used in teaching challenging physics topics. However, the finding that the experienced teachers, who also acknowledged the same challenges, maintained views, and enacted practice that were more progressive (i.e., mixed), seem to support the findings of Gunstone et al. (2009) involving experienced physics teachers. It appears that the less experienced teachers tend to align their beliefs and practices toward the transmissionist instructional model when teaching complex topics.

The transmissionist orientation of the beginning teachers' beliefs and teaching preferences may also reflect the nature and impact of the ITE program that they attended: It may have provided the teachers limited exposure to reform-oriented practices, or if it did, it was not sufficient to orient the teachers toward reform-oriented beliefs and predispose them to enact corresponding practices. The relatively short duration (1 year) of the ITE program experienced by most of the beginning teachers might be insufficient for the reform-based pedagogical approaches introduced during ITE to be "incubated" and "digested" by the beginning teachers, thereby making it difficult for them to critically engage with these approaches and interrogate their existing beliefs. It is however puzzling why BT4, who experienced longer ITE (about 4 years), had belief and practice profiles that were similar to those of the majority of the beginning teachers. Considering that teachers tend to teach the way they were taught (Nashon 2005), one possibility is that the prior school experiences of beginning teachers as learners had a larger influence on their own teaching practices than the ITE program. This leads to our suggestion for teacher educators to more explicitly "confront" these ingrained experiences as a way of encouraging an adaptation of reform-oriented practices into teaching. We urge a rethink on the quality of learning activities offered by ITE for the pre-service teachers, particularly concerning the inclusion of reflection on the trainee teachers' pre-ITE and ITE experiences and the forging of a deep connection between theory and practice.

Conclusion and Implications

The results of this study showed that beginning and experienced teachers differed in their beliefs about teaching and learning and in their instructional practices. Beginning teachers generally espoused transmissionist beliefs about learning and mixed beliefs concerning teaching electricity; experienced teachers expressed mixed views concerning learning and mixed to constructivist beliefs about teaching electricity concepts. Beginning teachers and experienced teachers enacted predominantly transmission-oriented and mixed approaches, respectively. Although the classroom lessons of both groups were found to be largely teacher-dominated, elements of constructivist pedagogy were more frequently observed in the classrooms of experienced teachers than in those of beginning teachers. Experienced teachers also tended to have a bigger repertoire of teaching approaches, both proposed and enacted, and more diverse views about their roles during instruction. The experienced teachers' greater familiarity with the students, curriculum, and assessment could have predisposed them to adopt student-oriented approaches, which are a step closer to but not equivalent to student-centered approaches. Student-oriented teaching approaches are those that are modified by the teachers in consideration of their perceptions of the students' learning needs and abilities but are delivered in teacher-dominated way; student-centered approaches, in contrast, are directed by students' ideas and objectives. The experienced teachers' increased knowledge of learners and the educational system may also be regarded as a double-edged sword: In some instances, it appears to narrow down the teachers' enacted repertoire of teaching approaches in order to suit an examination-driven pedagogy; in other instances, it seems to broaden this repertoire to promote students' purposeful learning. In light of the teachers' roles to prepare their students for the national examinations, they require some support on how their knowledge and beliefs about good teaching could be concomitantly integrated rather than separated from it; such a task has been perceived by Singapore teachers to be a challenge (Tan and Nashon 2013). Thus, we encourage efforts to help and guide teachers to turn possible challenges and constraints of enacting their desired classroom teaching and learning approaches into "enablers" to further promote student learning (Tan and Nashon 2015). For both initial teacher preparation and in-service professional development programs, we also underscore the need for investment in the formulation of approaches that can encourage coherence of student-centered teaching with student-oriented teaching and examination-based teaching. In examination-oriented education systems, we urge policymakers and school leaders to consider shifting their focus toward developing a teach-less-learn-more system.

We note that longer teaching experience does not necessarily mean that a teacher holds and practices reform-oriented views, but it does seem to enrich teachers' contextual knowledge, beliefs, and practices and increase their pedagogical sensitivity, as indicated by the greater prevalence of hybrid beliefs and practices among more experienced teachers in this study (see also Belo et al. 2014). The foregoing results may be useful for those concerned with improving teachers' instructional practices. For example, the mentoring model in Singapore, which involves experienced teachers (even with less than 10 years of experience), may prove fruitful in light of how the results suggest that experienced teachers possess a wide range of teaching practices and beliefs that are leaning toward constructivist orientations of teaching and learning. The experienced teachers' accumulated knowledge of students, curriculum, and assessment can be tapped as a resource to help improve the performance of both novice and experienced teachers who are struggling to meet the demands of a performance–based system. We encourage school administrators and professional development designers to provide a venue for experienced teachers to articulate and share this rich knowledge from experience.

Both novice and experienced teachers are encouraged to jointly reflect on their experiences to generate collective "mental images of constructivism as practiced in authentic classroom situations" (Windschitl 2002, p. 162) and put constructivist views into practice. They need to be provided with opportunities and structure to pool their resources and teaching experiences. They also need safe spaces where they can take risks to enact reform-based teaching. Approaches such as professional learning communities (e.g., Lave and Wenger 1991), the learning study (e.g., Pang and Lo 2012), and lesson study (e.g., Lewis et al. 2009) may well provide the contexts for teachers to begin engaging more deeply with their beliefs and teaching practices within a space that allows for these very beliefs and practices to be examined by "peers." These contexts may also serve as valuable vehicles for shifts in teachers' beliefs in directions to benefit their own and their students' learning and/or to support reform efforts (e.g., Tan and Nashon 2013).

The foundation for developing teachers' competence for collective reflection about their beliefs and instructional experiences, fostering beliefs change, and encouraging teachers to take pedagogical risks, such as enacting constructivist-oriented approaches, could be laid out during ITE. Pre-service teachers, as they are introduced to the "what" and "how to" of education, need to be provided ample opportunities to critically examine the approaches (particularly reform-based ones) presented in ITE, articulate and interrogate their existing beliefs and newly acquired knowledge, reflect on their pre-ITE and ITE experiences (especially those that occurred during practice teaching), and forge strong and explicit links between campus-based and classroom-based learning experiences (Chróinín and O'Sullivan 2014) and between theory and practice (Kahne and Westheimer 2000). They can work together to formulate a collective working theory of teaching and learning on the basis of their own individual experiences and the work of education theorists and then implement, as a group, a curriculum project borne out of their working theory (Kahne and Westheimer 2000). These opportunities can provide beginning teachers with a framework on how to critically engage in their beliefs about teaching and learning and direct their learning, both individually and collectively, after ITE— within the premises of their own classrooms.

Our sample of physics teachers' beliefs about learning and teaching electricity was found to be generally inconsistent and the instructional practices of the teachers (especially the beginning teachers) tended to be more coherent with their beliefs about learning than teaching. When teaching topics that feature several complex concepts, such as the topic of electricity, it appears that these teachers, regardless of their teaching experience, tended to be more influenced by their views of how their students learn than their beliefs about how to teach their students. These results could be a consequence of how prior experiences of teaching correspondingly catalyzed the shifts in teachers' beliefs (e.g., Guskey 1985; Waters-Adams 2006), albeit in a more complex and seemingly asynchronous manner (see Clarke and Hollingsworth 2002). In line with this speculation, we found that the more experienced teachers' beliefs about learning and classroom actions had a stronger tendency to lean more toward reform-oriented perspectives. A greater repertoire of approaches, which the more experienced teachers could have learned, tested, modified, and used through the years of teaching, might have favored this state of affairs.

For most of the teachers, their beliefs about students' learning, which tend to align with their classroom practices, appear to be highly dependent on their perceptions of students' academic abilities (i.e., the students' degree of competence in performing subject-related tasks) and language-related difficulties. We put forward the need to recalibrate teachers' beliefs about students' learning and perceptions of students' capabilities—as was also highlighted by Windschitl (2002)—before focusing on reform-based efforts aimed at improving teachers' practices, especially in relation to teaching subject areas such a physics that are associated with abstract concepts and microscopic systems. Changing teachers' perceptions of how low-achieving students are capable of engaging in higher-order thinking (see for example, Zohar and Dori 2003), which is needed in understanding complex topics, may encourage them to explore new pedagogical strategies that can subsequently deepen student learning. In the spirit of Vygotskian principles (Vygotsky 1978), teachers should be encouraged to take some risks to enact reform-based teaching strategies, even to the point of giving students some tasks that are slightly above their capabilities to optimize their potentials. We feel that the current emphasis on collaborative teacher inquiry may well amalgamate the necessary conditions to encourage teachers to take these risks. When teachers take the initial steps to practice reform-based approaches, even when teaching complex topics, the modification of their beliefs may follow suit. As Levitt (2002) asserted, experience can also be a catalyst to change beliefs.

It was a positive development that many of both the beginning and experienced teacher participants, in the present study were found to have some awareness of the challenges associated with the language used in teaching electricity, with most of the teachers recognizing the abstract nature of physics concepts and a significant proportion of them acknowledging that students grapple with differences in meaning between terms used in the physics context and in daily conversations. This finding counters Oyoo's (2012) reports indicating that physics teachers, especially the less experienced ones, tended to have limited awareness of the students' difficulty in the words included in their instructional language to students. Nevertheless, we concur with Oyoo's recommendation to emphasize the effective use of the language of instruction in ITE and in-service PD programs. We also underscore the need to support teachers in how to address the language-related difficulties in both teaching and learning physics. One way to do so is to point out to teachers that students need not "unlearn" all ideas that they have derived from everyday experiences; aspects of such ideas can be utilized as a resource—as hooks—for learning physics concepts and principles (Grayson 2004; Haglund et al. 2015).

Moving forward, we also encourage other researchers to revisit the findings reported in earlier studies (e.g., Lim and Chai 2008; Mellado 1998) that reported inconsistencies between the beliefs and practice of teachers, yet did not tease out teachers' beliefs about students' learning and beliefs about teaching. For future studies linking teachers' beliefs with other constructs, such as students' outcomes, we recommend separate assessments of teachers' beliefs on how students learn and teachers' pedagogical beliefs in order to gain more nuanced insights. Concerning initial and continuing teacher education, we underscore the need to equip teachers with tools to help them reflect on their beliefs and differentiate their beliefs about teaching from those about learning (Cho and Huang 2014). We premised such suggestions on the perspective that the conflation of beliefs about teaching and learning may risk losing opportunities for reflection on their relationships and coherence, which may put into question the common assumption that whatever is taught is learnt. Our suggestion extends to how collaborative teacher inquiry approaches may be utilized to provide opportunities for teachers to examine and reflect on the conflicting nest of beliefs within these belief systems (Bryan 2003), and to deal with this conflict in a way that would lead to the selection of a beliefs nest that would encourage the enactment of reform-oriented instruction.

As this study drew insights from a small sample of teachers, the generalizability of our findings beyond the context of this study is limited. The results of this study can be enriched and extended by focusing on both complex and simple topics within a single study. Another potentially valuable follow-up to the current efforts are investigations of how teachers' practices align with their beliefs change, and how this changes when teaching students in different academic streams. Of equal importance is acknowledging that we have captured the differences by framing the teachers' beliefs and practices as transmissionist, constructivist, or mixed. We recognize that the analysis presents a limitation pertaining to the lack of other crucial aspects in understanding science instruction, such as the foregrounding of teaching and learning related to sociocultural approaches in science education (Sadler 2009); these aspects are worthy of future research work in further unpacking the practices of science teachers. Particularly, it is necessary to investigate how teachers facilitate meaning-making and internalization of science knowledge and tools through analyzing the content and patterns of classroom interactions (Mortimer and Scott 2003). For a deeper analysis, researchers should pay attention to such discourse patterns as initiation-response-evaluation (or feedback) between a teacher and students. Through the communication with a teacher, students can internalize not only science concepts, principles, and theories but also the language of the scientific community. Nevertheless, our choice to focus on the transmissionist-constructivist-mixed framework stems from how these terms are dominant in science classroom discourses in Singapore and are ideas teachers readily use to describe their teaching—as observed from our interaction with science teachers. We realize that "transmissionist-constructivist-mixed" teaching practices have not been thoroughly researched in Singapore's context nor have these terms been addressed in the ways they are presented either explicitly or implicitly in recent science reform visions that entail inquiry-based learning and problem-solving strategies, which are underpinned by perspectives of constructivism. Despite the stated limitation, the current study provides glimpses into the domain-specific beliefs and practices of Singapore physics teachers, and underscores the important role that beliefs play in shaping practices situated within authentic instructional settings. Additionally, the substantial body of literature that corroborates various aspects of our findings lends credence to the claim that experience does matter in forging reform-oriented identities of teachers.

Appendix

Table 7 Classroom observation protocol (adapted and modified from Lawrenz et al. 2002)

Teaching strategies	Description	Category
1. Lecturing	Teacher (T) presents concepts and principles to students (Ss)	
Teacher-directed	T dominates the lesson. Ss give minimal input with questions and responses that are of low-cognitive level and mostly fragmented	TRANS
With SSI	T does more talking than Ss; Ss give some input (SSI) by giving a series of interconnected low-cognitive answers or questions (at least 5); or mixing low-cognitive and high-cognitive responses or questions (note: 1 high-cognitive = 2 low-cognitive answers/questions)	MIXED
With analogy	While lecturing, T introduces an analog (subject with properties assumed to be familiar with Ss) that has some similarities with the concept or object being discussed. Ss have minimal participation.	MIXED
With analogy and SSI	T uses analogy while lecturing, with SSI.	MIXED
With demos	While lecturing, T shows demonstration with real electrical equipment or using simulations. Ss have minimal participation.	TRANS
With demos and SSI	While lecturing, T shows demonstration with real electrical equipment or using simulations to illustrate concepts; with SSI	MIXED
With linking to daily life	While lecturing, T relates lessons with daily life but with minimal input from Ss	MIXED
With linking to daily life and SSI	While lecturing, T relates lessons with daily life and with SSI	MIXED
2. Active discussion	Active T-Ss and Ss-Ss discussion: T initiates the discussion but elicits ideas of Ss to develop understanding of particular concepts; Ss gives at least five answers or questions at high-cognitive level	CONS
3. Problem modeling	T demonstrates or models how to solve a new problem	
Teacher-dominated	T does most of the talking, and with minimal input from Ss	TRANS
With SSI	T does most of the talking but with SSI	MIXED
4. Seatwork	Ss answers typical problems from textbooks	
With "transmissive" guidance	T provides TRANS guidance: that is, T guides the Ss by telling the steps or answers, or telling the formula to Ss	TRANS
With "constructive" guidance	T provided CONS guidance by asking questions and giving clues on the needed principles but not telling the exact answers or steps.	MIXED
5. Hands-on activities	Ss carry out experiments or science investigations to answer particular problems or questions	
Teacher-structured	The activity is T-structured: T formulates the questions, designs the activity, and provides the steps. Ss follow the steps given by T. The activity is done for confirmatory purposes.	TRANS
Partly student-structured	T formulates the questions, but Ss give some input on the steps to carry out the activity. The activity is done by manipulating materials, usually for confirmatory purposes.	MIXED
Student-designed	The Ss carry out the activity that they planned or designed. It involves minimal teacher control.	CONS

Table 7 (continued)

Teaching strategies	Description	Category
6. Collaboration	Ss engage in sharing, negotiation, and/or critiquing of ideas with other Ss	
Pair work	Ss work in pairs to discuss a particular issue or solve a problem	CONS
Student presentation	Student presentation: Ss present or show their answers to other Ss, usually by writing their answers on the board. Ss do not explain or defend their answers	MIXED
Student presentation with explanation	Student presentation that includes Ss presenting, explaining, and defending their answers. Other Ss are asked to critique the answers.	CONS
7. Administrative	T engages in administrative tasks that are not involved in the main teaching activity (e.g., checking attendance, distributing laptops, etc.)	

TRANS transmission-oriented, *CONS* constructivist-oriented, *MIXED* mixed TRANS and CONS, *T* teacher, *Ss* students, *SSI* students give some input

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