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Moving from surviving to thriving: a taxonomy of beginning science teacher challenges

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Abstract
Induction programs have been promoted as a potential solution for alleviating aspects of job dissatisfaction that lead to attrition of beginning science teachers. We can meet the immediate concerns of beginning teachers that impact job satisfaction while simultaneously helping them improve their practices by better understanding the particular challenges they face. This qualitative study examines challenges as expressed within an online induction program for non-tenured Science educators with data from synchronous chat room sessions between mentors and beginning teachers. The results indicate that there is a more diverse and nuanced set of challenges that beginning in-service science teachers face than previously indicated by literature. The content-specific nature of these challenges supports the call for content-specific induction.

Contributions to the literature
• There is a much larger range of challenges that beginning science teachers face than previously identified in the literature.
• The challenges beginning science teachers face are both general challenges that many new teachers face and also specific to the teaching of science and specific science content.
• This study provides additional evidence to support the challenges in prior literature.

Keywords Science education, Induction, Mentoring, Teacher development, Challenges

Introduction
More than 44% of beginning teachers leave the profession within the first five years of their practice (Ingersoll et al., 2018). In science, turnover has created staffing shortages (Ingersoll, 2001; Ingersoll & May, 2012; Ingersoll & Perda, 2010) and 'revolving doors' of beginning teachers within many high-needs districts (Ingersoll, 2001). Retaining qualified science teachers is a more acute need, as there is a more limited supply than other teaching fields (Ingersoll & Perda, 2006). Additionally, as beginning science teachers gain more experience, they become more effective in improving student learning (Henry et al., 2012). Thus, high levels of beginning science teacher turnover lead to less effective student learning for our nation's youth. These high levels of attrition, coupled with the retirement of baby boomers (National Commission on Teaching and America's Future, 2009) have placed a focus on induction programs as high-quality induction programs can decrease attrition to help address the shortage of science teachers (Ronfeldt & McQueen, 2017).

While up to 90% of teachers nationwide receive some kind of induction support, science teachers are less likely to participate in induction supports (Smith & Ingersoll, 2004). In districts that serve higher percentages of

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low socio-economic students, rates of participation are as low as 57% (National Science Board, 2008). Even if teachers participate in induction programs, not all beginning science teachers are matched with a content-specific mentor. The National Science Board (2008) study found that 50% of science teachers were matched with another science teacher as a mentor, with even lower rates of content specific mentoring occurring in high needs schools. Additionally, finding mentors in small schools is challenging because in these settings the beginning science teacher may be the only science teacher in the school.

While induction programs can impact retention (Ingersoll, 2001; Ronfeldt & McQueen, 2017), some have raised serious concerns about focusing induction support solely on retention. For example Feiman-Nemser (2001) writes:

> Unless we take new teachers seriously as learners and frame induction around a vision of good teaching and compelling standards for student learning, we will end up with induction programs that reduce stress and address immediate problems without promoting teacher development and improving the quality of teaching and learning. (p. 1031)

Other researchers have echoed the importance of framing induction around standards-based visions of science teaching (Wang et al., 2008). Koballa and Bradbury (2009) argue mentoring within induction programs for science teachers should “advance standards-based science education reform, while at the same time addressing the science-specific needs of beginning teachers at all schooling levels” (p. 171). If appropriately structured, induction programs can both meet beginning teachers’ immediate concerns that impact job satisfaction (Feiman-Nemser, 2001) and help them improve their teaching practices (Darling-Hammmond & Richardson, 2009; Ingersoll, 2001). This support is even more important to help teachers enact the ambitious reforms of practice called for within Framework for K–12 Science Education (National Research Council, 2012) and the Next Generation Science Standards (NGSS Lead States, 2013) to improve student learning of science (Ingersoll & Strong, 2011).

By understanding the unique challenges faced by beginning teachers of science, sources of job dissatisfaction are better understood. And in understanding the unique landscape of beginning science teacher challenges, we can build targeted induction to support both teacher growth and improve job satisfaction. Thus, this study is guided by the following research question: What are the specific challenges beginning in-service science teachers may face in their first years of practice?

Review of relevant literature

In designing induction supports it is important to understand the range of challenges faced by beginning science teachers. The most commonly cited work on new teacher challenges is a landmark study by Veenman (1984) that reviewed 83 studies of elementary and secondary beginning teachers from 1960 to 1984. In this study, a challenge is described as “a difficulty that beginning teachers encounter in the performance of their task, so that intended goals may be hindered” (p. 143). Veenman created a rank order of the 24 most common problems beginning teachers faced based on the frequency in which they appeared within the study. Unsurprisingly, classroom management was the highest-ranking problem. Gold (1996) raised concern about Veenman’s work as it lacked focus on the relationships between subject matter knowledge and pedagogical knowledge, and between management and teacher instructional choices and curriculum. Gold (1996) argued that developing induction programs based on Veenman’s work could lead to the development of programs that provide a focus on classroom management support, and not on the complex processes of teaching such as acquiring and enacting pedagogical content knowledge.

A review of research within science education literature found several studies that explored at least one aspect of challenges faced by secondary science teachers. From this set of studies cross-referenced with Veenman’s work, we find that beginning science teachers face the following challenges:

- Limited time for planning and instruction (Bianchini, Johnston, Oram, & Cavazos, 2003; Adams & Krockover, 1997; Harmsen et al., 2018; Helms-Lorenz et al., 2016; Loughran, 1994; Veenman, 1984).
- Limited resources for teaching (Bradford & Dana, 1996; Rushton & Reiss, 2021; Varelas et al., 2005; Veenman, 1984).
- Content knowledge (Adams & Krockover, 1997; Council, 2016; Napier et al., 2020; Roehrig & Luft, 2004; Veenman, 1984; Watson, 2006).
- Pedagogical content knowledge (Adams & Krockover, 1997; Kelly et al., 2015; McNally, 2006; Navy et al., 2021; Roehrig & Luft, 2004).
- Developing productive learning environments (Adams & Krockover, 1997; Eick, 2002; Hong et al., 2017; Kelly et al., 2015; Roehrig & Luft, 2006; Rushton & Reiss, 2021; Simmons et al., 1999; Veenman, 1984).
- Supporting diverse learners, especially those facing challenges due to poverty (Brown & Livstrom, 2020; Kelly et al., 2015; Rushton & Reiss, 2021; Veenman, 1984).

- Conflicts between school culture and vision for teaching reform-based science (Council, 2016; Ellis et al., 2022; McGinnis et al., 2004; Rushton & Reiss, 2021).

Davis et al.'s (2006) review of 112 studies of challenges faced by pre-service and beginning in-service elementary and secondary science teachers, cites an overall lack of research focused on beginning science teachers. Missing from the literature is a comprehensive understanding of the challenges of learning to teach secondary science from a content-specific perspective from the perspectives of the beginning teachers that moves beyond rank order lists or specifically focused studies. It is important to explore which particular challenges they face within areas such as classroom management and pedagogical knowledge and how these challenges relate to both context and content. Therefore, this study seeks to provide a comprehensive landscape of the particular challenges faced by beginning secondary science teachers.

Methods

This study examines challenges as expressed within an online induction program for beginning science educators in a midwestern state. This program served 65 beginning Science, Technology Education, and Mathematics teachers, 24 of whom were in secondary science. This program's goals were to increase the retention of teachers and to improve beginning teachers' instructional practices. This program utilized both synchronous and asynchronous technologies to connect beginning teachers with content-specific mentors and a community of their peers. The teachers participated in activities such as Mentor/Beginning Teacher Chats, Case-Based Discussions, and 'Professional Development Investigations wherein beginning teachers worked with mentors in planning, implementing, and reflecting on a specific, pedagogically focused lesson.

The most commonly utilized support within this program was the mentor/beginning teacher chat, a synchronous private conversation between mentors and beginning teachers. Each beginning teacher was assigned a mentor who taught in the same content area (e.g. physics mentors with beginning physics teachers) content area and, if possible, in a similar context (e.g., rural, suburban, urban). Beginning teachers were required to chat at least weekly with their mentor. The primary goals of the mentor/beginning teacher conversation support were to meet the immediate needs of beginning teachers while helping to refine their repertoire of content-specific reform-based practices (Feiman-Nemser, 2001).

Participants

The following provides background on the 24 beginning science teachers in the study:

(a) 9 out of the 24 were not fully licensed for the subjects they taught (e.g., a Biology major with a Life Science License teaching Physics)

(b) There was a range of local mentorship support for the participants: 3 had local mentors who taught the same domain (e.g. physics teacher mentoring a new physics teacher), 4 had local mentors who taught science but not in the same domain (e.g. physics teacher mentoring a new life science teacher), 9 had local mentors but not in science (e.g. a social studies teacher mentoring a new physics teacher, 12 had no mentors.

(c) 7 taught in urban settings, 3 in rural settings, and 14 in suburban settings

(d) 19 taught in traditional school structures and 5 taught in non-traditional school structures such as charter/alternative schools

(e) 17 taught in high schools and 7 in middle schools

(f) 12 were in their first year of teaching, 9 in their second year, 1 in their third year, and 2 in their fourth year but were not yet tenured in their district

Data sources

The primary data source was synchronous chat room sessions between mentors and beginning teachers over six months from October to March, the length of the program. Synchronous chat rooms were selected for analysis because although there are differences in speech patterns and turn-taking in this form of computer-mediated communication, it is similar to patterns in a face-to-face or phone conversation with a mentor. Some sessions dedicated time to action-research tasks as part of the induction program, but a majority of these sessions were unstructured conversations about the beginning teachers' practices. These chat room sessions provide a somewhat naturalistic source of data containing beginning teacher's actual words in a conversational context with their content-experienced mentor.

Data analysis

This qualitative study used an inductive approach to data analysis (Miles & Huberman, 1994) in a naturalistic setting to explore the dialog within the chat room sessions. While no a priori codes were developed, the authors' prior knowledge developed from work with pre-service science teacher education, induction program development and mentoring experience, experience as a secondary science teacher, and familiarity with research on beginning science teachers helped to shape the initial codes.

Operationalizing challenges

To begin the coding process, chat room transcripts were read line by line, one participant at a time. As chat room sessions were read, the authors looked for phrases indicating a challenge. A challenge could be a problem that impacts an intended goal (Veenman, 1984) and/or could be a problem related to a source of emotional/psychological stress (Helms-Lorenz et al., 2016). Guided by the literature on the embodiment of challenges being expressed as inability to achieve a desired goal or stress, a phrase was classified as a challenge if it was (1) an expressed frustration, uncertainty, or concern, (2) was a question directed at the mentor, or (3) was a story that did not have a resolution.

Process of coding and creation of the taxonomy

During the coding process, statements classified as a challenge were first selected using the text of the statement as an 'in vivo' code (Glaser & Strauss, 1967). After reading several participant transcripts, these 'in vivo' codes were grouped into larger conceptual 'bins' or categories, such as General Pedagogical Knowledge, Classroom Management, and Pedagogical Content Knowledge. Returning to the data, other participant transcripts were read and additional 'in vivo' codes were created, then sorted into the larger 'bins.' If they did not fit into existing categories, additional categories such as 'Context' were created. This iterative process continued with occasional coding checks to ensure that the 'in vivo' codes fit in each of the bins.

As more 'in vivo' codes were created and sorted, the authors began to create sub-categories within each larger category. These sub-categories were given a short description to ensure internal consistency and were created not necessarily based on frequency, but on the challenge's uniqueness. The process continued through additional 'in vivo' transcript coding, sorting into codes into larger categories, then into sub-categories.

Using constant-comparative methods (Glaser & Strauss, 1967) for internal consistency, frequent checks of the 'in vivo' codes' original context ensured the code fit within both category and sub-category. This process continued until all transcripts were analyzed. The codes, sorted into categories and sub-categories, were then transformed into a series of tables, and a comprehensive figure showing the 'taxonomy of challenges'. The set of 'in vivo' codes within each of the taxonomy's categories and sub-categories was reviewed to ensure final consistency, and code frequencies were calculated.

As an additional level of analysis, the taxonomy was examined through the lenses of personal prior knowledge and literature to explore what was anticipated, what was not expected, and what was missing, as well as an exploration as to why certain challenges were faced and how beginning science teachers could receive support for these challenges.

Inter-rater reliability and member checking

To provide a more reliable set of data, inter-rater reliability assessments were done with two external researchers. These researchers were both former secondary science teachers and experts in science education. A sample of the data was selected for analysis based on the richness of the conversation. The raters were given the codebook containing descriptions of the 83 categories and sub-categories. They were then asked to code three transcripts one at a time, tallying discussed agreements and disagreements. Across the three transcripts, there was an initial agreement of 122 out of 138 possible codes, for an 88% agreement. The second round of coding had an approximate inter-rater reliability of 96%.

The taxonomy's set of represented codes was also given to this study's selected mentors and beginning teachers. This form of member checking (Glaser & Strauss, 1967) was useful in determining if the groupings were clear and if the table was complete. Throughout this analysis, mentors and beginning teachers provided additional challenges they felt were missing.

Limitations of the study

Data analysis may be limited by several factors. For example, conversations at times were driven by the mentor that may have limited the beginning teacher's ability to discuss freely the challenges they were facing. Additionally, text-based chat misses tonal and body language clues that could help mentors toward the exploration of challenges. Finally, this program began in October instead of in August, when the school year started, so the documented challenges may not be fully representative of the challenges faced within the first weeks of school.

Results

On average, each of the 24 participants communicated eight times (SD = 4.1) for an average of 39 min per conversation (SD = 14.4) over a period of six months for a total of 196 chat room sessions. When the coding was completed, 167 of the 196 (85%) chat room transcripts containing at least one challenge. From the 196 transcripts, there were an average of 5.2 challenges noted per conversation (SD = 3.9) with a total of 874 statements that were coded as challenges in this study. Each of the 24 participants had at least one chat session containing at least one challenge, with each participant averaging 4.1 challenges per transcript (SD = 2.6).

The categories identified include challenges related to (1) student academics, (2) external pressures, (3) working with diverse learners, (4) personal beliefs and attitudes, (5) the context of the school or district, (6) classroom management, (7) general pedagogical knowledge, (8) science pedagogical content knowledge. The codes within the categories are presented in alphabetical order, as the purpose of this study is to break convention from ranked orders of concern such as provided in the Veenman (1984) study. This will help to provide an exploration of the landscape of challenges faced by beginning science teachers and help shift thinking away from supporting the common challenges and begin to help us explore the complex ecology of these challenges. Each of the seven primary challenge categories is described in detail in the following section with quotes from the transcripts to help further unpack the challenges for the reader.

Student academic performance

As shown in Table 1, the Student Academic Performance category includes a general set of challenges related to how students were performing in their classes. While the conversations were within the context of science classrooms, they stayed at a general level; that is, they do not become discipline- or topic-specific. For example, one participant explained, "I am at a crossroads with ionic compounds…many of the kids are just not getting it, but most of the ones not getting it are not doing any work either…so my juniors just sit and complain but won't read the textbook book or look at their notes …I am really frustrated." This was coded as "Student effort related to completing assignments and other tasks." While this quote is contextualized by a specific chemistry topic, it represents a challenge related to the belief that the reason students are not succeeding is that they do not work through their assigned problems. Another participant stated concerns related to working with parents, "I agree completely about the pressure parents put on their kids. It is a bit obnoxious at times. Some kids are just B or C students."

External challenges

As shown in Table 2, the External Challenges category includes challenges related to demands on their time and energy not related to planning and implementation of instruction, such as being a teacher advisor for an after school club or sport, continuing education, and the uncertainty of future employment leading to the search for a new teaching position. For example, one participant noted challenges related to extra-curricular work stating, "I am a little stressed… I was thinking gymnastics would be done by now, but it has managed to get busier!" We also find other stressors like the need to find new employment such as when one participant notes that "I am still waiting to find out if I have a job here next year… [so] that stinks too".

Teaching diverse learners

As shown in Table 3, the Teaching Diverse Learners category includes challenges related to how they can improve instruction to meet these students' unique needs. One participant states that "the ELL students I have had them tell me a couple of times that they are learning 2 languages at once" then stating that "they are struggling with the language of science and the language

Table 1 Challenges related to student academic performance

Category	Description
Student effort related to improving personal understanding	Challenges related to teacher concerns that students understanding and academic success is hampered by their not working through challenges
Students failing courses	Challenges related to student failures in courses
Student effort related to completing assignments and other tasks	Challenges related to students that are not completing tasks, assignments, and other work in or outside of class due to effort
Student performance on formal assessments	Challenges related to understanding why students that are struggling to perform on formal assessments
Working with parents on student academic issues	Challenges related to working with parents to improve the academic performance of their students

Table 2 External challenges

Category	Description
Finding new employment	Challenges related to the need for a new teaching position caused by a variety of reasons
Lacking support from partner	Challenges related to a lack of support from a partner
Masters coursework	Challenges related to coursework for masters degree are placing a demand on time and energy
Voluntary extra-curricular	Challenges in which voluntary extracurricular work during the school day and beyond places demands on time and energy

Table 3 Challenges related to teaching diverse learners

Category	Description
Students who are EL	Challenges related to supporting students who are English Learners
Student receiving special education services	Challenges related to support of students who have learning disabilities and may be receiving special education services
Students displaying severe behavior	Challenges related to supporting of students with severe behavior in which counselors and other staff are involved

of English." Another participant stated, "I have way more special ed and ELL students this semester so I am working on my clarity, instructions, and writing on the board."

Personal beliefs, attitudes, and general concerns

As shown in Table 4, the Personal Beliefs, Attitudes, and General Concerns category refers to a set of internal challenges that they identify as impacting their job satisfaction. In other words, these challenges were related to teachers' internal beliefs and expectations about being a teacher and their perceived ability to enact their vision of what good teaching looks like to them. Some of these challenges relate to the day-to-day nature of planning that may conflict with their vision for teaching science. One participant expressed these concerns as follows, "look over materials…write the objectives and activities…then do individual lessons after doing the unit lesson…it worked well when I was student teaching, but right now…no time …I prefer to see the unit as a whole with clear objectives to check, but I am just trying to get by these days." Another participant stated, "I could definitely stand to be more reflective. I am just too tired to do it."

Coupled with this set of codes, were codes related to the 'Self-described challenges of being a new teacher' in which teachers demonstrated their belief that challenges related to becoming a new teacher would lessen with time. Comments in this sub-code dealt with frustration related to how they envisioned themselves as teachers, and how their lack of experience hampered this vision.

Table 4 Personal beliefs, attitudes, and general concerns

Category	Description
Concern about a general lack of content knowledge	Challenges related to general comfort in teaching a content area due to content area knowledge limitations
General frustration with profession	Challenges related to general frustrations with the profession and the tasks of the profession
Lack of time and energy to be effective	Challenges related to the lack of time and energy that is draining personally and impacting ability to teach in the ways they envision
Mental health issue impacting teaching	Challenges related to extreme personal anxieties that are impacting teaching
Preference for different age group	Challenges related to a preference to teach a different age group
Self-described challenges of being a new teacher	Challenges related to a belief that their frustration is part of the process of learning to teach that will be better with more experience
Self-efficacy	Challenges related to beliefs that they are not effective teachers due to personal attributes

For example, one teacher stated, "I guess I just want to be a "great teacher" at everything right away, even though I know it is not possible"

Within this larger category, were a set of general self-efficacy statements not solely related to classroom management. In this sub-category, teachers expressed their beliefs that they were ineffective teachers and lack of confidence in their teaching. When a mentor told their beginning teacher they might be over-critical of themselves, the teacher responded, "I know that I tend to be tough on myself… I am trying to be more positive…but I find it really hard."

Some of the participants, who were teaching courses for which they did not have a strong professional preparation, shared concerns related to content knowledge. For example, when discussing an upcoming chemistry demonstration, one out-of-field participant stated "fear of chemicals and explosions = biologist." As one teacher states "I feel so overwhelmed by how little I know… sometimes it feels like I am re-teaching myself chem-[istry] all over again."

Context of schools and/or district

As shown in Table 5, the Context of Schools and/or District category relates to challenges related to the human and physical resources available to support new science teachers. One participant, in discussing the pacing of his or her formal curriculum, stated it "would be nice to have [another science teacher] to keep pace with." Indicating a lack of local induction supports. Another participant expressed a similar concern when they stated, "I do not really have another life science person to work with to try to build an inquiry lesson." However, other teachers expressed how their colleagues added to the challenges of teaching science. One participant articulated the challenge of keeping on the same topic with other science teachers, "schedule is a "big deal around here: (Kind of limits you as far as creativity." Another participant states challenges related to conflict with staff when they state "I have two "supported" classes, which means I have 2 paras in each one to help me with my ELL and behavior problem kids. The one para I have is constantly lecturing me on how I need to be tougher. It doesn't help that she is next door with my mentor teacher the hour before me. My mentor teacher has been teaching for 13 years and she is tough." After the mentor empathized the participant continued, "I just don't appreciate the lectures. I have a different teaching style and if I choose not to respond to a particular situation, that is my decision, not hers."

Of interest to teaching science is the challenges related to 'poor facilities' and a 'lack of equipment and resources that may impact the teacher's ability to carry out hands-on investigations. Another beginning teacher stated that

Table 5 Challenges related to the context of school and/or district

Category	Description
Class length too short	Challenges related to the length of class periods or the number of instructional days and how that limits what can be taught and how it can be taught
Class size too big	Challenges related to large class sizes making classroom management and activities difficult to implement
Concerns about student population	Challenges related to perceptions about the overall student demographics in the school (e.g., crime, SES, and self-efficacy)
Curriculum mandates and constraints from staff or school	Challenges related to formal or informal mandates from staff and administration on what content is taught, how content is taught, and for how long
Issues with administration	Challenges related to interactions with administration that cause job dissatisfaction
Issues with district	Challenges related to issues within the district
Issues with staff	Challenges related to conflicts with other staff
Lack of equipment and resources	Challenges related to a lack of proper equipment and resources to teach science
Lack of local induction supports	Challenges related to a lack of induction supports such as lacking content-specific mentors or conflicts with content-specific mentors
Other assignments within school day	Challenges related to demands on time and energy due to assignment or to additions of teaching beyond science within the school day
Poor facilities	Challenges related to poor facilities (i.e., in which teacher has to move classrooms frequently or are in spaces not conducive to learning science)
School structures	Challenges related to the school structure (or lack thereof) as it relates to policies, staffing levels, and programs

their classroom is "not exactly great for science (one sink, no working gas lines, and I have lunchroom tables, not science tables)". Teachers also faced challenges related to a lack of materials. The following statement illustrates how this lack of materials can lead to classroom management issues, "this has to happen as a demonstration again because there are not enough materials for everyone, and I don't trust them enough either." This quote highlights both challenges related to materials and to challenges highlighted next section on Classroom Management.

Classroom management

As shown in Table 6, the 'Classroom Management' category includes issues related to the development of rules and classroom procedures, as well as issues related to enforcement of rules and procedures. Some participants sought help from their mentors in shaping classroom rules. For example, one beginning teacher asked their mentor for suggestions when students throw things in the classroom when they ask, "What are your consequences for flying stuff?" Another teacher stated, "I want to change their behaviors without punishing the kids who do a great job every day… and I am running low on strategies." Related were several challenges connected to 'Selected students disrupting whole class.' The following statement reflects the challenges related to fostering a respectful community of learners when individual students are disruptive,

> There is another boy in there that is constantly interrupting and fighting and getting up from his seat and I don't know what else to do with him. He likes to do his assignments in the hall, which is usually okay with me, but it's becoming more of a distraction to send him out because then all the students want to leave too.

Some of these codes reflected the management of behaviors, not the fostering of respectful learning environments.

Related with this sub-category relating to student disruptions were issues related to 'Efficacy, personal issues related to classroom management,' and 'Enforcing rules and procedures.' For example, one teacher stated, "I have a few students who like to push my 'niceness' and it's hard for me to [be] tough on them." Another demonstrated issues with efficacy, enforcement, and instruction stating, "I just need to buckle down on them, but this is the class I feel the least confident in, so it is a lot harder." Another states, "I don't talk to them about [their disrespect], because I am afraid that I will have to agree that this isn't the best class…"

Of particular interest to science educators are special management challenges when students move about during hands-on investigations. After a mentor suggested a laboratory activity, the beginning teacher responded, "My students can be so crazy at times though. It makes me nervous when they're all over the place." Having norms and procedures and productive learning environment can lead to more comfort and frequency of hands-on investigations.

General pedagogical knowledge

As shown in Table 7, codes in the 'General Pedagogical Knowledge' often originated in the context of a science-

Table 6 Challenges related to classroom management

Category	Description
Behavior management during activities	Challenges related to the behavior of students during activities such as laboratories, group activities, and field trips.
Cheating	Challenges related to students cheating on tests, activities, and other assignments
Developing classroom management rules, procedures, and norms	Challenges related to the development of rules and procedures as a way to improve the learning environment and to mitigate student misbehaviors
Efficacy and personal issues related to classroom management	Challenges related to teacher beliefs that they are not effective classroom managers and personal frustrations related to management
Enforcing rules and procedures	Challenges related to teacher enforcement of existing rules and follow-through of consequences in a fair manner
Fostering a respectful classroom environment	Challenges related to developing mutual-respect between teacher and student and between other students.
Frustration with disrespect of students	Challenges related to expressed teacher frustration stemming from student disrespect directed at the teacher or their classroom activity
Cannot bring whole self to classroom	Challenges related to beliefs that having light interactions, such as joking with the class, are not possible. Also related to the belief that classroom control may be lost if they do not have a serious personality
Individual student behavior modification	Challenges related to working with changing the behavior of individual students often in one-on-one situations as well as the exploration of various causes and possible solutions to behavior
Selected students disrupting whole class	Challenges related to individual or small groups of students who are disrupting the learning environment, often resulting in their removal from class
Staff or admin does not support teacher classroom management	Challenges related to staff or administrative policies, decisions, or follow through that undermine the classroom management and disciplinary decisions of the teacher
Theft	Challenges related to the theft of classroom supplies
Whole class off task	Challenges related to management of whole classes of students that are 'chatty' or off task

specific conversation but the challenge described was not specific to the teaching of science. For example, in the passage below, a beginning teacher described a chemistry class's post-laboratory activity:

> Certain students will just work on the post-lab [alone]..during lab one student will just not do the lab with the other student..sometimes I am unsure because I will see the students working but they have no idea what the other person/persons in the group are doing..and if they did present, sometimes they just don't say anything or leave it up to the same person over and over again.. I really suck at large group discussion cause some of my students are just so quiet or confused or not interested or nervous or all of the above

Within this passage, two codes were placed in the 'General Pedagogical Knowledge' category ('Cooperative Learning' and 'Fostering Student Discussion' sub-codes). The conversation, while clearly within the context of a science classroom, it did not rise to the level of science specificity.

Two codes within general pedagogical knowledge related to assessment; 'assessment policies and procedures and 'overwhelmed by grading.' Within these sub-categories, the 'in vivo' codes contained questions on assessing student learning and the processes by which to grade student work. Many of these sub-categories were technical in nature; however, some related to the vision of their teaching. For example, one beginning teacher stated, "I often wonder if my expectations are high enough… Pushing them or setting too low of expectations just to get by…" Within the assessment techniques, practical issues such as "how do you pre-assess and then design lessons and have them ready to go the next day?" and issues related to general pedagogical knowledge such as how "you know if the students usually have been taught [meiosis] before" were posed.

Another set of sub-categories, 'Student engagement,' 'Fostering Higher Order Thinking,' 'Fostering Discussion,' and 'Cooperative learning' related to student interactions. 'Student engagement' referred to general challenges when "students are bored" and discussions on how to make instruction more engaging. Related was the sub-category 'Fostering Student Higher-Order Thinking' in which the teachers expressed concerns their students would not engage in higher-order thinking activities. As one participant states, "My students are designing their own labs tomorrow to show saturation. I am afraid they will resist using their brains." The sub-category, 'Fostering Discussion and Student

Table 7 Challenges related to issues of general pedagogical knowledge

Category	Description
Assessment policies and procedures	Challenges related to the development and implementation of assessment policies and procedures
Cooperative learning	Questions and concerns related to structuring, implementing, and improving group work and cooperative learning activities
Daily time management during instruction	Challenges related to pacing within the period and running out of time during the class period
Fostering discussion and student questioning	Challenges related to facilitating discussions and promoting questions during demonstrations, lectures
Fostering student higher order thinking	Challenges related to encouraging student higher order thinking skills related to creativity, problem solving, and curiosity as well as student preference for more passive modes of learning
General concerns about instructional planning and activity creation	Challenges related to a general set of concerns about planning instruction and designing activities
Improve instructions given to students	Challenges related to improving instructions given to students and to having students follow instructions
Integrating other general teaching strategies	Challenges related to teaching strategies not necessarily specific to science
Overwhelmed by grading	Challenges related to the volume of grading or time required for grading
Standardized test preparation	Challenges related to preparing students for standardized tests
Student engagement in general	Challenges related to how to engage students as well as concerns about students who do not engage or are not excited for instruction
Want to lecture less	Challenges related to teacher unease with how much lecture they do in general
Want to do more activities	Challenges related to increasing the amount of activities that are done
Inquiry based instruction	Challenges related to the implementation or increases in frequency of inquiry-based instruction
Technology integration	Challenges related to the integration of technology

Questioning,' in which teachers were seeking ways to engage students in discussions so they become active participants was somewhat related. For example, one participant stated, "we had a discussion on [the physiology of] stress and they really wanted a power point instead

The four codes, 'want to lecture less,' 'want to do more labs and activities,' 'general concerns about instructional planning and activity creation,' and 'inquiry-based instruction' related to challenges where beginning teachers searched for ways to improve their enacted curriculum through more activities. Examples included one participant's comment, "I think there is always so much you can do, it is hard to narrow down what to do and what not to do" and another who stated they are "frustrated by the difficulty of creating active learning activities" indicating a conflict between their curricular vision (Darling-Hammond et al., 2005) and how to carry it out. For example, one teacher lamented, "I am also struggling with how much I talk in Biology." The 'inquiry-based instruction' referred to challenges regarding understanding and enacting inquiry-based instruction. For some, the barriers to the inquiry related to the time required, such as the comment that "the biggest stumbling block (to do inquiry) is the volume of content…to cover in the trimester." Another related challenge a participant shared is "really hard to break the cookbook mode… for both me and [the students] I think."

Science pedagogical content knowledge

As shown in Table 8, the 'Pedagogical Content Knowledge' category included codes related to science teaching within specific domains, such as Biology and Physics and in particular specific topics such as atomic theory. These challenges participants shared include both challenges related to longer-range 'formal curriculum' planning, such topics should be taught, and the order and depth they should be taught, and daily 'enacted curriculum' challenges. For example, related to 'topic selection and depth,' a participant explained, "I have no idea what I will do for the heredity/genetics unit!!! I have never taught it before and don't know how detailed I should go." Another participant expressed a similar challenge when they asked if their mentor had any resources for teaching ecology. They state, "There seems to be quite a bit of that in the standards, but I don't know how I will thoroughly cover it."

Participants shared many challenges related to Enacted curriculum, referring to daily instructional planning and teaching. Participants shared challenges where students struggled to understand a specific topic. For example, one participant explained, "I think that it was confusing for the students to learn about machines when we hadn't talked about work or power yet." This comment also spoke to 'sequencing' formal curricula. In another example, a beginning teacher shared particular topic challenges when they explained that their students were struggling to understand balancing chemical reactions: "I can teach those who get [balancing reactions] easily, but run out of ideas for those not so logical thinkers."

Table 8 Science pedagogical content knowledge

Category	Description
Sequencing of topics	Challenges related to creating logical sequences of topic and figuring out what order to teach certain topics
Topic selection and depth	Challenges related to what topics should be taught and how in depth they should be taught (i.e., how long)
Topics are taking too long	Challenges related to how long a topic took to teach
Trying to fit in new topics	Challenges related to running out of time to teach particular topics and the need to 'squeeze' them in
Assessment (formative and summative) of particular topics	Challenges related to ways to add and improve existing formative and some summative assessments for particular concepts and activities
Improve the 'real-world' relevance of activities and topics	Challenges related to connecting a topic to real world phenomena that are engaging and relevant to the students lives
Lesson and activity development	Challenges related to the development and possible implementation issues with a particular activity to teach particular concepts
Logistical and technical support with activity	Challenges related to the need for support with more technical and logistical issues with activities (i.e., how activities are done, where materials can be obtained/sampled, and safety concerns with activities)
Need activities and ideas to teach a particular topic	Challenges related to finding activities to teach particular topics, often expressed as requests to mentors for activities around specific topics
Not excited about teaching a particular topic	Challenges related to teacher boredom or lack of excitement as it relates to the teaching of specific topics
Setting objectives for a particular topic or activity	Challenges and concerns related to setting or creating objectives for topics and activities
Specific content question within context of activity	Challenges related to understanding a particular concept, usually a request for mentor clarification, within a specific lesson
Student engagement with a particular topic or activity	Challenges related to student engagement or boredom with particular activities or topics
Student understanding of a topic or specific skill	Challenges related to a lack of student understanding of particular concepts and processes
Teaching of controversial topics	Challenges related to navigating controversial topics such as evolution with students

Another participant stated, "I think the students are having a lot of difficulty with the DNA topic. It can be complicated and a lot of new words so I am trying to take my time."

The sub-category 'Need activities and ideas to teach a particular topic' is related to requests for topic-level support. Requests such as," I was just thinking I don't have a good limiting reagents lab…I'd love to see yours; o)" were frequent when mentors provided beginning teachers activities via email. During member checking, some noticed an absence of requests for assistance or challenges related to reform-based instructional practices (i.e., inquiry pedagogies, conceptual change, instruction related to the history and nature of science) beyond a limited discussion of student misconceptions.

Summary of challenges

Figure 1 summarizes the collective set, or taxonomy of challenges from this study.

Discussion

This study supports the general findings from literature on beginning science teacher challenges and challenges of teachers in general. However, this study shows that the challenges beginning science teachers face are more complex than rank order lists provided by Veenman (1984) and those identified in the literature review focused specific aspects of challenges faced by beginning secondary science teachers (e.g. Davis et al., 2006). This study provides a comprehensive understanding of the challenges beginning science teachers face from a content-specific perspective. Indeed, there is a large range of challenges that beginning science teachers face.

As one examines this set of challenges identified in this study, one may wonder how unique many of these are to the teaching of science. In many ways, these challenges may be similar to those of a beginning teacher in a high school statistics classroom or a beginning teacher in a middle school world history classroom. There are certain issues related to student academic performance, external factors, supporting diverse learners, classroom management, and general pedagogical knowledge for teachers that cross all subject areas as Veenman identifies in their seminal work (1984).

However, this study indicates that the challenges shared by the beginning teachers are also more specific and at times more directly related to their content areas they teach as argued by Gold (1996). This study provides not only a comprehensive view of challenges faced by beginning science teachers, it also reinforces and builds on prior literature that focused on specific challenges such as limited laboratory resources for teaching science (e.g. Varelas et al., 2005), classroom management related to the implementation of inquiry-based science activities (e.g. Rushton & Reiss, 2021), content knowledge (e.g. Roehrig & Luft, 2004), and science specific approaches to culturally relevant instruction (e.g. Brown & Livstrom, 2020).

General Pedagogical Knowledge a. Assessment policies and procedures b. Cooperative learning c. Daily time management during instruction d. Fostering discussion and student questioning e. Fostering student higher order thinking f. General concerns about instructional planning and activity creation g. Improve instructions given to students h. Integrating other general teaching strategies i. Overwhelmed by grading j. Standardized test preparation k. Student engagement in general l. Want to lecture less m. Want to do more activities n. Inquiry based instruction o. Technology integration	Science Pedagogical Content Knowledge a. Sequencing of topics b. Topic selection and depth c. Topics are taking too long d. Trying to fit in new topics e. Assessment (formative and summative) of particular topics f. Improving the real-world relevance of activities and topics g. Lesson and activity development h. Logistical and technical support with activity i. Need activities and ideas to teach a particular topic j. Not excited about teaching a particular topic k. Setting objectives for a particular topic or activity l. Specific content question within context of activity m. Student engagement with a particular topic or activity n. Student understanding of a topic or specific skill o. Teaching of controversial topics	Classroom Management a. Behavior management during activities b. Cheating c. Developing classroom management rules, procedures, and norms d. Efficacy and personal issues related to classroom management e. Enforcing rules and procedures f. Fostering a respectful classroom environment g. Frustration with disrespect of students h. Cannot bring whole self to classroom i. Individual student behavior modification j. Selected students disrupting whole class k. Staff or administration does not support teacher classroom management l. Theft m. Whole class off task	Context of School and/or District a. Class length too short b. Class size too big c. Concerns about student population d. Curriculum mandates and constraints from staff or school e. Issues with administration f. Issues with district g. Issues with staff h. Lack of equipment and resources i. Lack of local induction supports j. Other assignments within school day k. Poor facilities l. School structures
External Challenges a. Finding new employment b. Lacking support from partner c. Masters coursework d. Voluntary extracurricular	Teaching Diverse Learners a. Students who are EL b. Student receiving special education services c. Students displaying severe behavior	Student Academic Performance a. Student effort related to improving personal understanding b. Students failing courses c. Student effort related to completing assignments and other tasks d. Students performance on formal assessments e. Working with parents on student academic issues	Personal Beliefs, Attitudes, and General Concerns a. Concern about a general lack of content knowledge b. General frustration with profession c. Lack of time and energy to be effective d. Mental health issue impacting teaching e. Preference for different age group f. Self described challenges of being a new teacher g. Self efficacy

Fig. 1 Taxonomy of beginning science teacher challenges

As beginning teachers, each of the participants had a limited repertoire of lesson plans or other instructional materials to draw from. While they were responsible for instructional planning during their student teaching, they only experienced a small number of unit topics during their semester-long placements. Associated with the challenge to plan lessons for specific content areas is the desire to teach using an inquiry-based approach. When thinking about creating effective learning environments in a science classroom, it is important to think about supporting students to generate scientific knowledge and explanations through engaging in the practices of scientists and engineers (National Research Council, 2012). Teachers indicated specific challenges related to their ability to implement reform-based science, including lack of equipment and resources and time both to plan and implement inquiry-based lessons. These challenges were exacerbated by a frustration felt by teachers that their teaching practice was not aligned with their own beliefs about what good science teaching looks like (Ellis et al., 2022). The ability of teachers to navigate this discrepancy between their beliefs and their own practices can lead to self-efficacy concerns and result in teachers leaving the profession (Helms-Lorenz et al., 2016).

In addition, if a teacher is teaching out of field (e.g., a licensed Physics teacher who is teaching high school chemistry), their lack of content knowledge can also impede teachers from using reform-based science teaching approaches (Luft et al., 2020; Roehrig & Luft, 2004) and can be a significant challenges for new science teachers (Napier et al., 2020). If teachers do not feel comfortable with the particular content they are teaching, then the teacher may default to using more direct instructional practices to deliver content instead of helping their students make sense of content, collaboratively through the processes of doing science (Napier et al., 2020). Furthermore, without a strong content background, it becomes harder for teachers to motivate students (Keller et al., 2017). This out of field teaching can lead to decreased student outcomes (Sheppard et al., 2020; Taylor et al., 2020).

Finally, beginning teachers struggle to implement culturally responsive teaching practices. In general, beginning science teachers can feel unprepared to work with culturally diverse students (Titu et al., 2018). However, it is critical that beginning teachers can celebrate and leverage student prior knowledge and life experience to help learners better make sense of the world (Bang et al., 2017). This work happens through classroom discourse that support and honor students ways of speaking (Brown, 2017). Without connecting to their students' lives, the instruction becomes less relevant, and then classroom management can become a challenge when students are less engaged through a lack of connection to the science (Brown, 2021).

What can be done to support continued teacher growth and to stem attrition? Issues such as time pressures related to lesson planning are ubiquitous throughout the literature for not only general teachers (Harmsen et al., 2018) but also for beginning science teachers (e.g. Helms-Lorenz et al., 2016; Rushton & Reiss, 2021). Indeed, these factors have been shown to be related to the attrition of beginning teachers (Harmsen et al., 2018). In addition, issues within this study such as inadequate preparation time and large class sizes also contribute to attrition (Ingersoll & Perda, 2006). However, these challenges are mostly beyond the scope of induction support. These challenges, and additional challenges such as the limited teacher input into decision-making and non-competitive salaries for teachers, must be attended to at the policy level if we are to improve teacher retention (Darling-Hammond & Sato, 2006; Ingersoll & Perda, 2006).

However, as we look at the bulk of the content specific challenges within this study, we can see the importance of content specific induction (Roehrig & Luft, 2004). In many models of induction, even the more comprehensive models such as those promoted by the New Teacher Center (2007), the role of content-specific support is not addressed. In some induction models, there may be a full release mentor with a general set of facilitation skills who may not be teaching same content area or in the same grade band. There may be value in their work, particularly as they help facilitate teacher thinking, but the range of challenges for which they may need to provide direct instructional support may be difficult for a mentoring generalist. Although many states mandate at least some form of induction, there are no states that currently mandate content-specific support (Koballa & Bradbury, 2009). In practice, the National Science Board (2008) study found that 50% of science teachers were matched with another science teacher. Science teachers in schools with high minority enrollment (>45%) and high poverty (>50%) had much lower rates of content-specific mentoring; 40% and 35% respectively (National Science Board, 2008).

In many cases, well-prepared content-specific mentors may be the only ones to support these science-specific challenges. For example, if a beginning, in-field biology teacher is preparing to craft instruction around a topic such as DNA sequencing, biology mentors may provide a facilitated discussion around this complex topic. They also play a role in pushing the beginning teacher to focus their thinking on the individual students' needs in the planning of instruction attending to students' prior knowledge and engages them with relevant ideas and phenomena.

Content-specific mentors may also be best poised to support teacher learning in general areas such as classroom management and student academic issues. Even though conversations noted in this study at times did not rise to the level of science specificity, these issues can be supported through a domain and topic-specific lens. Mentors can play a critical role in helping to reframe and analyze practice "from different perspectives or by shifting beginning teachers' attention" (Wang et al., 2008). Even challenges not related to the teaching of specific content such as classroom management, content-specific mentors can support these issues through a content-focused lens to reframe and analyze practice "from different perspectives or by shifting beginning teachers' attention" (Wang et al., 2008). For example, the challenges cited above within classroom management all take place in the context of a science classroom and of a particular content-focused lesson. It may be useful for the content-specific mentor and beginning teacher to address issues of classroom management through a more holistic lens directed toward promoting a relevant, respectful learning environment that encourages dialog modeling how scientists argue through evidence and suggesting activities that engage students with relevant phenomena. Well-prepared content-specific mentors can help the beginning teacher to identify gaps in knowledge and levels of expertise throughout the many dimensions of teaching science (National Science Teaching Association, 2020) as well as help enact the reforms called for by the community (Koballa & Bradbury, 2009). This vision of mentoring, as one component of content-specific induction, may help to improve teacher expertise and retention.

Conclusions

This study suggests a vast range of challenges that beginning science teachers can face, and also implies that while a generalist mentor might be able to support many of these challenges, content-specific induction, with mentoring at its core, can help beginning teachers explore many of these challenges to provide support and growth in the context of content (Roehrig & Luft, 2004). This taxonomy of science teacher challenges can also be used to inform professional development supports within comprehensive induction programs. For example, conversations between beginning teachers and their mentors could use this set of challenges to identify challenges they are currently facing. Using their set of challenges, they could then explore standards for teaching science (National Science Teaching Association, 2020) to identify areas of expertise that the beginning teacher may wish to focus their induction work. Sustained induction experiences aligned to standards, and to the challenges these teachers face, could be used to design targeted learning experiences linked to practice that improves teacher knowledge of the standard while working to impact practice and could be done with beginning teacher peers who are facing similar challenges. Additionally, this study indicates that new science teachers face challenges related to planning instruction. High-quality, comprehensive instructional materials coupled with professional learning can help support the challenges teachers face as part of an induction program to support many of the Science Specific Pedagogical Content Knowledge concerns and other concerns such as those related to a lack of content knowledge. As indicated in prior research that suggests high-quality instructional materials can support the development of content knowledge for beginning teachers (Donna & Hick, 2017) and can improve practice (Pringle et al., 2017) especially for teachers who are teaching out of field (Taylor et al., 2020).

Finally, analysis of this taxonomy may lead to broader questions of practice regarding science teacher preparation such as wonderings related to how we might better prepare teachers to mitigate challenges and to navigate challenges related to the context of their schools. Future research may explore how these challenges change as a function of time among other variables such as preparation, context, and licensure. Additional research could explore how mentors respond to the challenges beginning teachers cite through various levels of support; explore what role the depth of mentor pedagogical content knowledge plays in supporting beginning teacher development of pedagogical content knowledge; explore the frequency of certain challenges; and to explore why expected challenges, such as issues related to the history and nature of science, do not appear in the language of the beginning teachers and mentors.

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Author contributions

JD analyzed and interpreted data between the mentors and mentees. GH was the PI on the grant and lead the design on the online environment. All authors have read and approved the final manuscript.

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Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests
There were no funding sources that financed or assisted in the publishing of this work, no personal financial holdings related to this subject matter, no consulting or other grant funding from entities that might have a financial interest in this work, no affiliations we serve on whose funding may be affected by these results, no royalties, patents, or licensing that relate to this work, and no personal relationships that would be affected by this work.

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