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Abstract
The purpose of this study was to identify effective science teachers and analyze why they persist. This study was conducted using a mixed-methods approach including the Local Systemic Change Classroom Observation Protocol (LSC-COP) to generate a quantitative measure of science teaching effectiveness, along with a phenomenological approach to investigate the experiences of effective science teachers who stayed in the profession. Thirty participants stayed in the profession and were divided across five focus groups, with a total of 234 observations. The LSC-COP capsule score was four and five, respectively on a five-point scale indicating participants’ instruction was likely to enhance students’ understanding of science and their capacity to do science. Interviews with participants about their experiences yielded seven themes that pertained to effective science teachers’ persistence: exposure to preservice/professional development programs, meaningful support, autonomy, student goals, engaging in deliberate practice, building relationships with students, and viewing teaching as a moral act. Our study found that for teachers to persist, they have to view teaching as more than a job and have the support and freedom to engage in deliberate practice in order to continually improve.

Methods
1. Observed two lessons for each participant.
2. Took field notes, collected artifacts including any student handouts, and evaluated teachers using the Local Systemic Change Classroom Observation Protocol (LSC-COP) (Hanawalt, 2005).
3. Scores were used as a guide to generate an overall capsule score (Table 1).
4. Conducted three semi-structured interviews focusing on understanding of science and their capacity to successfully do science. Interviews with participants about their teaching practices included: 1) observations of science teaching in a greater purpose began with their preservice programs. By attending either a preservice program or professional development that fundamentally shifted their view on education, participants received the education necessary to persist, even in the face of difficult working conditions. Participants repeatedly stated that without the preservice experience within their teacher education program they would not incorporate effective strategies, student-centered, and learning theory.
5. Interviews were transcribed and coded using significant statements.
6. Significant statements were grouped into tentative broader units or themes (Creiswell, 2017).
7. Participants were more detailed questions that related to the broader themes to glean more information about their experiences in the second interview.

Background
- Attaching and retaining teachers has been a long-standing problem in science.
- Nearly 50% of new science teachers leave the field in the first five years (Ingersoll & Smith, 2003; Podolsky et al., 2016).
- Common factors identified in research for why teachers leave include low quality of teacher preparation, poor working conditions, stress, and burnout, limited professional opportunities, and low salaries (Geiger & Storey, 2018, Ingersoll & May, 2012).
- A great deal of expertise and decision-making occurs “behind the curtain” of teaching (Darling-Hammond, 2006; Lortie, 1975; Munby et al., 2001).

Research Questions
1. To what extent are participants effective science teachers?
2. Why do effective science teachers persist in the teaching profession?

Results
Table 1: The LSC-COP synthesized rating scales. (modified from Horizon Research, 2007)

<table>
<thead>
<tr>
<th>Theme</th>
<th>Observation</th>
<th>Design</th>
<th>Implementation</th>
<th>Endorsement</th>
<th>Commitment</th>
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| Pre-service. Participants noted that a strong preservice program was an essential element to how they became and persisted with effective science teaching practices. Impactful attributes participants noted were: 1) professors effectively taught science pedagogy, 2) the practicum experiences were meaningful and included multiple teaching experiences where professors and cooperating teachers provided feedback, 3) throughout the experiences, participants engaged with a coherent framework that helped them develop a research-based making decisions.
| “If there’s a lot really hard as a teacher, then I see professors effectively teaching science practice, 2) the practicum experiences were meaningful and included multiple teaching experiences where professors and cooperating teachers provided feedback, 3) throughout the experiences, participants engaged with a coherent framework that helped them develop a research-based making decisions.” (Damien).
| Support. For science teachers to remain effective, they need a support system from a variety of sources—including colleagues and administrators. Many participants mentioned they would not be as effective as they are without the support to take risks, persist, and the reminders to keep their focus on what’s best for their students.
| “Teacher support is critical. I have a support team of students that I can go to when I need advice or guidance” (Payton).
| Autonomy. Given science teachers make numerous non-trivial decisions each day, the freedom to be responsive to students is a crucial need expressed by participants. When teachers have trust from outside of the classroom, they can make necessary adjustments with confidence.
| “If we as teachers don’t have choice to try new things and take some risks and go out on a limb and try things in a different way, it’s not working. I don’t know what you do without that freedom” (Brianna).
| Goals. All participants mentioned they have goals for students. These goals, similar to 21st-century skills, included: critical thinking, collaboration, creativity, being respectful, and a deep understanding of specific content.
| “Communication skills, compassion for other people, participation in society, understanding really important science ideas that are fundamental to how society functions, and some of the biggest challenges facing us... Nature of science is a goal, nature of technology is a goal” (Katie).
| Deliberate Practice. Participants often mentioned to promote student goals effectively, they had to engage in a variety of teaching practices and strategies. These include, but were not limited to, facilitating mindfully engaging activities, scaffolding with open-ended questions, having a logical sequence to lessons, considering students’ cognitive and emotional needs, managing time, and monitoring students’ engagement. Modifying instruction in order to improve learning for students and to stay fresh was a common strategy that participants employed to remain effective long-term.
| “I’m always trying something different. I almost never teach the same lesson the same way... So I’m always trying to tweak it, or fine-tune it” (Damien).
| Relationships. Participants valued relationships in order to better understand students’ and create a classroom where all students are engaged and motivated to work. Participants referred to a personal relationship or not only do they care about students, but they are actively finding ways to show students they care.
| “If my kids know very well, and there are many of these in this class too, that I know something like a kid’s creation or if there’s something off, I will step aside and I will tell everybody on something else... I can’t make anyone do something, they just come up to me and ask questions about relationships with kids, the content just follows for them. Like, they’ll work for you.” (Ellie).
| Moral Act. Participants touched on the profound moral nature of teaching. Katie, Tim, and Ellie specifically, “the passion of developing people... it just fascinates me”, “it’s a moral obligation”, and “it’s not just a job”, respectively. Why Do Effective Science Teachers Persist?: A Mixed Methods Approach Exploring Post-instruction Effective Science Teachers’ Experiences

Citations
Podolsky et al., 2016, 2017; B
Clough et al., 2009; Podolsky et al., 2016, 2017; B
Berlin (Banilower, 2005).
87; D
Mason (Munby et al., 2001).
Damien
Katie
Payton
Brianna

Discussion
- Effective science teachers need to believe teaching is more than just a job. The decision-making framework (Clough et al., 2009) provided a means for participants to incorporate morality into their teaching. As John Dewey (1909) associates moral growth with intellectual growth, so, too, do these teachers.
- Expressing student goals centered around life skills and building meaningful and caring relationships with students were a few ways participants blended intellectual and moral teaching into their science classrooms. For participants, situating science teaching in a greater purpose began with their preservice programs by attending either a preservice program or professional development that fundamentally shifted their view on education, participants received the education necessary to persist, even in the face of difficult working conditions. Participants repeatedly stated that without the preservice experience within their teacher education program they would not incorporate effective strategies, student-centered, and learning theory.
- Previous research has made clear that support systems can help retain teachers (Mercado-López et al., 2020, Podolsky et al., 2016). This study found that the support of the support system matters. Participants who had support systems with like-minded colleagues and an administration that empowers teachers decision-making and autonomy were much more likely to feel valued. Given meaningful support systems have been found to help science teachers remain effective and persist, these support systems were an important factor for participants to remain driven in difficult working conditions.
- Participants viewed teaching as a vessel to teach and shape the future through promoting student goals centered around crucial life skills and building long-lasting and meaningful relationships with students. While all participants articulated a coherent purpose of science education, the source of this purpose varied across participants. Having a rationale for teaching, therefore, appears to be much more important than the personal and moral reasons that underpin that rationale.

Conclusions
- Given close to 50% of science teachers leave in the first five years (Ingersoll & Smith, 2003), studying why effective science teachers persist has a number of implications for stakeholders in schools and teacher education programs.
- Our study found that teacher autonomy is a crucial factor for effective science teacher persistence. Teachers often face institutional constraints (Wilcox, 2017; Brickhouse & Bodner, 1992) that impact teacher autonomy. Therefore, administrators, who often have some control over the constraints teachers face, can work to actively support teachers.
- This study implices, to maintain effectiveness, teachers may need to make a change in order to have the support they need. Participants were more motivated and persist, but were not limited to, associating with alternate colleagues or moving schools to receive proper administrative support.
- This study also suggests teachers must have a strong relationship to cultivate student investment. To connect with students, teachers must employ these techniques. Learning unique facts about each student, displaying students’ work, asking about personal interests, and many others. Once this connection is established, students are more likely to engage and participate in effective science learning practices. Additionally, the teacher may now begin to strive for student goals as outlined in the paper. By using strong student relationships, and a decision-making framework (Clough et al., 2009), teachers have a mechanism for structuring instruction centered around students.
- Teacher educators should encourage preservice students in exploring the purposes of science teaching and develop a strong, personal rationale for science teaching (Herman et al., 2017). Our participants noted their methods programs included science instruction centered around the student goals and students’ real-world experiences. Therefore, teacher educators should strive to model and teach in a way that aligns to research-based teaching practices and demonstrate the educational value of place preservice teachers that are engaged in effective science teaching practices so preservice teachers have concrete experiences with how those practices look in the “real world.”