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Using qualitative methods to develop a survey measure of math and science engagement

Jennifer A. Fredricks [a,*], Ming-Te Wang [b], Jacqueline Schall Linn [b], Tara L. Hofkens [b], Hannah Sung [b], Alyssa Parr [b], Julia Allerton [b]

[a] Connecticut College, USA
[b] University of Pittsburgh, USA

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ABSTRACT

Student engagement in math and science is vital to students' academic achievement and long-term participation in science, technology, engineering, and mathematic (STEM) courses and careers. In this study, we conducted in-depth interviews with 106 students from sixth to twelfth grade and 34 middle and high school teachers about how they conceptualized math and science engagement and disengagement. Our qualitative analysis of student and teacher interviews supported the multidimensional construct of engagement outlined in the academic literature. Our analysis also revealed additional indicators that have been included in prior measures of engagement less frequently. We then described how we used this qualitative information from students and teachers to develop and validate a new student self-report measure of math and science engagement.

Student engagement in math and science is vital to students' academic achievement and long-term participation in science, technology, engineering, and mathematics (STEM) courses and careers. A growing body of research links student engagement in math and science to higher grades, higher standardized test scores, and a greater likelihood of enrolling in advanced math and science classes (Lent, Sheu, Singley, Schmdit, & Gloster, 2008; Maltese & Tai, 2010). Because engagement is a robust predictor of educational outcomes and a malleable state that can be increased by making improvements to the social and academic context, it holds tremendous potential as a key target for interventions (Appleton, Christenson, & Furlong, 2008).

Unfortunately, math and science engagement declines during the middle and high school years, particularly among minority and low-income students (Martin, Way, Bobis, & Anderson, 2015; Wigfield, Byrnes, & Eccles, 2006). This is problematic because every career requires a basic understanding of *math*, and advanced careers in the STEM fields are unattainable without a strong foundation of *math* and *science* (e.g., physics, chemistry, biology) skills. Currently, the number of students choosing STEM careers does not meet the demand (U.S. Congress Joint Economic Committee, 2012). An important component of ensuring our nation's economic future is increasing the number of students who pursue STEM careers, especially among students who have been traditionally underrepresented in these domains.

1. What is engagement?

Although there has been a dramatic increase in research on student engagement over the past two decades, inconsistencies in the definitions and measurement of this construct persist (Appleton et al., 2008; Christenson, Reschly, & Wylie, 2012; Fredricks, Blumenfeld, & Paris, 2004). Despite these inconsistencies, there is broad agreement in the academic literature that student engagement is a multidimensional construct, though there has been variation in both the number of dimensions (ranging from 2 to 4) and the indicators of each dimension. The most prevalent conceptualization in the academic literature is that engagement consists of three distinct, yet interrelated dimensions – behavioral, emotional/affective, and cognitive engagement (Fredricks et al., 2004). In the literature, *behavioral engagement* is defined in terms of participation, effort, attention, persistence, positive conduct, and the absence of disruptive behavior (Fredricks et al., 2004). *Emotional engagement* focuses on the extent of positive

* Corresponding author.
E-mail address: jfred@conncoll.edu (J.A. Fredricks).

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(and negative) reactions to teachers, classmates, academics, or school; individuals' sense of belonging; and identification with school or subject domains (Finn, 1989; Voelkl, 1997). *Cognitive engagement* is defined as the student's level of investment in learning. It includes being thoughtful, strategic, and willing to exert the necessary effort for comprehension of complex ideas or mastery of difficult skills (Fredricks et al., 2004; Meece, Blumenfeld, & Hoyle, 1988).

Recently, some scholars have added a social dimension to these conceptualizations of engagement to reflect the increasingly important role that social interactions play in learning. For example, Linnenbrink-Garcia, Rogat, and Koskey (2011) included a social-behavioral dimension of engagement, which they defined in terms of the social forms of engagement around classroom tasks, including participation with classmates and the quality of social interactions. Additionally, Finn and Zimmer (2012) defined social engagement as students' prosocial behavior in classrooms and the quality of interactions with peers around instructional content. Finally, Rimm-Kaufman, Baroody, Larsen, Curby, and Abruy (2014) included a social engagement scale with items about explaining academic context and discussing ideas in math.

2. Teacher and student conceptualizations of engagement

Although there is a growing body of research on student engagement, we know much less about how teachers and students understand this construct and the majority of this work has focused on behavioral indicators (Harris, 2011; Johansson, 2013; Zyngier, 2007). It is important to examine teachers' beliefs about engagement because these beliefs shape teachers' behaviors (i.e., teacher involvement, support, and use of autonomy-supportive practices), which have been shown to influence student engagement (Klem & Connell, 2004; Reeve, Jang, Carrell, Barch, & Jeon, 2004; Skinner & Belmont, 1993).

In a phenomenological study of teachers' conceptions of student engagement, Harris (2011) identified six qualitatively different conceptions including: 1) behaving; 2) enjoying; 3) being motivated; 4) thinking; 5) seeing purpose; and 6) owning and valuing learning. A few studies have also examined teachers' perceptions of classroom misbehavior and disengagement (Cothrane & Ennis, 2000; Little, 2005; Ravet, 2007). In these studies, teachers tend to focus on the behavioral and emotional indicators of engagement in relation to classroom management, as opposed to cognitive indicators that are associated with student learning (Harris, 2011). For example, Ravet (2007) found that teachers conceptualized disengagement in terms of behavioral (e.g., daydreaming, chatting, disruptive behavior) and emotional (e.g., boredom, anger, anxiety) indicators.

There is even less research on the meaning of engagement and disengagement to students. In an ethnographic study of academically successful students, Pope (2001) found that most high achieving students explained engagement in terms of behavioral indicators, describing school in terms of just going through the motions or "doing school." In addition, a few studies have focused on students' conceptualizations of behavioral disengagement (Sun & Shek, 2013; Supaporn, Dodds, & Griffin, 2003). For example, Sun and Shek (2013) used qualitative interviews to examine students' perceptions of classroom misbehavior. They identified 19 categories of student misbehavior, such as talking out of turn, disrespecting the teacher, not paying attention, and aggression.

Studies that examine how teachers and students think about engagement and disengagement can help to move the discussion of this construct beyond behavioral indicators to consider how engagement is a multidimensional construct that is socially and contextually conceptualized (Viberts & Shields, 2003; Zyngier, 2008). Investigating teachers' and students' conceptualization of engagement is also important for developing a measure that reflects the everyday language that teachers and students use around doing tasks and learning.

3. Measurement of engagement

Some scholars have suggested that a more systematic and thoughtful attention to the measurement of engagement is the most pressing and imperative direction for future research (Fredricks & McColskey, 2012; Glanville & Wildhagen, 2007; Veiga, Reeve, Wentzel, & Robu, 2014; Wang & Degol, 2014). Recently, Fredricks and McColskey (2012) reviewed the literature to identify instruments that have been used to assess student engagement in the upper elementary to high school years. In this review, they found a limited number of self-report engagement measures that included scales to assess all three of the dimensions. Moreover, the items in these instruments were used inconsistently across behavioral, emotional/affective, and cognitive engagement. For example, some measures included effort as an indicator of behavioral engagement to reflect compliance with required work in school, while others included effort as an indicator of cognitive engagement to describe the degree of psychological investment in learning. There was also limited evidence to support the validity of several of these measures.

Another concern was that the majority of measures identified in the review focused on general engagement in school rather than on engagement in specific subject areas (Fredricks & McColskey, 2012). The limited number of subject-specific engagement measures makes it difficult to determine which aspects of engagement are similar across subject areas and which aspects are domain-specific. In the motivational literature there is some support for the domain specificity of some motivational constructs, especially for constructs that are situation and subject relevant, such as valuing, expectancy for success, and self-concept (Green, Martin, & Marsh, 2007; Wigfield, 1997).

The research on the conceptualization and instrumentation of engagement in math and science is especially limited (see Kong, Wong, & Lam, 2003, for one exception). It is important to develop domain-specific measures because changes in instruction, the types of tasks, and increased emphasis on collaboration and cognitively challenging tasks in math and science classrooms can shape and interact with how students engage behaviorally, emotionally, and cognitively (Blumenfeld et al., 1991; O'Donnell & Hmelo-Silver, 2013; Sinatra, Heddy, & Lombardi, 2015). Key aspects of math and science outlined in both the Common Core State Standards Initiative in Mathematics (CCSI, 2015) and the Framework for Science Education (NRC, 2012) include a greater emphasis on group work, complex problem solving, quantitative data analysis, abstract reasoning, argumentation, and communication. By transforming the nature of academic tasks and the social learning formats in class, these instructional reforms will likely have a significant impact on how students engage in math and science classes. For example, cognitively challenging tasks call on students to apply cognitive strategies with effort and persistence. Completing challenging tasks in the context of a learning environment that emphasizes collaboration and social interaction impacts on the quality of students' behavioral, emotional, and social involvement in class.

4. Purpose

This study contributes to our understanding of the conceptualization and measurement of engagement and disengagement in math and science. In the first section, we describe how we used qualitative methods to examine how teachers and students conceptualize math and science engagement and disengagement. In the second section, we explain how we used this qualitative information from interviews with students and teachers to develop a new student self-report measure of math and science engagement. Our goal was to gain an "on-the-ground" perspective of student engagement and disengagement to determine whether prior research matches teachers' and students' perceptions and conceptualizations. In addition, the "on the ground perspective" helped us parse what students are actually doing in the classroom from what they are expected or required to do. Finally, the "on-the-ground" perspective helped us to identify the most salient features of engagement and disengagement to teachers and students. This information is important for measuring these constructs more accurately in the future and creating more effectively targeted interventions in order to increase engagement.

5. Sample

The teacher sample included 12 middle school teachers and 22 high school teachers. The teacher sample was 50% female and 97% white. Twenty-five of the teachers taught science (Biology = 9, Physics = 9, Chemistry = 2, Environmental Science = 1, General Science = 3, Astronomy = 1), 7 taught math, 1 taught both math and science, and 1 taught special education math. These teachers taught in 7 school districts, 14 in urban public schools, 4 in urban charter schools, 14 in suburban schools, and 2 in a private school. Nineteen of the teachers had their master's degree and 15 had their bachelor's degree. On average, they had 10 years of teaching experience, ranging from a new teacher to over 21 years of experience.

The student sample included 106 students from sixth through twelfth grade (mean age = 15.16, ranging from 11.33 to 19.19 years of age). The student sample was 54.7% female, 67.0% white (N = 71), 16.0% African American (N = 17), 5.3% multiracial (N = 6), and 11.3% (N = 12) Asian American. Approximately one-fourth of the student sample qualified for free or reduced price lunch (N = 25, 23.5%). Twenty-seven students attended an urban public school, 9 attended an urban charter school, 37 attended a suburban school, and 16 attended a private school.

All participants were recruited from seven different school districts in Pittsburgh and the surrounding communities. Schools were selected because of their interest in promoting student engagement in math and science and their diverse student populations. The schools represented a range of school types and were diverse in terms of socioeconomic status and race/ethnicity. We asked school leaders to identify their most engaged math and science teachers. After receiving information about the study, interested teachers were contacted by the research staff with consent forms and further information about the study to review prior to participating. We also asked school administrators and participating teachers to identify racially and ethnically diverse students in the 6th through 12th grades who were currently enrolled in math and science and varied in their level of engagement and achievement. Administrators and teachers sent consent forms home with students who were identified to participate. Any student who returned a consent form was eligible to participate.

6. Method

We used a semi-structured interview format to gather data from teachers and students. A semi-structured format ensures a degree of comparability across interviews but also allows for the elaboration of important themes that arise (Miles & Huberman, 1994). The purpose of these interviews was to learn how students and teachers conceptualized engagement and disengagement in math and science classes, whether they included or excluded the same categories as researchers, and what terminology they used to describe these constructs. The interview questions were organized around the following areas: (1) what does engagement and disengagement mean to you; (2) what do students do when they are engaged in math and science; and (3) what influences student engagement and disengagement in math and science? Both students and teachers were asked about whether and how their engagement in math and science was different than their engagement in other subjects.

First, we wanted to see how participants thought about engagement and disengagement with little prompting from interviewers. After eliciting unprompted information about engagement and disengagement in math and science, we asked more directed probing questions to see if participant responses aligned with the conceptions of engagement as a multidimensional construct including behavioral, emotional, and cognitive components as outlined in the literature. For example, we asked students to provide specific examples of times when either they or their peers were engaged or disengaged and what they were doing, feeling, and thinking at that time. We also asked teachers to describe examples of their most engaged and disengaged students and what these students were doing, feeling, and thinking at that time.

All teachers were interviewed individually. Participating students either took part in an individual semi-structured interview (N = 36) or in focus groups (N = 16, average of 4.25 students) that lasted between 30 and 45 min. Because we were interested in collecting as much information as possible about students' perceptions of engagement in a short period of time, our initial plans were to use focus groups with all students (see Krueger & Casey, 2014, for more description of focus group methodology). However, after completing focus groups with middle school students from 3 schools and high school students from 1 school, we found that the focus group format was not providing sufficient opportunity to pursue in depth responses to questions about the influences on engagement, nor was it providing a space for the less engaged students to be open and honest in their responses. We also found that, in many cases, it was difficult for schools to accommodate the space and time necessary for focus groups, and scheduling individual interviews was much less disruptive to students' schedules. As a result, we adjusted our protocol to allow for student interviews in addition to focus groups in the remainder of the participating schools. To ensure that the focus group sample would be diverse across school types, grade levels, race, and socioeconomic status, additional focus groups were conducted in 3 middle schools and 3 high schools, for a total of 6 middle schools and 4 high schools. Individual interviews were conducted in 5 high schools and 3 middle schools. Individual interview and focus group protocols were the same in regard to content and procedure.

Interviews were conducted by the project coordinator and 3 doctoral students (two white females, one African–American female, and one Asian-American female). Two of these interviewers had prior experience with semi-structured interviewing techniques and facilitating focus groups. The first author, an engagement researcher and qualitative research specialist, completed a few interviews as part of the training process. The decision to use multiple interviewers is common and desirable in qualitative research because multiple researchers can elicit a wider range of responses on a topic (Erickson & Stull, 1998). To increase comparability across interviews and interviewers, we used a detailed interview protocol, which outlined specific issues to attend to and suggested probes. However, in order to fully explore the perspective of students and teachers, we also allowed participants' answers to help guide the direction taken during individual interviews.

All interviewers completed mock interviewing prior to interviewing study participants to ensure that all interviewers were asking protocol questions and probing for additional information in similar ways. In addition, all interviewers were present for the first set of teacher interviews to help ensure that interviewers were asking questions and probing in the same fashion. Following this initial training period, interviewers listened to others' recorded interviews to review and discuss any differences, new questions that should be explored, and to continue to ensure consistency among the interviewers. The research team met weekly to discuss the substance, format, and facilitation of interviews and focus groups, as well as theoretical observations regarding themes that were emerging in the interviews. These meetings resulted in both substantial changes, such as the change from focus groups to individual interviews, and minor changes in the wording and structure of the interviews.

7. Data analysis

We used a combination of induction, deduction, and verification techniques to analyze the interviews (Miles & Huberman, 1994). All interview transcripts were coded by 5 members of the research team consisting of the Co-Principal Investigator (first author), 3 graduate students, and 1 project manager using Dedoose, a computer program for coding qualitative interview data. All transcripts were coded for examples of indicators of engagement and disengagement. Each indicator was coded for the 3 dimensions of engagement (i.e., behavioral, emotional, and cognitive), valence (i.e., positive and negative) and domain (i.e., general, math, or science). A coding instruction manual was created for each coder to follow. The research team met weekly during the coding process to discuss the definition of each code and any disagreements that arose about the best way to code some of the indicators. These discussions resulted in minor refinements and an elaboration of the coding framework. A subset of the interviews (7 teachers, 2 students, and 1 focus group) were coded by multiple interviewers in order to increase consistency in coding. All coders reviewed these coded excerpts together to identify discrepancies in types of code applied to each excerpt, differences in amount of text coded, and discrepancies in what should or should not be coded based on code definitions and criteria.

We used a combination of theory and frequency counts to identify a diverse range of indicators. After all interviews were coded, printed reports generated by Dedoose for behavioral, emotional, and cognitive codes for both student and teacher interviews were examined in order to compile different indicators for each construct. We sorted coded excerpts into indicator categories that represented the theme of the excerpts, and kept a tally of how often an indicator was mentioned. The purpose of this analysis was to get a sense of what types of indicators are most common to students' and teachers' conceptualizations of engagement. Initial categories were developed from the literature, previous measures of student engagement, and overall themes observed within the transcripts. New categories were created when excerpts did not fit under current categories. Indicator categories were then collapsed or further defined based on similarity, frequency, and salience. Initial survey items were developed to represent these indicator categories. In an effort to develop item questions relevant to students' and teachers' conceptualization and experience, particular attention was paid to student and teacher participant phrasing and meaning.

Following initial item development, a holistic review of the transcripts was completed by dividing all transcripts among the project manager and two graduate students. Transcripts were then macro-coded for themes related to the indicators and coding was compared to the developed items. Any additional themes identified were compared to the indicator categories and item questions developed. Adjustments were made to item phrasing and additional item questions were developed to encapsulate all relevant themes identified from the transcripts. Items were then compared to the literature and other measures of student engagement in order to create an exhaustive list.

Similarities and differences between students' and teachers' conceptions of engagement/disengagement and differences in themes across the 3 domains (i.e., math, science, and general) were also outlined. The summaries of overall themes and differences by group (teacher/student and domain) were then exchanged with another team member to verify the conclusions. The research team met on several occasions to discuss the table of indicators and emerging themes. Finally, the first author wrote a draft of the manuscript and distributed it to the other members of the research team for comments and edits.

7.1. *Study 1: Teacher and student conceptualizations of engagement*

Table 1 presents a summary of the indicators of engagement and disengagement of math and science engagement that emerged from both the student and teacher interviews. For each indicator, we noted the percentage of student (individual interview or focus group) and teacher interviews in which the indicator was mentioned at least once. In evaluating these percentages, it is important to acknowledge variability in the degree of probing and depth of responses. These percentages are also impacted by differences in context (type of class and level) and individual differences in how students engage. Students and teachers conceptualized engagement in math and science as a multidimensional construct that included behavioral, emotional, and cognitive dimensions. They also noted differences in how they engaged in math and science as compared to other school subjects like English, social studies, and history. One difference noted was that the other subjects were more likely to be taught with lecture-based methods, and students were less likely to describe engagement related to learning in problem-based activities. Students were also less likely to mention social indicators such as working in groups, sharing ideas, and teaching peers in other subject areas than in math and science.

The behavioral indicators of math and science engagement mentioned in both sets of interviews included many of the indicators outlined in the academic literature such as participation, attention, on-task behavior, and effort. Students' and teachers' conceptualizations of engagement also included many social-behavioral indicators, such as working with peers, interacting with peers and teachers, sharing ideas, explaining ideas to others, and asking a peer or teacher for help. These social-behavioral indicators, which are critical to work in a small group context, have generally not been included in prior conceptualizations and measures of student engagement (see Linnenbrink-Garcia et al., 2011, for one exception). In addition, indicators of body movement (e.g., moving around and making eye contact) and competence (e.g., getting good grades) were identified as indicative of engagement and have tended not to be included in academic conceptualizations of behavioral engagement.

Students and teachers also noted many emotional indicators of student engagement that have been outlined in the academic literature, including positive and negative emotions, interest, liking, perception of the value of the topic, and perceptions of the value of learning. We also identified additional negative emotions that have not been included in measures of student engagement, such as anger, confusion, and feeling overwhelmed. Fatigue and tiredness

Table 1
Indicators of engagement from teacher and student interviews.

Behavioral engagement	Disengagement
Involvement/Participation (S-48%, T-41%)	Not Participating (S-40%, T-66%)
Raising Hand/Asking Questions (S-77%, T-71%)	Not Asking Questions/Being Quiet (S-40%, T-66%)
Paying Attention/Listening (S-52% T-50%)	Not Paying Attention/Not Listening (S-50%, T-29%)
Focused/Concentrating (S-39%, T-15%)	Sleeping (S-40%, T-18%)
Effort/Trying Hard (S-50%, T-59%)	Not Putting in Effort (S-10%, T-21%)
Completing Homework (S-27%, T-21%)	Unprepared/Not Completing Homework (S-31%, T-21%)
On-Task/Doing Work (S-42%, T-29%)	Off-Task/Not Doing Work (S-27%, T-71%)
Respectful/Following Directions (S-6%, T-71%)	Playing On Phone (S-15%, T-9%)
Doing Extra Work/Research (S-19%, T-3%)	Doing Other Work (S-12%, T-6%)
Interacting/Working with Peers (S-62%, T-24%)	Talking to Friend about Non-School Content (S-10%, T-3%)
Interacting with Teacher (S-15%, T-6%)	Zoning Out/Spacing Out/Checked Out (S-42%, T-33%)
Speaking Out/Discussing Ideas (S-27%, T-29%)	Not Discussing/Expanding Ideas (S-6%, T-0%)
Sharing/Contributing/Explaining (S-33%, T-32%)	Just Sitting/Taking Notes (S-40%, T-12%)
Reviewing/Studying (S-29%, T-0%)	Putting Head on Desk/Slouching in Chair (S-10%, T-36%)
Asking Teacher or Peers for Help (S-23% T-15%)	Not Helping (S-0%, T-6%)
Active/Moving Around (S-17%, T-0%)	Getting Out of Chair (S-0%, T-6%)
Getting Good Grades/Doing Well (S−25%, T-0%)	Doing Bare Minimum/Going through Motions (S-16%, T-21%)
Attending School (S-0%, T-6%)	Missing School/Tardy (S-0%, T-6%)
Eye Contact (S-8%, T-15%)	Goofing Around (S-31%, T-33%)
Emotional	
Enjoyment/Fun/Cool (S-38%, T-33%)	Boredom (S-38%, T-18%)
Excitement/Enthusiasm (S-38%, T-59%)	Tired/Apathetic (S-12%, T-9%)
Interest in Topic/Class (S-44%, T-17%)	Not Interesting in Topic/Class (S-28%, T-21%)
Like Topic/Class (S-3%, T-21%)	Don't Like Topic/Class (S-27%, T-27%)
Care/Value Learning (S-27%, T-15%)	Don't Care/Value Learning (S-54%, T-35%)
Value Good Grades/College (S-10%, T-6%)	Frustrated/Discouraged/Confused (S-25%, T-24%)
Relevant to Life (S-19%, T-2%)	Not Relevant to Life (S-12%, T-12%)
Want to Do It (S-12%, T-21%)	Don't Want to Do It (S-33%, T-29%)
Looks Forward to Class (S-10%, T-3%)	Just Want to Be Done with Class (S-10%, T-0%)
Happy (S-23%, T-6%)	Unhappy/Sad/Miserable (S-6%, T-6%)
Pride/Satisfaction (S-10%, T-4%)	Nervous/Anxious/Worried (S-17%, T-15%)
Comfortable (S-8%, T-9%)	Uncomfortable/Annoyed (S-8%, T-3%)
Confident (S-8%, T-6%)	Stressed Out/Overwhelmed (S-8%, T-0%)
Feel Part of Group (S-6%, T-3%)	Feel Left Out/Disconnected (S-6%, T-0%)
Like Teacher/Working in Groups (S-19%, T-0%)	Confused/Embarrassed (S-13%, T-0%)
Cognitive	
Thinking Hard (S-19%, T-21%)	Not Thinking Hard (S-0%, T-9%)
Applying/Connecting Ideas	Not Making Connections

(*continued on next page*)

Table 1 (*continued*)

Behavioral engagement	Disengagement
(S-19%, T-26%)	(S-0%, T-12%)
Trying to Understand/Process Ideas	Mindlessly Taking Notes
(S-28%, T-32%)	(S-12%, T-12%)
Taking Apart and Integrating Ideas	Guessing/Forgetting
(S-0%, T-12%)	(S-8%, T-9%)
Persisting/Using New Strategies	Giving Up When Hard, Not Using Strategies
(S-0%, T-21%)	(S-0%, T-9%)
Self-Reflective/Self-Monitoring	Zoned Out/Tuned Out
(S-19%, T-21%)	(S-10%, T-9%)
Trying to Understand Mistakes	
(S-8%, T-12%)	
Understand Different Perspectives	
(S-8, T-9%)	
Using Strategies to Learn/Understand	
(S-17%, T-10%)	
Light Bulb Comes On	
(S-0%, T-18%)	
Solving Problems Different Ways	
(S-19%, T-35%)	
Teaching Self and Peers	
(S-13%, T-12%)	
Coming up With New Strategies on Own	
(S-10%, T-26%)	
Going In-Depth on Topic	
(S-8%, T-10%)	
Doing Extra Work/Finding Ways to Learn More	
(S-12%, T-29%)	

were also common indicators of disengagement identified in the interviews. Finally, students and teachers described some cognitive indicators in their conceptualizations of math and science engagement that matched the academic literature. These indicators include trying to understand ideas and using metacognitive strategies to integrate and apply ideas.

Additionally, both students and teachers noted some social cognitive indicators of engagement that have not tended to be included in previous measures of cognitive engagement, such as understanding different perspectives, building off others' ideas, and teaching peers. Indicators of cognitive disengagement were less likely to be noted by teachers and students, and tended to be more reflective of low levels of cognitive engagement. These indicators included using surface level strategies to only memorize information for a test, not trying to understand the material, and giving up. Finally, there was some overlap in behavioral and cognitive indicators (e.g., doing extra work and zoning out). For example, students and teachers discussed doing extra work both in terms of a deeper psychological investment in learning (i.e., cognitive engagement) and doing just what was required in school (i.e., behavioral engagement).

There were a few differences in teachers' and students' conceptualizations of math and science engagement. Only students noted aspects of competence, or showing mastery of math and science, as indicative of engagement. Many of these students did not differentiate engagement from “doing well in class” or doing things in order to do well in class. Students were also more likely to mention working with peers as indicative of engagement, and were less likely than teachers to describe engagement in terms of cognitive indicators. Teachers were more likely to talk about coming up with new strategies to solve difficult problems. Teachers were also much more likely than students to report behavioral indicators such as following rules and being respectful as indicative of engagement. However, for many teachers these indicators were basic requirements for school, and deeper engagement meant going beyond the basic requirement and being more invested in learning and understanding content.

Although there were large commonalities in students' and teachers' perceptions of math and science engagement, we also noted a few differences in the salience of different indicators in each subject domain. For example, competence beliefs and behavioral indicators were more important aspects of engagement in math. Students talked more about the importance of paying attention and focusing in math than in science. This may reflect the fact that math content was more likely to be taught sequentially in lecture-based formats, requiring students to build on what they have already learned. Many of the students also perceived encountering more challenges in math than science. They also discussed more negative emotions in math, such as frustration, boredom, and anxiety in this domain. Perceiving that they had ability was an important factor in whether they persisted in math.

In science, students' and teachers' conceptualizations of engagement included more social aspects, such as sharing ideas, contributing to others' ideas, and thinking about others' perspectives. These social indicators may reflect the fact that students were more likely to work in small groups in their science classes than in their math classes. Moreover, in science, students tended to have more opportunities to work on open-ended tasks, where there were multiple ways to solve a problem. As a result, students were more likely to conceptualize engagement as opportunities for them to explain their thinking and to teach other students. In general, students were more likely to report positive emotions in science than in math, which may reflect opportunities for greater social interactions and the perception that science has greater relevance to their lives. Although many students reported positive emotions toward/in science, some students reported frustration and confusion, and several of the disengaged students reported being bored and questioning the relevance of science to their lives.

7.2. Study 2: Survey development

The goal of the second study was to use the qualitative information from the interviews with students and teachers to develop a new questionnaire of math and science engagement.

We used the steps outlined in Gelhbach and Brinkworth (2011) to develop our student self-report questionnaire and enhance the validity of our scales. First, we reviewed the academic literature for different conceptualizations of student engagement. We also reviewed engagement measures from which potential items might be borrowed or adapted for use in math and science. This step provided us with a definition of student engagement, a working knowledge of the major characteristics that the previous literature has identified as being important to student engagement, and a sample of potential items.

As suggested in Gelhbach and Brinkworth (2011), in the next step, we compared responses from our focus groups and interviews with students and teachers about the meaning of engagement and disengagement in math and science against the results from the literature review to determine points of overlap, divergence, and disparities in terminology. This step was important to determine if students and teachers included and excluded the same categories as those that have been identified in the academic literature, as well as to provide insight into the language respondents use to describe this construct. In developing items, when there was agreement in the conceptions of engagement but differences in the wording of a specific item, we used the vocabulary of the respondents.

In our initial list of survey items, we included indicators that were either mentioned by students/and or teachers but were not identified in the research, as well as items from prior measures of engagement that were not mentioned in the interviews. It was important to include both teachers and students because teachers may report on aspects of students' engagement that students themselves can report on but are less likely to reflect on without specific prompting. By looking at teacher excerpts, we were also able to create a larger pool of items that could be reviewed by experts and by students in cognitive pre-testing. The list of items were then reviewed by the co-principal investigators (first and second authors) and the research team in intensive workshops to examine and discuss face validity of each item, and cut items that seemed unnecessary or unclear. Items were continuously refined by dialoging themes from the transcripts with concepts from the literature. Items in each dimension were grouped into constructs that reflected themes in the transcripts.

To ensure that the list of items we developed corresponded to the construct of student engagement, we identified eight experts on student engagement and math and science instruction to judge how well the items represented the construct. Each expert was asked to rate each of the items on clarity (how understandable each item was) and relevance (how well each item represented the construct) (see McGartland Rubio, Berg-Weger, Tebb, Lee, & Rausch, 2003, McKenzie, Wood, Kotecki, Clark, & Brey, 1999; for description of the expert validation process). In addition, experts were asked to provide suggestions on alternative wording and on any aspects of the construct that they felt were not adequately represented by the set of items.

Our experts noted some issues with our list of potential items including: 1) overlap of some items across the behavioral and cognitive dimensions of engagement; 2) differences between items that reflected individual and social engagement; and 3) potential developmental differences between how middle school and high school students might interpret some items. Furthermore, they suggested adding items that reflected basic behavioral and cognitive engagement, as they thought our items tended to focus on higher levels of each dimension. Based on the experts' suggestions we made several changes to our items and scales including: 1) creating a separate scale for social engagement with all of the social items; 2) changing the wording of some items; 3) deleting items about competence, 4) adding items about basic levels of behavioral engagement (e.g., completing homework); 5) adding questions about use of surface level cognitive strategies (e.g., when I am studying, I only review questions I have solved before); and 6) dropping some items that might be misinterpreted by students (e.g., I often count the minutes left in math and science class, I am afraid of looking dumb in math/science class, I teach myself more about topics we cover in class even when math/science is over). Although changes were made to some items, those changes were made with the participant language and meaning in mind.

In the final step, we cognitively pre-tested the revised items with several focus groups of low and high achieving sixth to eleventh graders to assess the validity of individual items (see Karabenick et al., 2007, for a description of cognitive pre-testing). We were interested in whether or not students comprehended and interpreted the items as we had expected. We followed the procedures outlined in Wooley, Bowen, and Bowen (2004) for conducting cognitive interviewing with children. Specifically, students were asked the following questions: 1) is the item clear; 2) what do they think the item means; 3) how would they answer the item; and 4) why did they choose that answer?

Our cognitive interviews revealed that students interpreted the majority of items as we had intended, though there were a few items that were interpreted differently than we had conceptualized. In addition, students did not understand the wording of some of our items and noted differences in the meaning of some of the items in math and science. Some examples of themes from the cognitive interviews include: 1) students did not tend to differentiate between learning math and science content and learning in math and science class, and 2) students thought some items did not apply to both math and science (e.g., memorizing steps of a problem only applied in math classes). In addition, students noted some questions that were difficult to answer because they depended on the contextual affordances in the classroom. For example, some students had a hard time answering a question about participating in science labs because their science class did not have a lab component. Based on the students' responses, we deleted some items and changed the wording of other items to better reflect the meaning.

The final list of survey items is presented in Table 2. All students were asked to answer the item in respect to their math and science classes. This newly developed math and science engagement measure was then given to a separate and larger sample of 3936 sixth through twelfth graders. Each subscale of the engagement measure has good reliabilities ($\alpha = .73$ - .90, see Table 3). The PCA and CFA also suggested that the engagement measures demonstrated a multidimensional factor structure, including behavioral, emotional, cognitive, and social dimensions. Due to space limitations, this psychometric information is included in the subsequent paper in this special issue (see Wang, Fredricks, Hofkens, Schall & Parr, 2016).

8. Conclusions

Although the construct of engagement holds considerable promise in explaining school-related outcomes, research on how to define and measure this construct is still emerging. The need for well-validated and reliable instruments of student engagement is outlined in two recent reviews of current engagement self-report measures (Fredricks & McColskey, 2012; Veiga et al., 2014). The goal of this study was to develop a theoretically grounded measure of math and science engagement that reflects a multidimensional construct. One way to enhance the validity of scales is to see if potential respondents think of the construct of interest in the same way as researchers. Therefore, in the first step of survey development, we interviewed teachers and students about the meaning of engagement and disengagement (Gelhbach & Brinkworth, 2011).

Table 2
Survey items of math and science engagement.

Behavioral engagement
1. I stay focused.
2. I answer questions in class.
3. I put effort into learning.
4. I keep trying even if something is hard.
5. I ask questions in class.
6. I complete my homework on time.
7. I talk about math and science outside of class.
8. I try to learn more about the topics we cover in class.
9. I don't participate in class (Reverse coded).
10. I do other things when I am supposed to be paying attention (Reverse coded).
11. If I don't understand, I give up right away (Reverse coded).

Emotional Engagement
1. I often like to be challenged in math and science class.
2. I look forward to math and science class.
3. I enjoy learning new things in math and science class.
4. I want to understand what we are learning in class.
5. I feel good when I am in math and science class.
6. I often feel frustrated in math/science class (Reverse coded).
7. I think that math/science class is boring (Reverse coded).
8. I don't want to be in math/science class (Reverse coded).
9. I don't care about learning math/science (Reverse coded).
10. I often feel discouraged when I am in math/science class (Reverse coded).
11. I often get worried when I learn new things about math and science (Reverse coded).

Cognitive engagement
1. I go through work that I do for class to try to make sure it is right.
2. I think about different ways to solve a problem.
3. I try to connect what I am learning to things I have learned before.
4. I try to understand my mistakes when I get something wrong.
5. When I am studying, I only review problems I have solved before.
6. I would rather be told the answer than have to figure it out myself (Reverse coded).
7. I don't think that hard when I am doing work for class (Reverse coded).
8. When work is hard, I only study the easy parts (Reverse coded).
9. I do just enough to get by (Reverse coded).

Social engagement
1. I build on others' ideas.
2. I try to understand others peoples' ideas in math and science class.
3. I try to work with others who can help me in math/science.
4. I try to help others who are struggling in math/science.
5. I don't care about other peoples' ideas (Reverse coded).
6. When working with others, I don't share my ideas (Reverse coded).
7. I don't like working with my classmates (Reverse coded).

This is a critical step because too often surveys are developed without input or feedback from the population of interest. Information on both students' and teachers' conceptualizations of engagement were included in our initial list of items, though some of these indicators were dropped in additional validity tests. Incorporating both teacher and student conceptualizations of engagement provided greater insight into how students experience engagement in math and science class and how teachers perceive students' engagement. These perspectives together allowed for item development that attended both to both student characterization and to teacher assessment.

Our analysis of student and teacher interviews supported the multidimensional conceptualization of engagement outlined in the academic literature. Many of the indicators developed through our qualitative analysis overlap with and validate current conceptualizations of engagement, though few of the previous measures include all dimensions in the same instrument. For example, some of the indicators of behavioral (e.g., paying attention and participation), affective/emotional (e.g., interest and value), and cognitive engagement (e.g., shallow and deep strategy use) are similar to items in current measures of engagement (see Fredricks & McColskey, 2012; for a review).

Our qualitative analysis also revealed additional indicators that have been less frequently included in previous measures. For example, both teachers and students discussed positive emotions, such as happiness and pride, and negative emotions such as frustration, anxiety, and anger, when describing their experience of being engaged and disengaged. These affective indicators aligned with many of the emotions that have been identified in the literature on academic emotions (Pekrun, Goetz, Titz, & Perry, 2002; Pekrun & Linnenbrink, 2012). Furthermore, we noted indicators of cognitive engagement (i.e., doing extra to learn more and being self-reflective) that have tended to not be included in previous measures. These indicators aligned with measures of self-regulated learning and study strategies (Greene, 2015).

One of the most important differences between our qualitative analysis and the majority of other surveys of engagement is the inclusion of a social dimension (see Linnenbrink-Garcia, et al, 2011; Rimm-Kaufman, Baroody, Larsen, Curby, & Abruy, et al., 2014, for exceptions). Until recently, the concept of engagement has focused primarily on individual learning situations. Because social interactions, collaborative learning, and help seeking from peers are playing an increasingly important role in education (O'Donnell & Hmelo-Silver, 2013; Ryan & Pintrich, 1997), conceptualizations of engagement should move beyond just emphasizing individual aspects to also consider social dimensions. These social indicators also are key aspects of the new instructional emphases in both math and science classrooms on small group work, argumentation, and justifying your reasoning to others (NRC, 2012; CSSE, 2015).

Teachers and students discussed social indicators such as sharing ideas and expanding on peers' ideas as indicative of engagement. To reflect these social interactions, we created a separate scale to assess social engagement. Our scale differs from previous measures of social engagement, which focuses primarily on social-behavioral indicators, by including items that reflect social-affective (e.g., caring about others ideas) and social-cognitive (e.g., building on others ideas) dimensions of group interactions. We believe that social engagement represents a promising construct to develop further, especially in reform-based science and math classrooms that are more likely to include a small group component. An important question is whether social engagement is indeed a distinct dimension of engagement, and whether social engagement can be conceptualized as social behavior, social emotion, and social cognition. Future research should also explore whether social engagement is a moderator of students' behavioral, emotional, and cognitive engagement or whether the construct is the foundation of other types of engagement.

Table 3
Descriptive statistics and reliability.

	Behavioral engagement		Affective engagement		Cognitive engagement		Social engagement		Full scale	
Subject	Math	Science	Math	Science	Math	Science	Math	Science	Math	Science
Mean (*SD*)	3.79 (*.74*)	3.72 (*.70*)	3.62 (*.90*)	3.74 (*.84*)	3.79 (*.67*)	3.74 (*.68*)	3.77 (*.70*)	3.79 (*.69*)	3.73 (*.64*)	3.74 (*.62*)
Cronbach Coefficient	.84	.83	.90	.89	.78	.78	.74	.73	.93	.93

Coefficient alphas of the item scores of each subscale and the full scale of STEM engagement are presented in Table 3. The four subscales demonstrated high level of internal consistency ($\alpha s = .73–.90$) and the full scale also had excellent internal consistency (.93).

Using qualitative methodology also demonstrated the importance of considering engagement as a multidimensional construct. Teachers and students discussed behavioral, affective/emotional, and cognitive indicators in their conceptualizations of engagement, though teachers more strongly emphasized cognitive dimensions than did students. Teachers reported that behavioral aspects of engagement were necessary, but not sufficient for being engaged in class. Instead, they thought that indicators of cognitive engagement, such as going beyond the requirements, and using strategies to learn and understand the material, were necessary for deeper learning. Interestingly, the math and science teachers in this sample had a much more complex conceptualization of engagement than has been noted in other studies in which teachers tended to emphasize behavioral dimensions (Harris, 2011). One possible reason for this difference is that our study focuses on engagement in math and science, while the other studies have looked more broadly at general conceptions of engagement/disengagement in school.

In general, the indicators in math and science were similar, though there are some differences in the salience of these indicators. For example, participants noted more social engagement components, such as sharing and explaining ideas, in science than in math. In addition, there were a few differences in the indicators of cognitive strategy use described in math and science. For example, in science, students talked more about connecting and applying what they were learning to what was happening outside of the classroom. Although there were some subject-specific indicators, there was not enough difference between the two domains to create two separate measures. In our work with schools, we have found that in upper-level math and science classes, like engineering, physics, and robotics courses, students are often engaging in both math and science. Having a single STEM measure has the benefit of being appropriate in STEM coursework that is math-intensive and non-math intensive.

Since there are few subject-specific measures of engagement, we don't know the extent to which engagement is domain-general and what extent it varies across domains (Fredricks & McColskey, 2012). Though indicators of engagement may be valid across a more general measure of school engagement and between subject areas, little work has been done to explore what indicators exist within subject areas. Understanding what aspects of engagement are subject-specific will help distinguish those differences and inform the best methods of instruction within subject-specific domains.

Our findings both confirm domain-general items that conceptually align with existing measures, as well as adding additional domain-specific items that are reflective of engagement in math and science domains. For example, many of the indicators we developed were not necessarily unique to math and science. This is most true of the behavioral engagement scale, in which several of the items, such as attention and participation, are similar to other previously developed measures of engagement (see Fredricks & McColskey, 2012). Our results also suggest some adaptions to these previous measures to reflect domain-specific aspects of engagement, including indicators of emotional disengagement (i.e., frustration, anxiety, confusion), deep strategy use (i.e., solving problems in different ways), and social engagement (i.e., sharing ideas, building ideas, and working with others). Although these indicators could exist in other subject areas, they are likely reflected differently in math and science because of the instructional emphases on collaboration, complex problem solving, abstract reasoning, argumentation and explanation (Sinatra, Broughton, & Lombardi, 2014; Sinatra et al., 2015). For example, students are more likely to experience frustration and confusion when working on complex learning activities, which are common in science classrooms (Sinatra et al., 2015). It remains an open question for future research whether these items are also important indicators of engagement in other subject areas.

Our findings also raise questions about the measurement of subject-specific disengagement. The indicators identified were more indicative of low effort, low affect, and shallow strategy use than of problem behaviors. Examples of math and science disengagement included dozing off, playing on phones, being bored, doing only the minimum required, and talking with friends. A few of these indicators, like dozing off and playing on phones, have not been included in prior domain-general measures of engagement. In addition, some of the indicators of problem behaviors like fighting and being tardy that are commonly included in domain-general measures, were not mentioned by either teachers or students as indicative of math and science disengagement.

Typically, disengagement has been operationalized in the literature as the absence of engagement. Recently, some researchers have begun to conceptualize and measure engagement and disengagement as separate scales (Skinner, Kinderman, & Furrer, 2009; Wang, Chow, Hofkens, & Salmela-Aro, 2015). We found evidence to support both interpretations of the relation between engagement and disengagement. For example, some of the indicators of disengagement were the opposite of engagement (e.g., participating/not participating, caring about learning/not caring about learning). Other indicators mentioned in the interviews operated on a continuum from basic or lower levels to higher levels of engagement. For example, indicators of behavioral engagement went from basic compliance, such as completing homework, to doing extra work and going beyond the requirements. Additionally, indicators of cognitive engagement went from basic shallow strategies that help students to memorize material to deeper learning strategies, such as connecting and elaborating on knowledge, that help students understand the material. Furthermore, some indicators noted by participants, such as sleeping, were specific to disengagement and did not have an engagement counterpart. These results suggest that the relation between engagement and disengagement is more complex than outlined in the prior literature and differs across and within dimensions.

The results of this study need to be interpreted in light of the following methodological decisions. In our selection process, we asked teachers and administrators to identify high and low-achieving students that varied in their level of engagement. However, our resulting sample had more high-achieving and highly engaged students than low-engaged and low-achieving students. Though teachers and administrators were asked to identify students on a range of achievement and engagement levels, many of the students who ultimately returned consent forms reported high grades and high engagement in their math and science classes. In addition, we changed the methodology during the study period from focus groups to individual interviews. We examined differences in themes and indicators across two methodologies and did not find differences, though there was greater elaboration of reasons for engagement and disengagement in the interview format.

Our goal was to develop an instrument that reflects the experiences of teachers and students in math and science classes. Although many of the indicators were similar to prior measures, we also identified some additional indicators that have not usually been included in domain-general measures of engagement. Testing the relevance of these items in other subject areas is an important area of future study, but is beyond the purview of this study. Because there were few differences in the indicators for math and science engagement we also created one measure for both subject areas. One limitation with using a combined measure it is makes it more difficult to test for the effects of possible contextual differences in math and science on engagement. Future research should examine differences in domain specific indicators to better understand how different indicators matter in relation to teacher and classroom climate differences and for different population characteristics (i.e., development, gender, ethnicity). Additionally, we created one measure for both middle and high school students. However, there are some aspects of math and science engagement, such as science labs, that tend to be more common in the later grades. The size of our interview sample and small number in each group made it difficult to examine potential developmental differences in conceptions of engagement/disengagement by grade level (i.e., middle versus high school), school, and teacher. Finally, the goal of this study was to develop and validate a student self-report measure of engagement. An important next step is to develop a reliable and valid teacher measure of engagement.

In sum, without greater attention to measurement development, the potential of student engagement in math and science in explaining academic achievement and career choices will not be realized. Developing valid and reliable measures is especially important in math and science because engagement in these subjects is so critical to academic achievement and career choices related to STEM. We anticipate this newly developed measure will be of interest to researchers exploring the relation between context, engagement, and achievement and STEM career choices. Furthermore, our hope is that this measure will be useful for teachers interested in identifying students at risk of disengaging from math and science class and STEM courses and careers.

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