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# Development and Evaluation of a Survey to Measure Student Engagement at the Activity Level in General Chemistry

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# Exploring Student Perceptions of Behavioral, Cognitive, and Emotional Engagement at the Activity Level in General Chemistry

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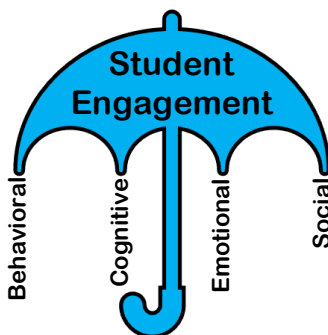
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## Abstract

Although active learning strategies are being incorporated into many higher-education STEM courses, not all students benefit from these activities to the same extent. As these types of activities are designed to engage students in their learning, differences in student engagement may explain some of the differences in learning outcomes. However, before student engagement in active learning activities can be meaningfully measured using a self-report survey, it is important to evaluate if students perceive engagement similarly to the literature definitions these measures are based on. Therefore, this study sought to explore students' perceptions of the behavioral, cognitive, and emotional dimensions of engagement with respect to specific worksheet activities incorporated into a general chemistry course. This was completed through the use of open-ended written responses and interviews. Results indicated that although students generally perceived behavioral, cognitive, and emotional engagement similarly to the literature definitions of these dimensions, students tended to conflate many ideas of behavioral and cognitive engagement. Additionally, social themes were also discovered to be threaded throughout student responses to the three dimensions of engagement, suggesting students also perceived the presence of a social engagement dimension when considering engagement at the activity level.

## Graphical Abstract



## **Keywords**

First-Year Undergraduate / General, Chemical Education Research, Collaborative / Cooperative Learning, Student-Centered Learning

## **Introduction**

Incorporating active learning strategies in the classroom has been found to generally improve student performance outcomes with respect to exam scores, course grades, withdrawal rate, and other measures when compared to traditional lecture classes.<sup>1,2</sup> However, the benefits of active learning may not be realized to the same extent for every student. Case-studies of individual students found that university students' experiences in the same active learning environment varied and were not necessarily reflected in their course grades.<sup>3</sup> Additionally, another study found that students' grades were not dependent on their attitude toward the active learning environment.<sup>4</sup> In general, higher student engagement in an environment has been shown to be positively related to student learning outcomes.<sup>5,6</sup> As active learning environments focus on engaging students in their learning through the use of discussion and activities,<sup>1</sup> variations in how students engage in these tasks may influence if and how they benefit from them.

Student engagement in the classroom has been conceptualized through two different but related perspectives. The "behavioral perspective" of student engagement focuses solely on the behavioral dimension of engagement, such as time and effort, and the relation of certain behaviors to students' achievement.<sup>7</sup> However, this perspective may underrepresent equally important aspects of engagement related to students' psychological state, such as the students' investment in their learning and emotions.<sup>7</sup> Therefore, the "psychological perspective" of student engagement encompasses several dimensions of engagement, including ones related to behavioral, cognitive, and emotional aspects.<sup>7</sup> Frameworks based in the psychological perspective can be single or multidimensional in nature. For example, the ICAP (interactive-constructive-active-passive) framework<sup>5</sup> focuses solely on categorizing different modes (i.e., levels) of students' cognitive engagement. Other frameworks consist of multiple overlapping dimensions. One such framework, defined by Fredricks et al.,<sup>8</sup> characterizes engagement as including interrelated behavioral, cognitive, and emotional components and emphasizes that these dimensions should be evaluated simultaneously to better assess the complex construct of engagement and account for any effects due to the overlapping nature of the dimensions.

Therefore, when evaluating student engagement, a multidimensional engagement framework can

provide a more complete perspective of student engagement than simply focusing on a single component.

Within this multidimensional framework of engagement, behavioral engagement focuses on students' positive conduct and involvement in the classroom, which can include behaviors related to asking questions, putting in effort to do the work, and paying attention.<sup>8,9</sup> Cognitive engagement is often considered in relation to students' psychological investment in their learning, which includes putting in effort to understand and master the material, as well as going above and beyond the requirements.<sup>8,9</sup> Emotional engagement centers around students' affective reactions to interactions they have in the classroom. Many different types of emotions are often included when considering emotional engagement, such as, interest, boredom, value, etc., and can be related to students' interactions with peers, instructors, the course material, or in-class activities.<sup>8,9</sup>

Observational measures can be used to evaluate student engagement in the classroom (e.g., Chi & Wylie,<sup>5</sup> Harris & Cox,<sup>10</sup> Lane & Harris<sup>11</sup>); however, they are often difficult to implement in large enrollment courses and generally are only used to assess the engagement of a subset of students. Additionally, observational measures are generally cautioned against when evaluating cognitive and emotional engagement, as indicators of these dimensions tend to be internal to the students.<sup>12</sup> Instead, self-report surveys can be used to collect information from all students in a class, as well as allow the simultaneous evaluation of behavioral, cognitive, and emotional engagement. Multiple self-report survey measures have been used to collect data on student engagement in higher-education STEM courses (e.g., Aceti,<sup>13</sup> Gasiewski et al.,<sup>14</sup> Seery,<sup>15</sup> Skinner et al.,<sup>6</sup> Smith & Alonso<sup>16</sup>). Measures focused on specific dimensions of engagement often rely on the literature definitions, expert feedback, and factor analysis to create initial items and to group the items into the different dimensions (e.g., Skinner et al.,<sup>6</sup> Smith & Alonso<sup>16</sup>). While these methods provide evidence of item groupings and alignment of items to the literature definitions through the perceptions and interpretations of experts, it is unknown whether students' perceptions of the dimensions of engagement align with their definitions in these environments. Exploring students' perceptions of engagement would provide additional evidence for the validity of data collected with engagement measures. Therefore, the main goal of this study was to assess students' perceptions of behavioral, cognitive, and emotional engagement with relation to active learning worksheet activities incorporated into a general chemistry lecture

course and to evaluate the alignment of student perceptions with the literature definitions of these dimensions. This goal is met by answering the research question: How do students perceive behavioral, cognitive, and emotional engagement in these general chemistry worksheet activities?

### Course Information

All students included in this study were part of the general chemistry (GC) course sequence at Portland State University (PSU). Student data from two different academic years and terms (GC I and GC II) were collected (Table 1). During both years the course included both lecture and activity days. The activity days focused around completing worksheet activities that were similar in structure to Process-Oriented Guided Inquiry Learning (POGIL) materials. Because of the Covid-19 pandemic, this course was transitioned from meeting in-person during the Winter of 2020 to meeting remotely (i.e., online) by Fall 2020. Due to the change in classroom environment, the implementation of the activity days differed between the two years.

Table 1. Course information for each general chemistry (GC) classroom environment.

Classroom environment	Term	Sections included in study	Week 1 enrollment
In-person	Winter 2020 (GC II)	1	N = 249
Remote	Fall 2020 (GC I)	2	N = 629

In the in-person environment, students were expected but not required to work on the worksheets in groups of 2 – 4 students. In this environment, the instructor, graduate teaching assistant (TA), and multiple undergraduate learning assistants (LAs) all moved throughout the room to facilitate group discussion and answer questions. Clicker questions were used periodically to gauge students' understanding of the content. Data were collected from a single section of the course, which was taught by an instructor who also conducted one of the remote instruction sections the following year.

In the remote environment, both sections were facilitated using the video platform software Zoom. During activity days, students were directed to work through the worksheets in randomly assigned groups in breakout rooms, although some students opted to stay in the main

room to work on the worksheet by themselves. Students who did work with others in a breakout room generally worked with 2 – 6 other students. Multiple undergraduate and graduate LAs each rotated through an assigned set of breakout rooms to facilitate discussion and answer questions. The main role of the instructor and graduate TA during the activity days was to manage the remote breakout rooms through check-ins with the LAs. Although two instructors taught this course, both implemented the worksheets similarly and students from both sections are represented in the data collected.

## **Methods**

### *Data Collection*

Institutional Review Board (IRB) approval from Portland State University was received for all data collected within this study and appropriate consent was obtained from students as required by the IRB.

Student responses from the in-person environment were collected through the use of open-ended survey items. Students were notified about the survey two weeks before the end of the course through an in-class announcement, as well as one posted on the course's learning management site. The posted announcement included a link to the Qualtrics survey. Students were given one week to access and complete the survey and were offered a nominal amount of extra credit for accessing the survey regardless of completion. Student responses from the remote environment were collected through the use of interviews. Students who were interested in participating in an interview were asked to provide their email at the end of a related survey. All interested students were contacted and directed to fill out a consent form and provide their availability. These responses were used to schedule group interview sessions with at least two students per time slot. Each interview only contained students from the same class section and all students who participated in the interviews had worked on the worksheet in breakout rooms with other students for at least some of the activities. A total of 14 students from both sections participated in 8 interviews. Although the goal was to have at least two students to create a group interview (i.e., focus group) environment, to respect participants time, an interview proceeded even if only one student showed up to the agreed upon time. Therefore, 3 interviews were conducted with individual students, 4 interviews included two students, and one interview

included three students. All interviews were completed over Zoom with audio and visual recording and recordings were transcribed prior to analysis.

### *Open-ended Survey Items*

As part of a larger survey, each student was randomly given a definition of engagement that aligned with either behavioral, cognitive, or emotional engagement. These definitions were based on the descriptions of the three engagement dimensions given by Fredricks et al.<sup>8</sup> They were initially created by the primary researcher (author N.N.) and then were slightly modified for meaning and clarity with the input of a secondary researcher. These definitions are presented in Table 2. Based on the presented definition, students were asked to respond to the following two items:

- 1) How would you describe a student who is **NOT engaged** in the worksheet activities based on the definition above?
- 2) How would you describe a student who is **VERY engaged** in the worksheet activities based on the definition above?

Table 2. Definitions of the three dimensions of engagement presented to students.

Engagement Dimension	Definition presented to students
Behavioral	Engagement is the physical participation or involvement in the worksheet activities.
Cognitive	Engagement is [exerting mental effort] <sup>a</sup> to comprehend ideas or skills presented in the worksheet activities.
Emotional	Engagement is the positive feelings towards the worksheet activities.

<sup>a</sup>The phrase “exerting mental effort” was replaced with “trying” for the version presented to students during the interviews.

### *Interview Protocol*

Interviews were completed remotely over Zoom using a semi-structured interview approach. The students were first asked to generally describe their engagement in the worksheet activities. They were then presented with definitions of engagement related to behavioral, cognitive, and emotional engagement (see Table 2) one at a time using the chat function in Zoom. These definitions were similar to the definitions given during the open-ended survey; however, the cognitive definition was slightly modified to remove the word “effort”, as it has been associated with both behavioral and cognitive engagement components.<sup>8</sup> One student was

asked to read each definition out loud and then all students were asked to describe what it meant to be *very engaged* and *not engaged* in the worksheet activities based on the definition provided. Follow-up questions were asked as needed for further clarification.

### *Data Analysis*

Data collected from the open-ended surveys were coded using an inductive approach where codes were created from the data. Before coding, the responses were first cleaned to remove any illogical responses from the dataset (i.e., responses that only included random characters such as “n”, “.”, etc.). To create the initial codebook, the two coders individually separated each response to the two items (i.e., *not engaged* and *very engaged*) into statements that each coder felt represented different topics related to any dimension of engagement defined by Fredricks et al.<sup>8</sup> These statements were then organized by each coder into groupings that related to a possible code. They then came together to discuss these possible codes and through consensus compiled the initial codebook (version 1). The coders used the initial codebook to individually code the full set of responses to the two items related to behavioral engagement (n = 55 each) and then met to discuss any discrepancies or possible new codes that appeared. Based on the discussion, codes were modified or added as needed and the codebook was updated to create a second version. The set of responses for the cognitive (n = 57 for each item) and emotional (n = 58 for each item) definitions were then coded in a similar manner and subsequent discussion between the two coders resulted in some modifications and updates to the codebook to create a third and final version. This final version of the codebook was then used by both coders to recode approximately 20% of the responses to the items for each of the definitions. Inter-coder reliability (ICR)<sup>17</sup> was calculated to evaluate agreement between the coders through the use of Cohens’ kappa,<sup>18</sup> which accounts for agreement due to chance. Cohen’s kappa was calculated using the *irr* package (version 0.84.1) in the statistical software R (version 3.6.2). The ICR for the responses coded by both coders was 0.87, which is considered substantial agreement.<sup>19</sup> The remainder of the responses were then recoded by the primary researcher using the final version of the codebook. The percentage of student responses that mentioned each code was calculated out of the total number of responses for each definition of engagement.

Responses from the interviews were coded using both an inductive and deductive approach, such that codes were created from a subset of the interview data and then applied to



the remaining interviews. The two coders started by individually reading through two transcripts and highlighting phrases and statements from the students that corresponded to their engagement in the activities. The coders then came together to discuss any discrepancies in the highlighted sections to reach a consensus on which statements did or did not relate to engagement. Agreed upon phrases were then grouped together into categories to create the initial codebook (version 1) and similar codes to the in-person environment were used when possible. Version 1 of the codebook was then used by the coders to separately code two additional transcripts. The coders came together to discuss any discrepancies and modified the codebook as needed, producing the second and final version. This final codebook was then used to code the remainder of the interview transcripts and to recode the first two transcripts. During this process, both coders would separately code two transcripts at a time and then come together to discuss any discrepancies. No new codes were discovered during this process and each transcript was coded to consensus. ICR was evaluated throughout the process through the use of Cohen's kappa and found to be between 0.43 – 0.63 among the transcripts, which is considered moderate agreement.<sup>19</sup> Although ICR was lower when coding the interviews compared to the short-answer survey responses, ICR is generally expected to be lower when coding something with a larger amount of text.<sup>17</sup> The number of students who mentioned each code at least once throughout the three engagement definitions was calculated to determine overall how many students perceived engagement related to that code. Additionally, the number of students who mentioned each code during the section of the interview where they were provided one of the engagement definitions (i.e., behavioral, cognitive, emotional) was also calculated. If a student mentioned the same code in relation to multiple definitions, they were counted as having mentioned that code during each definition section. Therefore, the number of students who mentioned the code *overall* throughout the interview may be lower than the sum of the number of students who mentioned a code for each of the definitions.

For both sets of data (i.e., open-ended and interview responses), each code that was discovered was organized into either behavioral, cognitive, or emotional engagement. Codes were first categorized by the primary researcher based on if they were related to positive engagement or negative engagement (i.e., disengagement). The primary researcher then further categorized the codes into the different dimensions of engagement based on the theoretical definitions given by Fredricks et al.<sup>8</sup> Behavioral codes included ones that were related to

participation and involvement, as well as behaviors involving staying focused, paying attention, and asking questions. Cognitive codes were selected based on if they described students' investment in their learning. This included codes related to putting effort into understanding, applying and/or connecting the activity to prior material or classes, and learning from mistakes. As there is some known overlap between behavioral and cognitive engagement,<sup>8,9</sup> codes that focused specifically on behaviors related to student participation (i.e., talking with others, asking questions, etc.) were coded as behavioral and codes that focused on going "above and beyond" to understand the material (i.e., discussion, writing extra notes, helping others, etc.), were categorized as cognitive. Codes were grouped into emotional engagement if they were related to students' feelings about the activity, working with others, or the content material in general. A secondary researcher independently reviewed the categorizations and some uncertain codes related to cognitive and behavioral engagement were discussed among the researchers until a consensus was reached.

## **Results and Discussion**

From the in-person environment survey responses, 63 codes were discovered related to how students perceive behavioral, cognitive, and emotional engagement in this environment (details included in Tables S1-S3 in the Supporting Information). These codes represented 31 positive aspects of engagement and 32 aspects related to negative engagement (i.e., disengagement). From the remote environment interview responses, a total of 58 codes related to how students perceive engagement in this environment were discovered (details included in Tables S4-S6 in the Supporting Information), which included 33 codes related to positive aspects of engagement and 25 related to disengagement.

### *Behavioral Engagement*

When provided with the behavioral definition of engagement, students' perceptions of what constitutes behavioral engagement were described by 31 codes across environments (Table 3). This included 15 codes that were similar between the two environments, and 11 and 5 codes only discovered in the in-person and remote environments, respectively.

Table 3. Number of students that mentioned each behavioral code when provided with the behavioral definition of engagement.

Behavioral Codes <sup>a</sup>	Number of Students (%)	
	In-person Environment n = 55	Remote Environment n = 14
<b>Engagement</b>		
Asked questions	21 (38.2)	2 (14.3)
Worked on worksheet	13 (23.6)	7 (50.0)
Wrote things down	--	11 (78.6)
Focused/paid attention	8 (14.5)	5 (35.7)
Was prepared	8 (14.5)	4 (28.6)
Tried to do worksheet	8 (14.5)	2 (14.3)
Completed worksheet	8 (14.5)	--
Talked to/worked with others (positive)	8 (14.5)	4 (28.6)
Read question to self	--	3 (21.4)
Shared screen	--	3 (21.4)
Participated	5 (9.1)	3 (21.4)
Asked for group feedback	5 (9.1)	2 (14.3)
Engaged with others	3 (5.5)	--
Put in general effort	2 (3.6)	--
Listened to others	--	1 (7.1)
<b>Disengagement</b>		
Didn't work on worksheet	18 (32.7)	3 (21.4)
Just "there"	--	10 (71.4)
Was on a non-class related device	19 (34.5)	--
Worked on other things	8 (14.5)	6 (42.9)
Distracted	6 (10.9)	9 (64.3)
Didn't try to do worksheet	6 (10.9)	5 (35.7)
Participated in off-topic conversations	6 (10.9)	--
Didn't talk to/work with others	6 (10.9)	4 (28.6)
Didn't ask questions	4 (7.3)	1 (7.1)
Wasn't prepared	3 (5.5)	1 (7.1)
Left class early	3 (5.5)	--
Talked to others (negative)	3 (5.5)	--
Didn't put in general effort	2 (3.6)	--
Didn't participate	2 (3.6)	--
Didn't complete worksheet	2 (3.6)	--
Copied answers from others	2 (3.6)	--

<sup>a</sup>Although some codes are the same between the two environments, there may be slight differences in the type of responses included in each due to the different data collection formats. Details are included in Tables S1 & S4 in the Supporting Information.

One of the more common perceptions related to positive behavioral engagement was working on the worksheet. Students described many different actions related to working on the

worksheet, such as writing things down and reading the questions. Additionally, students talked about asking questions, staying focused, paying attention, being prepared for the activity, and participating as indications of behavioral engagement. Behavioral engagement was also perceived as working with other students. This included coded actions such as asking for feedback and/or assistance on problems and, in the remote environment, taking a leadership role in the group, sharing their screen over Zoom, and listening to others.

When students talked about disengagement, they would generally mention not working on the worksheet at all, doing or working on other things (e.g., other coursework, ALEKS, etc.), being distracted, and not asking questions. In the in-person environment, students also perceived specific actions as being related to behavioral disengagement such as using a phone or laptop (i.e., “device”) in class when not used for the activity and participating in off-topic conversations with fellow students. In the remote environment, the most prevalent perception of behavioral disengagement was the idea of simply “being there” in the Zoom meeting without doing anything. In both environments, students also perceived not working or interacting with the other group members as an aspect of behavioral disengagement. However, not all the students perceived working with others to be necessary for their own engagement, although they did mention that it was generally beneficial to work with others. For example, in an interview, one student said,

*“I mean, you can be on your own and doing it engaged. Just being in a group helps because you can share answers and point out mistakes.”*

The behavioral engagement definition provided to students during this study emphasized physical participation and involvement. Students’ perceptions of what constitutes behavioral engagement based on this definition closely matches behavioral engagement as described by Fredricks et al.,<sup>8</sup> which includes students’ positive conduct in the classroom, as well as “effort, persistence, concentration, attention, asking questions, and contributing to class discussion.” Many of the students’ perceptions of behavioral engagement included these aspects, which can be seen through the codes *tried to do the worksheet*, *focused/paid attention*, *asked questions*, and *talked to/worked with others*. Additionally, students’ perceptions of behavioral disengagement included concepts related to negative conduct, such as using a phone or working on other things.

### *Cognitive Engagement*

A total of 19 codes were found to relate to students' perceptions of cognitive engagement and disengagement across both environments (Table 4). The in-person and remote environments shared 8 similar codes, with 7 unique codes discovered in the in-person responses and 4 codes in the remote responses.

Overall, students perceived more aspects of cognitive engagement compared to disengagement in both environments. Specifically, when students were asked about cognitive engagement in the worksheet activities, they referred to the idea of trying to understand the material. This idea was often expanded on by students in the interviews by describing techniques they perceived as being related to cognitive engagement, including checking their work and understanding their mistakes. Students also described aspects related to thinking through how to solve the problems, going through problems step-by-step, and trying to connect material with prior course information, in addition to writing down extra notes (i.e., interacting with the worksheet) and using resources to help solve the problems. Students also perceived cognitive engagement in relation to working with other students to better understand the material, including discussing the worksheet with their peers and helping others.

Students' perceptions of cognitive disengagement centered around not contributing to the group (i.e., not discussing with or helping others), as well as not trying to understand the worksheet or material being covered and just writing the answers down on the worksheet without trying to understand how to actually solve the problems. Additionally, some students perceived disengagement as only doing the minimum required for the worksheets or giving up on trying to solve the problems. Overall, more students mentioned ideas related to positive cognitive engagement compared to cognitive disengagement. This suggests that students might have found it more difficult to conceptualize cognitive disengagement compared to cognitive engagement.

Students in this study were presented with a cognitive engagement definition that centered around trying to comprehend the skills and ideas present in the worksheets. Results from the coding indicated that students' perceptions of cognitive engagement align with the definition from Fredricks et al.,<sup>8</sup> which includes concepts related to students putting in mental effort to understand the material, as well as going above and beyond the minimum requirements. For example, many students perceived cognitive engagement as trying to understand the material. Additionally, codes such as *interacted with the worksheet* (e.g., wrote down extra notes,

read the worksheet thoroughly, etc.), *used resources* (to help them work through the problems), and *discussed with others*, suggest that students perceived cognitive engagement as doing more than what was required of them.

Table 4. Number of students that mentioned each cognitive code when provided with the cognitive definition of engagement.

Cognitive Codes <sup>a</sup>	Number of Students (%)	
	In-person Environment n = 57	Remote Environment n = 14
<b>Engagement</b>		
Tried to understand	15 (26.3)	12 (85.7)
Helped others	16 (28.1)	5 (35.7)
Checked work/answers	--	5 (35.7)
Discussed with others	9 (15.8)	4 (28.6)
Thought about how to solve problems	--	4 (28.6)
Interacted with worksheet	4 (7.0)	2 (14.3)
Put effort into learning	2 (3.5)	--
Tried to solve problems a different way	2 (3.5)	--
Used resources	1 (1.8)	4 (28.6)
Connected or applied material	1 (1.8)	3 (21.4)
Went through problems step-by-step	--	2 (14.3)
Tried their best/didn't give up	1 (1.8)	--
Learnt from and/or corrected mistakes	1 (1.8)	--
<b>Disengagement</b>		
Didn't try to understand	7 (12.3)	--
Just wrote down answers	5 (8.8)	6 (42.9)
Didn't discuss with others	4 (7.0)	1 (7.1)
Only did the minimum required	4 (7.0)	--
Didn't help others	--	1 (7.1)
Didn't try their best/gave up	3 (5.3)	--

<sup>a</sup>Although some codes are the same between the two environments, there may be slight differences in the type of responses included in each due to the different data collection formats. Details are included in Tables S2 & S5 in the Supporting Information.

### *Emotional Engagement*

Students' perceptions of emotional engagement were described by a total of 27 emotional engagement codes in the two environments (Table 5). Of these codes, 9 were similar between the two environments, 7 were unique to the in-person environment and 11 to the remote environment.

Table 5. Number of students that mentioned each emotional code when provided with the emotional definition of engagement.

Emotional Codes <sup>a,b</sup>	Number of Student Responses (%)	
	In-person Environment n = 58	Remote Environment n = 14
<b>Engagement</b>		
Positive feelings	6 (10.3)	9 (64.3)
Felt confident	--	10 (71.4)
Felt activity was beneficial	8 (13.8)	7 (50.0)
Liked/enjoyed the activity	4 (6.9)	6 (42.9)
Excited about activity	--	4 (28.6)
Wanted to learn	--	3 (21.4)
Liked chemistry/science	--	3 (21.4)
Didn't feel frustrated	1 (1.7)	2 (14.3)
Wanted to/liked working with others	--	3 (21.4)
Interested in content	2 (3.4)	--
Looked forward to activity	2 (3.4)	--
<b>Disengagement</b>		
Negative feelings	6 (10.3)	7 (50.0)
Felt activity wasn't beneficial	8 (13.8)	3 (21.4)
Felt self-doubt	--	6 (42.9)
Felt frustrated	3 (5.2)	5 (35.7)
Felt disconnected	--	4 (28.6)
Didn't want to learn	--	3 (21.4)
Didn't like/enjoy activity	5 (8.6)	2 (14.3)
Didn't like chemistry/science	1 (1.7)	2 (14.3)
Felt confused or discouraged	7 (12.1)	--
Didn't care about activity	3 (5.2)	--
Not interested in content	3 (5.2)	--
Didn't look forward to activity	1 (1.7)	--
Didn't want to do activity	1 (1.7)	--
Didn't want to/like working with others	--	1 (7.1)
Felt left behind/rushed	--	1 (7.1)
Felt bored	--	1 (7.1)

<sup>a</sup>Although some codes are the same between the two environments, there may be slight differences in the type of responses included in each due to the different data collection formats. Details are included in Tables S3 & S6 in the Supporting Information.

Overall, many students perceived emotional engagement as feeling like the activities were beneficial for their learning. Students also described feelings of confidence, especially when getting problems correct, and generic positive feelings, such as feeling “good”. Additionally, students perceived emotional engagement as wanting to learn, as well as wanting

to work with and/or help others in the group. Other positive feelings that students mentioned in relation to their perception of engagement were liking, enjoying, and being interested in the material/content, or chemistry and science in general. In the interviews, one student summed up many of these feelings by saying,

*“I actually really enjoy learning about chemistry. It can be super interesting at times, it can be really hard at times, but keeping that positive outlook on it – like, I really enjoy this topic – is important to be engaged.”*

Students perceived emotional disengagement as being related to negative (i.e., “not good”) feelings and self-doubt, as well as not feeling like the activity was beneficial or useful for learning the material, feeling confused and/or discouraged, and not liking or caring about the worksheet or activity. Students also described the idea of feeling disconnected with the material in relation to big picture ideas and how the content fit together

The idea of feeling frustrated also appeared in both environments, although student responses in the interviews indicated that some students may perceive frustration as disengagement, while others perceive it as positive engagement. For example, when talking about working through some of the problems, one student said that,

*“When I actually tried to do it, I was extremely frustrated and gave up multiple times.”*

This instance of frustration seems to indicate disengagement, as the student gave up when they felt frustrated. Although not engagement-specific, measures of emotional satisfaction with learning chemistry, which have included frustration as a negative component,<sup>20, 21</sup> have found that lower emotional satisfaction is related to lower student performance outcomes.<sup>20</sup> However, the idea that frustration always indicates disengagement was not universal throughout the interviews. In a different session, a student perceived frustration as an indicator of engagement,

*“I also think that if they're really engaged, sometimes they might not get the right answer, so they might feel frustrated. But that, that isn't a bad thing in my opinion. Because you can feel frustrated, but that could be a good type of frustration because you're, you just encountered a roadblock, but it's not ultimately preventing you from understanding the ideas. So you can feel frustrated, but it doesn't mean you aren't really engaged because you are engaged already by feeling frustrated because you only feel frustrated when you actually do the activity, because if you don't do that activity in the first place, then you can't really experience any feeling of frustration in the first place.”*



Some definitions of emotional engagement include the idea of positive and negative emotions being either activating or deactivating, where an activating emotion would increase engagement and a deactivating emotion would decrease engagement.<sup>9, 22</sup> From these interviews, it appears that although frustration may be a negative affective reaction, students may perceive it as deactivating or activating for engagement depending on how they approach frustration in the context of these worksheets. One study that looked at frustration intolerance (i.e., the inability to continue working on an activity based on negative feelings) found that frustration intolerance influenced college students' academic outcomes, such that students who were more willing to feel discomfort or frustration had higher performance outcomes.<sup>23</sup> Therefore, although how students handle frustration may be an important factor to consider for student achievement, frustration itself may not be a good indicator of students' emotional engagement in classroom worksheet activities due to potential differences in how students may perceive it in relation to engagement.

The Fredricks et al.<sup>8</sup> definition of emotional engagement centers around students' affective reactions and includes emotions such as value, "interest, boredom, happiness, sadness, and anxiety." Overall, students' perceptions of emotional engagement in these worksheet activities included many of these aspects, indicated through codes related to *felt activity was beneficial*, *interested in content*, and *felt bored*, for example. Additionally, although not specifically listed as examples in Fredricks et al.,<sup>8</sup> students perceived other affective reactions in relation to the worksheet, including *felt confident*, *excited about activity*, *felt self-doubt*, and *felt disconnected*.

### *Conflation of Behavioral and Cognitive Engagement*

Codes related to all three dimensions of engagement were identified throughout all short-answer responses and interview transcripts regardless of the definition students were provided. The prevalence of codes across definitions are provided in Tables S7 – S12 in the Supporting Information. Most students only mentioned emotional engagement codes when asked to describe engagement based on the emotional definition. However, more overlap was seen with the behavioral and cognitive codes across definitions in both the in-person and remote environments. When students were provided with the cognitive definition of engagement, they often mentioned ideas related to the behavioral dimension. For example, many students would indicate behavioral

aspects related to working with others, reading the question out loud, and asking for help/feedback. Similarly, when the behavioral definition was given, students would indicate ideas related to cognitive engagement codes (i.e., discussing the worksheet with their group, thinking through how to solve the problems, using resources, etc.). This overlap may indicate that students perceived cognitive and behavioral engagement to be very similar constructs when considering engagement at the activity-level.

As the different dimensions all assess engagement, they are inherently interconnected. However, it has been noted that the overlap between behavioral and cognitive engagement may make it difficult to clearly distinguish between these two dimensions. Specifically, an overlap between cognitive and behavioral engagement may be prevalent when cognitive engagement is perceived primarily through the lens of students' investment in their learning (e.g., putting effort into understanding the material, going above and beyond, etc.).<sup>9</sup> As 'putting in effort' can be perceived as both behavioral engagement (e.g., putting in effort by doing multiple examples) or cognitive engagement (e.g., putting in effort by trying hard to understand mistakes), there may be a lack of distinction between these two constructs that make them difficult to separate.<sup>8, 9</sup> Overlap between the two dimensions is also seen in one of the cognitive engagement frameworks. The ICAP framework<sup>5</sup> of engagement includes four levels, or modes, of cognitive engagement with respect to learning activities. Passive engagement is the lowest level followed by active and then constructive, with interactive as the highest mode. In this framework, each mode of cognitive engagement is defined through observing students' overt behaviors.<sup>5</sup> For example, if a student is listening to a lecture, they could just *passively* listen, *actively* take notes, *constructively* draw a concept map to connect ideas, or *interactively* discuss the material with a small group (see Table 1 in Chi & Wylie<sup>5</sup>). However, although these are characterized as indicators of cognitive engagement within the ICAP framework, the actions that indicate lower levels of cognitive engagement, such as listening and taking notes, also readily describe behavioral engagement as defined by Fredricks et al.<sup>8</sup> Therefore, when focused on evaluating engagement related to specific actions students take in relation to an activity, it may be more difficult to clearly delineate between which actions indicate behavioral or cognitive engagement.

### *Social Engagement*

One theme that appeared throughout all three dimensions of engagement was a social aspect. When talking about cognitive engagement, students also talked about discussion and collaboration with their group, including sharing ideas back and forth and helping others. Behaviorally, many students mentioned working with others and asking their group for feedback. Students also would refer to ideas related to liking or wanting to work with others when discussing emotional engagement. The idea of a social engagement dimension has previously been presented in a qualitative study conducted by Fredricks et al.,<sup>24</sup> who found the presence of a social component threaded throughout behavioral, cognitive, and emotional engagement dimensions when exploring middle- and high-school students' perceptions of engagement. They found that when students talked about engagement in their science classes, they included many social aspects related to sharing ideas and working together to solve problems.<sup>24</sup> Additionally, they found evidence for modeling social engagement as a separate, but related, dimension of engagement in a subsequent quantitative study.<sup>25</sup>

The idea of social engagement also appears in the ICAP framework, where the highest level of cognitive engagement, *interactive*, is defined as dialoguing between students where both make generative comments during the discussion.<sup>5</sup> This suggests that students are expected to work with each other in order to be cognitively engaged at the highest mode. Collaboration and working with others has been seen as an important component to students' engagement at the college level, especially when considering STEM students. One study noted that STEM students found that positive collaborative environments encouraged them to be more engaged,<sup>14</sup> while another study noted that STEM students were generally represented within a 'culture of engagement' that included collaboration and problem-solving with peers.<sup>26</sup>

Students in the interviews also noted that social interactions influenced their engagement. For example, when talking about their general engagement, one student stated that,

*“I would say my engagement almost is based off the group. So if you have a group that's willing to actually work together and put in the effort, then my engagement's great. I have no problem keeping up. I have no problem, you know, being invested in the activity. But if you have a group that's just going to sit there silently over Zoom, then I'll try and do the activity by myself and that's fine, but you definitely lose engagement very quickly that way.”*

This sentiment, along with the presence of social themes throughout all three dimensions of engagement, indicate that students perceived a social engagement dimension when participating in these activities.

### *Perceptions of Engagement by Activity Environment*

Results from one study completed immediately after the beginning of the Covid-19 pandemic found that students' perceptions about their engagement in class were influenced by the changes in environment and human interactions resulting from the shift from in-person to online learning.<sup>27</sup> Although in our study direct comparisons between in-person and remote environments cannot be made due to the differences in method and depth of data collection, it is worth noting some of the general similarities and differences in how students perceived engagement between the two environments. Many of the codes that were discovered were the same or very similar, which suggests that students perceived engagement similarly in both environments. For example, students from both environments discussed helping others, using resources, being prepared, and feeling like the activity was beneficial to their learning. Additionally, the overlap of perceptions related to both behavioral and cognitive engagement was found in both environments. This suggests that students conflated behavioral and cognitive engagement regardless of whether the activity was completed in-person or remotely.

There were also some codes that only appeared in one environment. Although some of these differences in codes may be due to the different methods of data collection, there are some inherent aspects to the environments that may have facilitated some of the differences. For example, leaving class early may be more obvious to others when physically in a classroom and, in the remote environment, students may have felt more comfortable reading questions out loud to themselves since other students couldn't hear them, whereas it might have been considered distracting in the in-person environment. Additionally, some of the different codes were related to their interactions with other students, which was an inherently different experience in the two environments. For example, in the remote environment it is often difficult for people to have side conversations with a subset of group members since only one person can effectively talk at a single time over Zoom, which may have made off-topic conversations between just a couple people less likely to occur. For similar reasons, having a person step up as "group leader", sharing screens with each other, and listening to others may have been more important to

engagement in the remote setting. These differences indicate that although social engagement may be an important aspect for students in both environments, how students perceive social engagement in these environments may vary slightly. For example, one student summarized how their interactions with peers in a general classroom had changed with the switch to remote instruction and how that influenced the social situation,

*“In a [in-person] class setting, you find that one buddy. And if that, if you and that one buddy can go make other friends, that’s great! But you don’t have a time, you don’t have a chance online to find that one buddy. And then maybe find another pair of buddies that you’re also able to communicate with in that small group. Because when I go into a breakout room and it’s six strangers, I can’t, I can’t be the first one and be like, ‘Hey guys, what’s up?’”*

## **Conclusions**

This study explored students’ perceptions of behavioral, cognitive, and emotional engagement in relation to worksheet activities completed in a general chemistry course. The results indicated that students perceived a variety of positive and negative aspects of behavioral, cognitive, and emotional engagement to be present during the worksheet activities in both in-person and remote learning environments; however, there were some overlaps between how students perceived behavioral and cognitive engagement. These overlaps may indicate a lack of distinction between the two dimensions of engagement when focusing on the worksheet-based activities. Studies that have quantitatively measured multiple dimensions of engagement in middle-school aged students have found evidence for both separating behavioral and cognitive dimensions,<sup>25</sup> as well as combining the two to create a single “behavioral & cognitive” dimension.<sup>28</sup> One of the differences between these two studies was the focus of the measures. In the study completed by Wang et al.<sup>25</sup>, where the behavioral and cognitive dimensions remained separate, students were asked about their engagement in relation to their science class. However, in the study by Ben-Eliyahu et al.,<sup>28</sup> students were asked about their engagement related to specific science activities and the results indicated the presence of a combined dimension. Additionally, a recent quantitative study by Naibert and Barbera in higher-education, which assessed student engagement in active learning activities of general chemistry students, found further evidence for combining behavioral and cognitive engagement into a combined

behavioral/cognitive dimension.<sup>29</sup> The results of our qualitative and quantitative studies provide support for students' perceiving a large overlap between behavioral and cognitive engagement when asked specifically to think about the specific activities. Therefore, it may be that students conflate the two dimensions when the focus is on engagement in a specific activity instead of the class as a whole.

The results from this study also provided support for the existence of a social engagement dimension. Throughout all three dimensions of engagement (behavioral, cognitive, and emotional), students mentioned social aspects such as working with other students, including discussion, asking for feedback, and wanting to work with others. In other studies, collaboration with peers has been included as an indicator of higher student engagement in learning activities<sup>5</sup> and has been found to be one of the defining aspects of the 'culture of engagement' seen in STEM courses.<sup>26</sup> Ideas related to social engagement have also been discovered in qualitative studies of middle- and high-schoolers' perceptions of engagement in their science classes,<sup>24</sup> where the presence of a social engagement dimension centered around students' interactions with others in the classroom and a willingness to invest in those relationships was further supported during a subsequent quantitative study.<sup>25</sup> Results from our study supported the presence of a similar social engagement dimension, as students would talk about their interactions with their group members (i.e., having discussions, helping their group members, etc.), as well as ideas related to *wanting* to work with other students and help them understand the material.

Responses from the in-person and remote environments indicated that students perceived behavioral, cognitive, and emotional engagement to be similar between the two environments. For example, students from both environments perceived engagement as trying to understand the material, helping others, staying focused, and liking/enjoying the activity. However, there were some differences in how students perceived engagement in the worksheet activities between the two environments, specifically related to social interactions (i.e., social engagement). For example, students' perceived disengagement in the in-person environment included participating in off-topic conversations, whereas in the remote environment disengagement was viewed as simply "being there" in the Zoom meeting. Many of the aspects that students found important in only one environment could have been due to the inherently different experience the two environments had to offer in terms of interacting with others (i.e., face-to-face vs. over a computer screen).

## **Limitations**

One of the limitations of this study was that data were collected from a single institution and in relation to worksheet activities developed for a single course. Although data saturation was reached when coding responses from both types of environments, collecting data from other institutions, courses, and/or types of active learning activities would provide more generalizable insights into how students perceive engagement in active learning classrooms. Additionally, the data only included responses from students who self-selected to participate in the short-response survey or interviews; therefore, it is unknown if the results encompass the perceptions of all students in the course or those of varying engagement levels. Although students' perceptions of activity-level engagement within the in-person and remote environments were reported, direct comparisons cannot be made due to the differences in the data collection methods employed.

## **Implications for Research**

This study aimed to explore how students perceived engagement in worksheet activities implemented in the PSU general chemistry course. Although the results provided evidence that students' perceive engagement similarly to the definitions provided by Fredricks et al.,<sup>8</sup> this may not be the case for every student population, learning environment, or active learning activity. Therefore, future work may benefit from collecting qualitative data about students' perceptions of engagement in other environments through the use of open-ended surveys, focus groups, or interviews.

One of the major findings of this study was the conflation in how students perceive behavioral and cognitive engagement. This finding, combined with support from our quantitative study,<sup>29</sup> implies that these two dimensions of engagement cannot be measured and evaluated separately. Therefore, it is suggested that future studies combine these dimensions when seeking to evaluate students' engagement in learning activities. Although an overlap between these two dimensions has been noted in literature definitions,<sup>8,9</sup> further studies are needed to understand why students might perceive behavioral and cognitive engagement similarly in these types of active learning activities. As studies at the middle-school level have found evidence for modeling behavioral and cognitive engagement as separate constructs when asking students about class-level engagement,<sup>25</sup> as well as for modeling behavioral and cognitive engagement as a single

construct when asking about activity-level engagement,<sup>28</sup> investigating student perceptions of engagement at various levels of focus (e.g., activity-specific, class-specific, etc.) could provide information about whether students perceive there to be more distinction between the two dimensions when focused on engagement in the course as a whole.

Another major finding of this study was support for the presence of a social engagement dimension, suggesting that students perceived social interactions and relationships to be an important factor in their engagement in the worksheet activities. Collaboration and working with other students have been noted previously as being an important aspect to students' engagement.<sup>5, 25, 26</sup> Therefore, future studies into students' engagement may benefit from considering the presence of a possible social engagement dimension. Additionally, further research into how students perceive social engagement in different active learning activities and/or the class in general may provide more insight into the importance of a social dimension in different environments and focuses of engagement.

### **Implications for Practice**

Although results from this study indicated that students perceived behavioral, cognitive, and emotional engagement to be similar to the literature definitions of these dimensions, specific indicators of engagement may vary between different student populations and environments. For example, the data from the remote environment suggested that some students felt that sharing their screen was an aspect of engagement. Therefore, providing students with the ability to share their screen over Zoom may have encouraged students to engage more. Similarly, instructors may gain useful information about how to better engage their students in the material by asking their students for feedback on how they perceive engagement in a class or activity through the use of open-ended surveys, focus groups, or interviews.

### **ASSOCIATED CONTENT**

#### **Supporting Information**

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.XXXXXXX. [ACS will fill this in.] Code descriptions and examples, coding results (DOCX)

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## Notes

The authors declare no competing financial interest.

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Supporting Information for  
**Exploring Student Perceptions of Behavioral, Cognitive, and Emotional Engagement at the  
Activity Level in General Chemistry**

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## Student engagement codes from the in-person environment

Tables S1-S3 include the codes, descriptions, and example texts that comprised the codebook when coding the short-answer responses.

Table S1. Behavioral engagement codes, descriptions, and examples segments from short-answer responses. Key words and phrases are bolded.

Code	Description	Example from responses
Asked questions	asked questions in general can include: to TA, LA, or instructor must not include: to other group members	<b>Asking questions</b> when they don't understand.
Worked on worksheet	actively worked on worksheet did worksheet	<b>only doing...the worksheet</b>
Focused/paid attention	includes: not distracted	I would describe someone who was very engaged in the worksheet activities as <b>someone who was focused, present</b>
Tried to do worksheet	tried to do the worksheet put effort into doing the worksheet must not include: understanding, etc.	as a good student, who is <b>trying to do what is asked of the</b>
Completed worksheet		<b>completing the worksheet assignment.</b>
Was prepared		A student who is very engaged <b>comes to class prepared with the information by reading the appropriate chapters. They review the activity before coming to class.</b>
Worked with others	only includes: worked with others does not include: talked, discussed, etc.	Someone who... <b>works in groups</b>
Asked for group feedback	asked for feedback from group members asked questions to group members asked group members for help	The student... <b>seeks feedback from</b> the mentors and <b>peers.</b>
Participated		Someone who <b>actively participates</b>
Engaged with others		Someone who is active (asking questions, <b>engaging classmates</b> , and doing the presented work).
Talked to others (positive)	talked to group members but does not specify type of conversation only coded for responses to item related to a <i>very engaged</i> student	<b>talking with classmates</b>
Put in effort	put in effort but does not specify into what (e.g., doing the worksheet, understanding the material, etc.) also includes: tried, etc.	A very engaged student is one who stays completely focused on the task at hand and aims to understand the topics of the activity to the best of their ability <b>while giving full effort..</b>
Was on a non-class related device	was on a teach device (e.g., phone, laptop, etc.) not related to activity	<b>sits on phone the whole time.</b>
Didn't work on worksheet	didn't actively work on worksheet didn't do worksheet	<b>Not working on the worksheet</b>
Worked on other things	worked on a different assignment or class	<b>doing other activities.</b>
Distracted	includes: not focused, not paying attention	<b>distracted</b>
Didn't try to do worksheet	didn't put effort into doing worksheet didn't try to do worksheet must not include: not understanding, etc.	The student <b>does not attempt the worksheet</b>
Participated in off-topic conversations		They are... <b>chatting with their friends without doing the worksheet.</b>

Didn't work with others	didn't work with others didn't work in a group does not include: didn't talk, didn't discuss, etc.	A student who <b>does not...work on it with other students.</b>
Didn't ask questions	didn't ask questions in general can include: to TA, LA, or instructor must not include: to other group members	<b>do not ask questions</b>
Left class early		<b>Leaving class early</b>
Wasn't prepared	Includes: not bringing the worksheet to class	<b>not bringing a copy of the worksheet</b>
Talked to others (negative)	talked to group members but does not specify type of conversation only coded for responses to item related to a <i>not engaged</i> student	Not doing the worksheet and just doing other things or <b>talking</b>
Didn't put in effort	didn't put in effort but does not specify into what (e.g., doing the activity, understanding the material, etc.) also includes: didn't try, etc.	Someone who <b>doesn't give any effort to the activity.</b>
Didn't participate		Somebody who <b>doesn't...otherwise participate in the activity.</b>
Didn't complete worksheet		A student who <b>does not complete the worksheet.</b>
Copied answers from others	copied answers from group members	A student who is not engaged will <b>passively write answers their group members come up with.</b>

Table S2. Cognitive engagement codes, descriptions, and examples segments from short-answer responses. Key words and phrases are bolded.

Code	Description	Example from responses
Helped others	helped group members taught group members provided feedback to group members	A person that is <b>helping everyone around them with the worksheet</b>
Tried to understand	tried to understand put effort into understanding	<b>trying to understand the material.</b>
Discussed with others	discussion with group members communicated with group members includes: collaboration or talking with group members about the worksheet, sharing ideas with group members, etc.	A student who does all the exercises and <b>discusses them with the students around them.</b>
Interacted with worksheet	e.g., read through worksheet, wrote down notes, studied worksheet, etc.	Someone who... <b>took specific notes to later put on their sheet for the final</b>
Put effort into learning	put effort into learning the material tried to learn the material	Someone who...is <b>trying to learn the content</b>
Learnt from and/or corrected mistakes		Somebody who... <b>strives to correct any mistakes made on the paper.</b>
Tried to solve problems a different way		<b>trying to solve the problem a different way.</b>
Used resources	used resources to help with worksheet (can include: previous notes, internet, book, worksheet models, etc.)	<b>using phone to find information that they may need to complete the activity</b>
Connected or applied material	...to previous or future course material, to other classes, to real-life, etc.	they would rather take the time to complete the worksheet <b>to learn and understand how it can be applied to real-life scenarios or problems seen on the test</b> instead of completing the worksheet to get it done.
Tried their best/didn't give up	tried their best when the worksheet was difficult didn't give up when it was difficult	Also a student who seeks for help when stuck <b>instead of giving up.</b>
Did more than the minimum	i.e., went beyond simply doing the activity	<b>Going out of their way for activity</b>
Made sure everyone understood	made sure everyone had the answer and/or understood the material	who solved the worksheet with all members and <b>make sure everyone understand</b>
Didn't try to understand	didn't try to understand didn't put effort into understanding	<b>not trying to understand concepts and equations</b>
Just wrote down answers	i.e., filled out or did worksheet without trying to understand includes: just looked up the answers	<b>only writing down the answers.</b>
Didn't discuss with others	didn't discuss with group members includes: didn't collaborate, didn't contribute, didn't talk, etc. with group members	<b>The student doesn't</b> put a lot of efforts in doing or <b>collaborating with others</b> to complete the worksheets.
Only did the minimum required	only did the minimum needed for the class i.e., only did clicker questions	Someone who... <b>is just there to get clicker participation credit.</b>
Didn't try their best/gave up	didn't try their best when the worksheet was difficult gave up when it was difficult	<b>giving up on the problem just to move on to the next one</b>
Didn't put effort into learning	didn't put effort into learning the material didn't try to learn the material	Someone that <b>does not...put any effort in learning the materials.</b>

Table S3. Emotional engagement codes, descriptions, and examples segments from short-answer responses. Key words and phrases are bolded.

Code	Description	Example from responses
Felt activity was beneficial	felt the activity was beneficial or useful for learning (i.e., valuable, etc.)	A person who <b>thinks the worksheets are important to understanding the concept</b>
Positive feelings	positive feelings in general (e.g., good)	Did all of the problems with a <b>positive attitude throughout the process.</b>
Liked/enjoyed the activity	liked the activity enjoyed the activity (e.g., had fun) must be specific to the worksheet or activity (not chemistry or science in general)	A student <b>who really likes the worksheets</b> would be engaged.
Interested in content	interested in specific content or topics covered on worksheet	someone <b>who finds the topic very interesting</b>
Looked forward to activity	looked forward to the activity excited about the activity	<b>those who actually look forward to activity days.</b>
Didn't feel frustrated	includes: not frustrated, not overwhelmed	<b>not feel overwhelmed or frustrated</b> by the assignment
Liked working with others	Includes: interested in working with others	<b>They are interested in teamwork.</b>
Felt activity wasn't beneficial	felt the activity was not beneficial or useful for learning (i.e., not valuable, etc.)	Someone who <b>views the worksheets as a waste of time or not worth even attempting to complete.</b>
Felt confused or discouraged	includes: had a hard time, struggling	Someone is not grasping the material fully <b>and is too confused to know where to start</b>
Negative feelings	negative feelings in general (e.g., bad)	<b>Not having good feelings towards worksheet</b>
Didn't like/enjoy activity	didn't like the activity didn't enjoy the activity must be specific to the worksheet or activity (not chemistry or science in general)	A student <b>who really dislikes the worksheets</b> would not be engaged.
Didn't care about activity	didn't care about doing the worksheet or activity	A student <b>who doesn't care about the worksheets</b>
Not interested in content	not interested in specific content or topics covered on worksheet	someone <b>who is not interested in the topic</b>
Felt frustrated	includes: frustrated, overwhelmed	<b>being frustrated</b> and not doing anything about it.
Didn't like chemistry/science	didn't like chemistry or science can also include: not excited, not interested, etc. must be directed toward the subject/field in general	<b>they just don't like chemistry as much as others.</b>
Didn't look forward to activity	also includes: not excited to do activity	<b>someone who doesn't...look forward to doing them in class.</b>
Didn't want to do activity		Someone who is <b>not wanting to work on them</b>
Didn't like working with others		Maybe <b>they don't like teamwork</b>

## Student engagement codes from the remote environment

Tables S4-S6 include the codes, descriptions, and example segments that comprised the codebook when coding the interview transcripts.

Table S4. Behavioral engagement codes, descriptions, and examples segments from interview transcripts. Key words and phrases are bolded.

Code	Description	Example from transcript
Wrote things down	includes: on paper or on computer	I feel like everyone that is engaging in it <b>writes down</b> ...so I'll just like, if it's like a math one then I'll <b>write out the equation</b> ...
Talked to/worked with others	must include: some kind of interaction with group members (e.g., talked to, used chat function, worked with, etc.) does not include: discussion or collaboration, etc. to solve problems on worksheet	...you're <b>talking and working on it with other people</b> .
Read question to self	read question out loud to self	I would say an engaged student would probably...they would just <b>read it out loud</b> .
Focused/paid attention	includes: not distracted	...you're <b>paying attention</b> , there's <b>no other distractions</b> .
Worked on worksheet	actively worked on worksheet did worksheet	One being that we're active, we're <b>doing the worksheet</b> ...
Tried to do worksheet	tried to do the worksheet put effort into doing the worksheet must not include: understanding, etc.	...I just <b>try to work through</b> what I can...
Asked for group feedback	asked for feedback from group members asked questions to group members asked group members for help	I'll voice out my reasons, say, "oh <b>I need help</b> . You know, can someone help me." And that's just how I've been doing it. You know, I just <b>try to get feedback from other people</b> .
Led the group	took actions related to keeping the group on task, directing the group, etc.	...a lot of times my priority...is to <b>make sure that the group is on the same page</b> ...I have tried to <b>ensure that we're all on, at least on the same point</b> , even if we're not all talking...
Was prepared		...what it really comes down to is...you got to <b>be prepared</b> .
Participated		...someone who is actively <b>participating</b> ...
Asked questions	asked questions in general can include: to TA, LA, or instructor must not include: to other group members	...then you <b>ask your question</b> ...
Shared screen	shared their screen to group	I would say a good example of that is probably someone or two...but usually one person <b>sharing their screen</b> .
Listened to others		...there was one time where I just got stuck and I think I just kinda stopped talking and <b>just listen</b> ...
Just "there"	e.g., just listened, not writing things down, not thinking about things, camera/mic off, etc.	They're <b>just there</b> . ...if I was not engaging physically or physically participating, I would probably <b>never write things down</b> ...I would probably <b>never like even flip a page in my notebook</b> ... ...I'm <b>just going to sit here and be here</b> ...



Distracted	i.e., distracted actions (on phone, etc.) not including doing other work includes: not focused, not paying attention	I would be <b>doodling</b> on the sheet <b>daydreaming</b> . ...I'll be <b>on my phone</b> ...
Worked on other things	worked on a different assignment or class	...you're actually <b>working on a different assignment</b> from a different class.
Didn't try to do worksheet	must not include: not understanding, etc.	...I <b>don't try to do the activity</b> ...
Didn't work on worksheet	didn't actively work on worksheet didn't do worksheet	...just <b>not doing it</b> .
Didn't ask questions	didn't ask questions in general	I would probably <b>never</b> even... <b>ask a question</b> , I guess, <b>to anybody</b> .
Wasn't prepared		Probably <b>not bother reading any of the textbooks</b> ...
Didn't talk to/work with others	didn't talk to group members (e.g., quiet) didn't work with group members didn't interact with group members (e.g., didn't use chat function, etc.)	Someone that's <b>quiet, not looking to talk to other people</b> .
Didn't lead the group	didn't take actions related to keeping the group on task, directing the group, etc.	...I might <b>not be exactly the one that's leading</b> ...

Table S5. Cognitive engagement codes, descriptions, and examples segments from interview transcripts. Key words and phrases are bolded.

Code	Description	Example from transcript
Tried to understand	tried to understand put effort into understanding	... <b>making sure that I understand</b> the content fully.
Checked work/answers	checked answers (okay if checked with other group members) tried to find mistakes tried to understand mistakes	So that would just include specifically...going over what you've already done on it, <b>trying to find an error</b> . We'll <b>go over answers</b> .
Thought about how to solve problems		I suppose usually what I do is I try to <b>think about</b> kind of very briefly, like, what am I, <b>what's the general story</b> of the question, but very quickly I go to, what are the numbers that, what are they, which answer do they want? Uh, or I don't even want to put it like that. <b>What answer is being sought and what are the initial pieces of information that are actually pertinent to that?</b>
Discussed with others	includes: discussion, collaboration, sharing ideas, bouncing ideas, etc. with group members	I just try to <b>bounce back ideas back and forth</b> just to get a common understanding of what's going on. ...just <b>discussion, discussing with other people</b> about the question.
Helped others	helped group members understand provided feedback to group members answered group members questions	<b>I assist others</b> if they have trouble.
Interacted with worksheet	e.g., took down extra notes, wrote down extra details, etc.	I would just be <b>really detailed in my notation</b> to prove that I'm really <b>interacting with the material</b> .
Used resources	used resources when working on worksheets (can include: previous notes, internet, book, worksheet models, etc.)	So I usually <b>refer back to the notes</b> that we took on the lecture day...occasionally I'll <b>open my book</b> ... <b>I look stuff up on the internet on the activities</b> and stuff...
Went through problems step-by-step		I like to like read the question out loud and then kind of <b>go step by step through it</b> .
Connected or applied material	...to previous or future course material, to other classes, to real-life, etc.	...I'm trying to <b>connect it to past topics</b> that we went over.
Just wrote down answers	i.e., filled out or did worksheet without trying to understand.	I could <b>write down other people's answers</b> if I wasn't engaged...like just <b>going through the worksheet not understanding</b> .
Gave up		...they might try to do one problem and then they <b>give up</b> ...
Didn't discuss with others	didn't discuss, collaborate, share ideas, bounce ideas, etc. with group members	We <b>wouldn't be building a conversation</b> at all.
Didn't help others	didn't help group members didn't provide feedback to group members	... <b>not...trying to answer them [other's questions]</b> .

Table S6. Emotional engagement codes, descriptions, and examples segments from interview transcripts. Key words and phrases are bolded.

Code	Description	Example from transcript
Felt confident	confidence empowered emotions related to getting answers correct	...it feels good to...get things right, you know, and like positive feedback, if you get one thing right, you're <b>more confident</b> that you can get the next thing right.
Positive feelings	positive feelings in general (e.g., good)	...almost just like <b>a good feeling</b> , just like you're doing <b>something good and positive</b> and, you know, adding to yourself or what you're doing for that day.
Felt activity was beneficial	felt the activity was beneficial or useful for learning (i.e., valuable)	I do like when <b>it helps me understand the concept more</b> .
Wanted to learn		<b>I want to learn</b> and be able to absorb this stuff.
Wanted to/liked working with others	a desire to work with others or an enjoyment of working with others includes: liked working with others, wanted to work with others, interested in working with others, etc.	...I just <b>want to</b> , you know, <b>talk to everyone</b> ...
Wanted to help others	wanted to help group members wanted to make sure all group members understood the material	I think an engaged person is someone that's <b>really eager to help others</b> .
Liked/enjoyed the activity	liked the activity enjoyed the activity (e.g., had fun) must be specific to the worksheet or activity (not chemistry or science in general)	...if someone's like, yeah, <b>this is fun. I like it</b> .
Liked chemistry/science	liked chemistry or science can also include: enjoyed, interested, etc. must be directed toward the subject/field in general	I actually <b>really enjoy learning about chemistry</b> .
Didn't feel frustrated	includes: not frustrated, not stressed	<b>Not</b> so much <b>stressed out</b> ...
Excited about activity	excited/enthusiastic about activity can also include: being excited about learning through the activity	I think engagement is...kind of like <b>enthusiasm</b> , really.
Interested in content	interested in specific content or topics covered on worksheet	And <b>I think it's [the content] interesting</b> too...
Felt self-doubt	doubt not empowered emotions related to getting answers incorrect	I have like a feedback loop that happens, where your...thought process starts getting really negative and <b>self-doubting</b> and deprecating.
Negative feelings	negative feelings in general (e.g., bad)	...if you're feeling <b>negative, pessimistic</b> .

Felt frustrated	includes: frustrated, stressed	...I was extremely <b>frustrated</b> .
Felt disconnected	felt disconnected in relation to the activity or material/content must not be related to working with others	...where I feel like I'm <b>untethered</b> and so I <b>don't know where to put that information</b> and I <b>don't know where that fits in</b> with the rest of it.
Didn't want to learn		...you <b>don't want to actually learn</b> how to do it, how to get the answer, how to get the right answer.
Didn't want to/like working with others	didn't want to work with others didn't like working with others can include: wanted to/liked to work on their own	<b>They don't want to work with others.</b>
Felt activity wasn't beneficial	felt the activity wasn't beneficial or useful for learning (i.e., not valuable)	...personally I feel, if <b>I feel like the learning is already</b> , I would say <b>sufficient</b> ...I would probably...be more prone to not engage...
Felt left behind/rushed		...you definitely <b>feel a little bit rushed</b> .
Didn't like/enjoy the activity	didn't like the activity didn't enjoy the activity must be specific to the worksheet or activity (not chemistry or science in general)	...you <b>don't like</b> what you're doing [the activity]...
Didn't like chemistry/science	didn't like chemistry or science can also include: not excited, not interested, etc. must be directed toward the subject/field in general	So like with <b>chemistry</b> , I'm like, <b>it's not what I'm excited to learn</b> but I'm here.
Felt bored		Feeling <b>bored</b> , like a strong feeling of <b>boredom</b> probably.
Not interested in content	not interested in specific content or topics covered on worksheet	...that would probably just, that would include... <b>not being as interested</b> in why a particular answer is incorrect.

### Coding results from the in-person environment

Tables S7-S9 include the number of students whose responses aligned to each code when students were asked to describe VERY engaged and NOT engaged students in the context of the worksheet activities through short-answer responses.

Table S7. Number of students that mentioned each behavioral engagement code when asked to describe students who were VERY engaged and NOT engaged in the worksheet activities relative to a specific definition of engagement (i.e., behavioral, cognitive, emotional).

Behavioral Code	Number of Students (%)		
	Engagement definitions given		
	Behavioral, n = 55	Cognitive, n = 57	Emotional, n = 58
<b>Engagement</b>			
Asked questions	21 (38.2)	21 (36.8)	11 (19.0)
Worked on worksheet	13 (23.6)	16 (28.1)	5 (8.6)
Focused/paid attention	8 (14.5)	9 (15.8)	10 (17.2)
Tried to do worksheet	8 (14.5)	8 (14.0)	10 (17.2)
Completed worksheet	8 (14.5)	8 (14.0)	6 (10.3)
Was prepared	8 (14.5)	2 (3.5)	0 (0.0)
Worked with others	6 (10.9)	2 (3.5)	5 (8.6)
Asked for group feedback	5 (9.1)	4 (7.0)	2 (3.4)
Participated	5 (9.1)	2 (3.5)	3 (5.2)
Engaged with others	3 (5.5)	1 (1.8)	2 (3.4)
Talked to others (positive)	2 (3.6)	3 (5.3)	2 (3.4)
Put in general effort	2 (3.6)	0 (0.0)	3 (5.2)
<b>Disengagement</b>			
Was on a non-class related device	19 (34.5)	15 (26.3)	8 (13.8)
Didn't work on worksheet	18 (32.7)	17 (29.8)	12 (20.7)
Worked on other things	8 (14.5)	11 (19.3)	4 (6.9)
Distracted	6 (10.9)	12 (21.1)	5 (8.6)
Didn't try to do worksheet	6 (10.9)	8 (14.0)	5 (8.6)
Participated in off-topic conversations	6 (10.9)	5 (8.8)	5 (8.6)
Didn't work with others	6 (10.9)	2 (3.5)	4 (6.9)
Didn't ask questions	4 (7.3)	3 (5.3)	0 (0.0)
Left class early	3 (5.5)	3 (5.3)	4 (6.9)
Wasn't prepared	3 (5.5)	3 (5.3)	0 (0.0)
Talked to others (negative)	3 (5.5)	1 (1.8)	0 (0.0)
Didn't put in general effort	2 (3.6)	6 (10.5)	8 (13.8)
Didn't participate	2 (3.6)	2 (3.5)	1 (1.7)
Didn't complete worksheet	2 (3.6)	2 (3.5)	1 (1.7)
Copied answers from others	2 (3.6)	2 (3.5)	1 (1.7)

Table S8. Number of students that mentioned each cognitive engagement code when asked to describe students who were VERY engaged and NOT engaged in the worksheet activities relative to a specific definition of engagement (i.e., behavioral, cognitive, emotional).

Cognitive Code	Number of Students (%)		
	Engagement definitions given		
	Behavioral, n = 55	Cognitive, n = 57	Emotional, n = 58
<b>Engagement</b>			
Helped others	6 (10.9)	16 (28.1)	10 (17.2)
Tried to understand	3 (5.5)	15 (26.3)	7 (12.1)
Discussed with others	14 (25.5)	9 (15.8)	6 (10.3)
Interacted with worksheet	1 (1.8)	4 (7.0)	2 (3.4)
Put effort into learning	2 (3.6)	2 (3.5)	4 (6.9)
Learnt from and/or corrected mistakes	3 (5.5)	1 (1.8)	0 (0.0)
Tried to solve problems a different way	0 (0.0)	2 (3.5)	0 (0.0)
Used resources	1 (1.8)	1 (1.8)	0 (0.0)
Connected or applied material	0 (0.0)	1 (1.8)	2 (3.4)
Tried their best/didn't give up	0 (0.0)	1 (1.8)	2 (3.4)
Did more than the minimum	1 (1.8)	0 (0.0)	2 (3.4)
Made sure everyone understood	4 (7.3)	0 (0.0)	0 (0.0)
<b>Disengagement</b>			
Didn't try to understand	3 (5.5)	7 (12.3)	2 (3.4)
Just wrote down answers	2 (3.6)	5 (8.8)	4 (6.9)
Didn't discuss with others	2 (3.6)	4 (7.0)	2 (3.4)
Only did the minimum required	0 (0.0)	4 (7.0)	0 (0.0)
Didn't try their best/gave up	0 (0.0)	3 (5.3)	1 (1.7)
Didn't put effort into learning	2 (3.6)	0 (0.0)	2 (3.4)

Table S9. Number of students that mentioned each emotional engagement code when asked to describe students who were VERY engaged and NOT engaged in the worksheet activities relative to a specific definition of engagement (i.e., behavioral, cognitive, emotional).

Emotional Code	Number of Students (%)		
	Engagement definitions given		
	Behavioral, n = 55	Cognitive, n = 57	Emotional, n = 58
<b>Engagement</b>			
Felt activity was beneficial	1 (1.8)	0 (0.0)	8 (13.8)
Positive feelings	0 (0.0)	0 (0.0)	6 (10.3)
Liked/enjoyed the activity	0 (0.0)	0 (0.0)	4 (6.9)
Interested in content	0 (0.0)	0 (0.0)	2 (3.4)
Looked forward to activity	0 (0.0)	0 (0.0)	2 (3.4)
Didn't feel frustrated	0 (0.0)	0 (0.0)	1 (1.7)
Liked working with others	1 (1.8)	0 (0.0)	0 (0.0)
<b>Disengagement</b>			
Felt activity wasn't beneficial	0 (0.0)	1 (1.8)	8 (13.8)
Felt confused or discouraged	1 (1.8)	2 (3.5)	7 (12.1)
Negative feelings	0 (0.0)	0 (0.0)	6 (10.3)
Didn't like/enjoy activity	0 (0.0)	0 (0.0)	5 (8.6)
Didn't care about activity	3 (5.5)	0 (0.0)	3 (5.2)
Not interested in content	1 (1.8)	0 (0.0)	3 (5.2)
Felt frustrated	0 (0.0)	0 (0.0)	3 (5.2)
Didn't like chemistry/science	0 (0.0)	0 (0.0)	1 (1.7)
Didn't look forward to activity	0 (0.0)	0 (0.0)	1 (1.7)
Didn't want to do activity	0 (0.0)	0 (0.0)	1 (1.7)
Didn't like working with others	1 (1.8)	0 (0.0)	0 (0.0)

### Coding results from the remote environment

Tables S10-S12 include the number of students that mentioned ideas related to each code when students were asked to describe engaged and not engaged students in the context of the worksheet activities during interviews.

Table S10. Number of students that mentioned each behavioral engagement code when provided the specific definitions of engagement (i.e., behavioral, cognitive, emotional).

Behavioral Code	Number of students (%), n = 14			
	Overall <sup>a</sup>	Engagement definitions given		
		Behavioral	Cognitive	Emotional
<b>Engagement</b>				
Wrote things down	11 (78.6)	11 (78.6)	3 (21.4)	0 (0.0)
Talked to/worked with others	8 (57.1)	4 (28.6)	6 (42.9)	0 (0.0)
Read question to self	8 (57.1)	3 (21.4)	6 (42.9)	0 (0.0)
Focused/paid attention	6 (42.9)	5 (35.7)	2 (14.3)	0 (0.0)
Worked on worksheet	8 (57.1)	7 (50.0)	3 (21.4)	2 (14.3)
Tried to do worksheet	4 (28.6)	2 (14.3)	2 (14.3)	2 (14.3)
Asked for group feedback	5 (35.7)	2 (14.3)	4 (28.6)	0 (0.0)
Led the group	5 (35.7)	0 (0.0)	5 (35.7)	1 (7.1)
Was prepared	5 (35.7)	4 (28.6)	1 (7.1)	0 (0.0)
Participated	4 (28.6)	3 (21.4)	1 (7.1)	0 (0.0)
Asked questions	3 (21.4)	2 (14.3)	1 (7.1)	0 (0.0)
Shared screen	3 (21.4)	3 (21.4)	0 (0.0)	0 (0.0)
Listened to others	1 (7.1)	1 (7.1)	0 (0.0)	0 (0.0)
<b>Disengagement</b>				
Just “there”	12 (85.7)	10 (71.4)	6 (42.9)	0 (0.0)
Distracted	9 (64.3)	9 (64.3)	4 (28.6)	0 (0.0)
Worked on other things	10 (71.4)	6 (42.9)	4 (28.6)	3 (21.4)
Didn’t talk to/work with others	8 (57.1)	4 (28.6)	3 (21.4)	1 (7.1)
Didn’t try to do worksheet	7 (50.0)	5 (35.7)	1 (7.1)	1 (7.1)
Didn’t work on worksheet	6 (42.9)	3 (21.4)	2 (14.3)	2 (14.3)
Didn’t ask questions	3 (21.4)	1 (7.1)	2 (14.3)	0 (0.0)
Wasn’t prepared	2 (14.3)	1 (7.1)	1 (7.1)	0 (0.0)
Didn’t lead the group	1 (7.1)	0 (0.0)	1 (7.1)	0 (0.0)

<sup>a</sup>Number of students who mentioned code at least once during the three definitions.



Table S11. Number of students that mentioned each cognitive engagement code when provided the specific definitions of engagement (i.e., behavioral, cognitive, emotional).

Cognitive Code	Number of students (%), n = 14			
	Overall <sup>a</sup>	Engagement definition sections		
		Behavioral	Cognitive	Emotional
<b>Engagement</b>				
Tried to understand	13 (92.9)	0 (0.0)	12 (85.7)	3 (21.4)
Checked work/answers	7 (50.0)	1 (7.1)	5 (35.7)	1 (7.1)
Thought about how to solve problems	7 (50.0)	3 (21.4)	4 (28.6)	0 (0.0)
Discussed with others	6 (42.9)	3 (21.4)	4 (28.6)	2 (14.3)
Helped others	5 (35.7)	2 (14.3)	5 (35.7)	0 (0.0)
Interacted with worksheet	5 (35.7)	3 (21.4)	2 (14.3)	0 (0.0)
Used resources	6 (42.9)	4 (28.6)	4 (28.6)	0 (0.0)
Went through problems step-by-step	4 (28.6)	1 (7.1)	2 (14.3)	1 (7.1)
Connected or applied material	4 (28.6)	1 (7.1)	3 (21.4)	1 (7.1)
<b>Disengagement</b>				
Just wrote down answers	6 (42.9)	1 (7.1)	6 (42.9)	1 (7.1)
Didn't discuss with others	3 (21.4)	2 (14.3)	1 (7.1)	0 (0.0)
Gave up	3 (21.4)	1 (7.1)	0 (0.0)	2 (14.3)
Didn't help others	1 (7.1)	0 (0.0)	1 (7.1)	0 (0.0)

<sup>a</sup>Number of students who mentioned code at least once during the three definitions.

Table S12. Number of students that mentioned each emotional engagement code when provided the specific definitions of engagement (i.e., behavioral, cognitive, emotional).

Emotional Code	Number of students (%), n = 14			
	Overall <sup>a</sup>	Engagement definitions given		
		Behavioral	Cognitive	Emotional
<b>Engagement</b>				
Felt confident	10 (71.4)	0 (0.0)	0 (0.0)	10 (71.4)
Positive feelings	9 (64.3)	0 (0.0)	0 (0.0)	9 (64.3)
Felt activity was beneficial	8 (57.1)	1 (7.1)	3 (21.4)	7 (50.0)
Wanted to learn	4 (28.6)	1 (7.1)	1 (7.1)	3 (21.4)
Wanted to/liked working with others	5 (35.7)	1 (7.1)	2 (14.3)	3 (21.4)
Wanted to help others	4 (28.6)	1 (7.1)	4 (28.6)	0 (0.0)
Liked/enjoyed the activity	6 (42.9)	0 (0.0)	0 (0.0)	6 (42.9)
Liked chemistry/science	3 (21.4)	0 (0.0)	1 (7.1)	3 (21.4)
Didn't feel frustrated	2 (14.3)	0 (0.0)	0 (0.0)	2 (14.3)
Excited about activity	4 (28.6)	0 (0.0)	1 (7.1)	4 (28.6)
Interested in content	2 (14.3)	0 (0.0)	2 (14.3)	0 (0.0)
<b>Disengagement</b>				
Felt self-doubt	6 (42.9)	0 (0.0)	0 (0.0)	6 (42.9)
Negative feelings	7 (50.0)	0 (0.0)	0 (0.0)	7 (50.0)
Felt frustrated	5 (35.7)	1 (7.1)	0 (0.0)	5 (35.7)
Felt disconnected	6 (42.9)	2 (14.3)	0 (0.0)	4 (28.6)
Didn't want to learn	5 (35.7)	0 (0.0)	2 (14.3)	3 (21.4)
Didn't want to/like working with others	5 (35.7)	1 (7.1)	3 (21.4)	1 (7.1)
Felt activity wasn't beneficial	4 (28.6)	0 (0.0)	2 (14.3)	3 (21.4)
Felt left behind/rushed	2 (14.3)	1 (7.1)	0 (0.0)	1 (7.1)
Didn't like/enjoy the activity	2 (14.3)	0 (0.0)	0 (0.0)	2 (14.3)
Didn't like chemistry/science	2 (14.3)	0 (0.0)	0 (0.0)	2 (14.3)
Felt bored	1 (7.1)	0 (0.0)	0 (0.0)	1 (7.1)
Not interested in content	1 (7.1)	0 (0.0)	1 (7.1)	0 (0.0)

<sup>a</sup>Number of students who mentioned code at least once during the three definitions.