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NSF COMPLEAT: Year 2 Evaluation

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INTRODUCTION

The objective of the COMPLEAT project is to improve prospective elementary teacher (PSET) engagement through an innovative, interdisciplinary, and inquiry-based approach that addresses the pressing need for integration of multiple disciplines in Science, Technology, Engineering, and Mathematics (STEM). The project seeks to improve learning experiences for PSETs in acquiring mathematics (math) skills by exploring the rules of math in other STEM disciplines and solidifying knowledge and skills in teaching contexts as sustainable practices.

The project aims to meet these objectives through the Applying, Connecting, Experiencing (ACE) instruction model, integrating Community-Based Experiential Learning (CBEL) into PSET courses, and using Integrated Math-Enhanced (IME) STEM inquiry activities.

The COMPLEAT project is being implemented at Augusta University (Augusta) in Georgia, Boise State University (Boise State) in Idaho, Kapiolani Community College (KCC) in Hawaii, and University of Texas San Antonio (UTSA) in Texas.

METHODOLOGY

This report evaluates the impact of the second year of the COMPLEAT project on PSETs, elementary students participating in the community activity, and the instructors leading the PSET courses. This is done using data collected from the three groups throughout each semester, including four surveys taken by PSETs, three written critical reflections done with PSETs, two surveys taken by elementary students, and interviews done with the instructors (See Table 1). The first part of the evaluation focuses on participants in the Fall 2022 semester and the second part of the evaluation focuses on participants in the Spring 2023 semester.

Table 1: Sample Size of Each Data Set

	Fall 2022		Spring 2023
	3D Printing	Windmill	Windmill
PSET Data			
Beginning of the course			
ME.ET*	74	24	98
Reflection 1	69	23	83
Beginning of the IME Module			
T-STEM Pre-Test	59	13	81
End of the CBEL activity			
Reflection 2	60	20	78
T-STEM Post-Test	59	14	81
End of course			
ACE Course Evaluation	66	22	81
Reflection 3	59	21	80
Elementary Student Data			
S-STEM Pre-CBEL Test	65	30	80
S-STEM Post- CBEL Test	60	27	73
Instructor Data			

End of Course Interview	5		5

* ME.ET = Mathematical Education of Elementary Teachers

In Fall 2022, Augusta, KCC, UTSA, and one group from Boise State used the 3D Printing STEM module during the course while one group from Boise State piloted the Windmill STEM module. In Spring 2023, all universities used the Windmill module.

Analysis of data in this report compares the frequency of responses across universities and between the pre- and post-test results where applicable. Data from interviews and open-ended survey questions was coded to identify themes relevant to research questions. IPI read through responses and created simple summaries for each. These simple summaries allowed for identification of commonalities across responses. These commonalities are referred to as themes emerging from the research throughout the report. The number of times a theme is mentioned indicates the number of respondents mentioning something related to the theme directly. When respondents mentioned multiple themes in one response, all themes were included in the final frequency count.

This report aims to answer the six research questions identified in the project outline. As such, any data from the surveys, reflections, or interviews that is not relevant to the research questions is not included in the analysis.

LIMITATIONS

The data for this evaluation has some limitations. The first is that not all PSETs take every survey, meaning sample sizes change and there is little opportunity to make individual longitudinal connections. This is also true for elementary students participating in the activity, many did not complete both the pre- and post-assessment.

The second limitation is that once split out into universities, samples sizes become too small to perform a robust evaluation. Throughout the report, patterns in data are reported in the aggregate and only broken out by university when the differences are sizable.

FALL 2022 ANALYSIS

PROGRAM IMPACT ON PRE-SERVICE ELEMENTARY TEACHERS

Research Question 1: To what extent does the ACE model promote PSETs' mathematics learning and increase their teaching abilities?

PSET Math Skills Attainment

High School Math Courses

The ME.ET survey indicated that before entering university, most PSETS participating in the 3D printing project (n=74) took math courses through Grade 12 of high school (about 80%). Almost all PSETs across universities took both a Geometry and an Algebra 2 course, with most students completing Geometry before Grade 11 and Algebra 2 before Grade 12.

When looking at higher level math courses, only 23% of PSETs took a calculus class though 60% reported taking precalculus. The most commonly reported class taken in Grade 12 was statistics, followed closely by precalculus. At least half of all PSETs at each university took precalculus, though UTSA and Augusta had higher rates of students completing the course.

Table 2: Number of PSETs from a university taking each course

Module	3D Printing (Crystal Lattice Solids)				Windmill Activity
Course*	Augusta (n=12)	Boise State (n=35)	KCC (n=6)	UTSA (n=21)	Boise State (n=24)
Calculus	2	8	3	4	5
Statistics	6	15	4	4	6
Precalculus	8	19	3	15	15

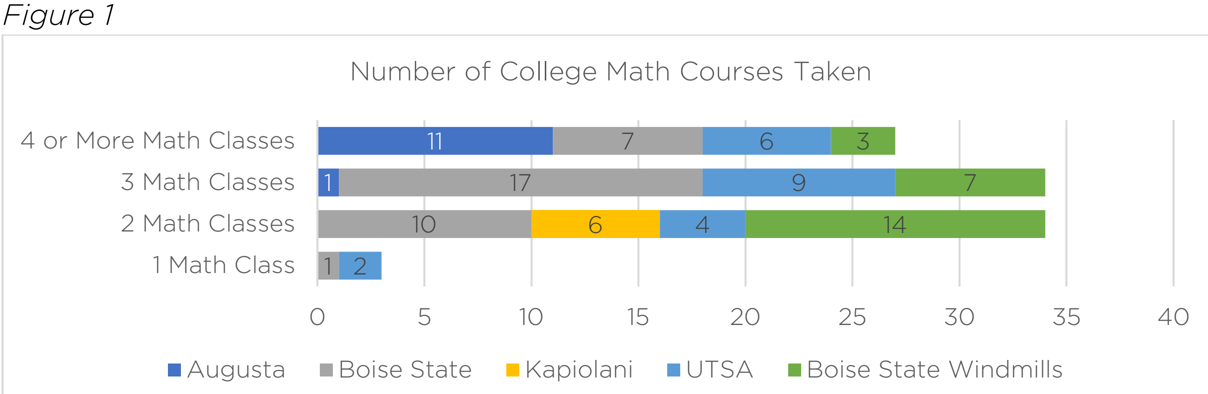
*See Appendix A (Charts A1-5) for more details

Before entering university, 75% of PSETs at Boise State participating in the Windmill project (n=24) completed a math course through Grade 12 of high school. Over 80% of PSETs completed a Geometry or Algebra 2 course. When looking at higher level math courses, 21% took a calculus class while 63% reported taking precalculus. The most common course taken in Grade 12 was precalculus, followed by statistics and calculus.

College Math Courses

When asked in **the ME.ET survey** how many college math classes students took, 72 out of 74 PSETs completing the 3D printing project took at least two. All students from KCC completed two courses, all but one student from Augusta completed 4 or more, and Boise State and UTSA students varied in their experience. About 70% of students at Boise State and UTSA completed three or more college math courses. Across all universities, 69% of students completed three or more courses, the same number of students were either juniors or seniors. Though the level of math course is unknown, the number of classes taken indicates that most students were recently in a math learning environment before taking this course.

Figure 1



* Math courses include statistics and computer science courses

A little more than half (58%) of Boise State students participating in the Windmill Project took only 2 College Math courses at the time of the project, while 30% took three. Only three of the students took four or more math courses. Though these numbers are slightly lower than the students participating in the 3D printing project, the participating students also tended to be less further along in the program, with 76% being sophomores and 24% being juniors and no seniors participating. This means students had less opportunities to complete math courses than their 3D printing counterparts.

Course Learning

During the first critical reflection, PSETs were asked if there was a unique experience (either positive or negative) that influenced their interest or perception in STEM. The most common positive experiences were those that made STEM fun (19 mentions), involved hands-on activities (9 mentions), or used STEM to understand the world (9 mentions).

The most common reported negative experiences for the same question were those that siloed STEM subjects (14 mentions), those that caused feelings of frustration (10 mentions), and anxiety around math (8 mentions). There is not a notable pattern or difference across universities for these responses.

Some lesser mentioned but notable experiences in the same question include having to overcome gender stereotypes associated with STEM (2 mentions), experiences that involve critical thinking (5 mentions), and the importance of experiences that allow creativity while practicing STEM (8 mentions).

In the ACE Course Evaluation, PSETs were asked what aspects of the course were most valuable to their learning experience. Overwhelmingly, PSETs reported the hands-on experience (34 mentions) and the opportunity to work with students (31 mentions) were the most valuable aspects of the course. This encompasses the value placed on working directly with students and engaging in CBEL activities. PSETs expressed the importance of being able to apply their knowledge in real-world settings, work with elementary students, collaborate in teams to teach lessons, and interact with students to enhance their learning.

The next highest reported value of the course for this question was the opportunity to apply their knowledge and the relevance of course assignments (14 mentions). This includes the value of being able to apply what they learned in class to teaching and working with students, finding connections between concepts and elementary math, and seeing the practical relevance of the coursework.

When looking at the whole of the above analysis, it is clear that coming into the course, PSETs in this group had a lot of experience with taking math courses both in high school and in college. At the outset of the course, it is not clear if the course increased their ability to learn STEM subjects as PSETs did not mention STEM learning when reflecting on the course. It does seem clear that PSETs felt what they did learn was relevant to their desired outcomes and they gained valuable experience.

PSETs Math Teaching Ability

In the first critical reflection at the beginning of the course, PSETs were asked "what do you most want to learn about teaching STEM?" The five most common responses were:

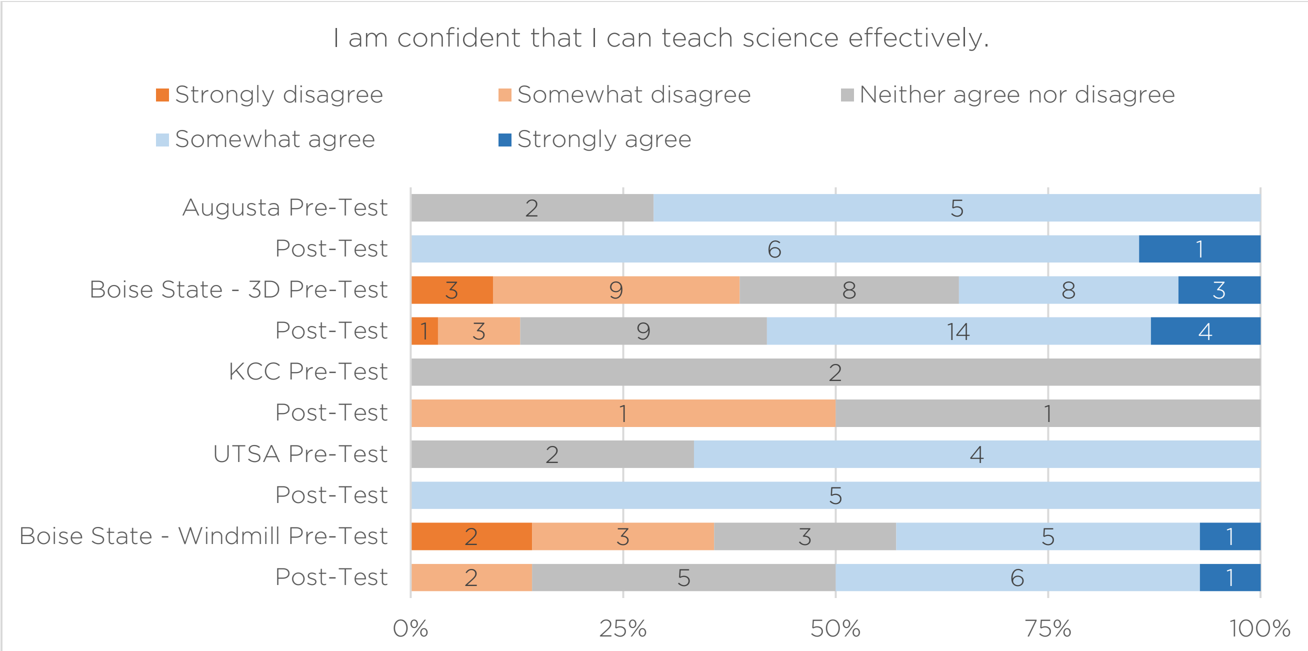
- Knowing how to apply what they learn in the course in the future (14 mentions)
- Gaining more technological knowledge (14 mentions)
- Learning how to make STEM fun for students (13 mentions)
- Gathering STEM teaching resources (12 mentions)
- Understanding how to teach the importance of STEM (11 mentions)

Despite being the most mentioned desired objective and the university with the most participating PSETs, no PSETs from Boise State reported wanting to learn about how to apply their knowledge in the future. Boise State PSETs did account for more than half of the PSETs reporting wanting to know how to teach the importance of STEM. Boise State PSETs also accounted for almost all of those reporting wanting to gain more technological knowledge (10 mentions). UTSA accounted for half of the PSETs wanting to know how to apply what they learn in the course in the future.

Some lesser mentioned but notable objectives of the course included wanting to know how to remove the negative connotations associated with STEM (6 mentions), knowing how to inspire critical thinking (5 mentions), and learning how to foster student passion in STEM (3 mentions).

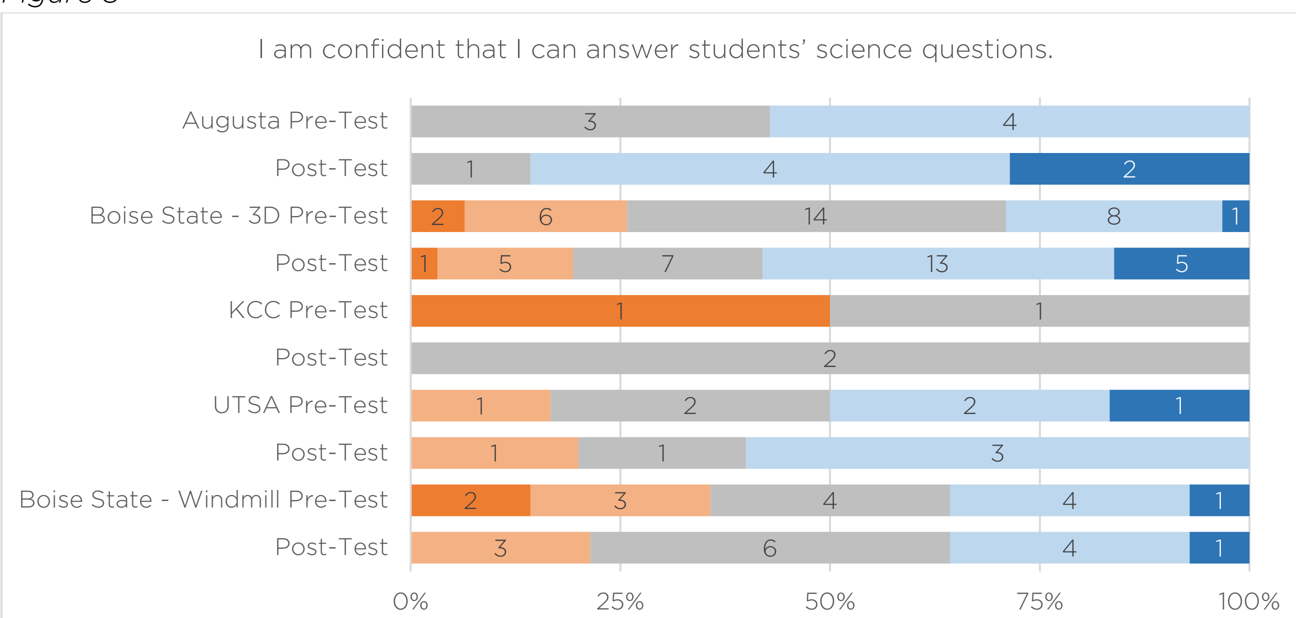
Figures 2-4 demonstrate data from the PSETs pre and post T-STEM surveys. At the end of the course, the confidence of PSETs to teach science effectively increased. Both Augusta and UTSA went from all but two PSETs agreeing they felt confident, to all PSETs agreeing they feel confident. The most notable change was in Boise State PSETs participating in the 3D printing project. This group decreased the number of PSETs not feeling confident from 12 to four and increased the number of PSETs feeling confident from 11 to 18.

Figure 2



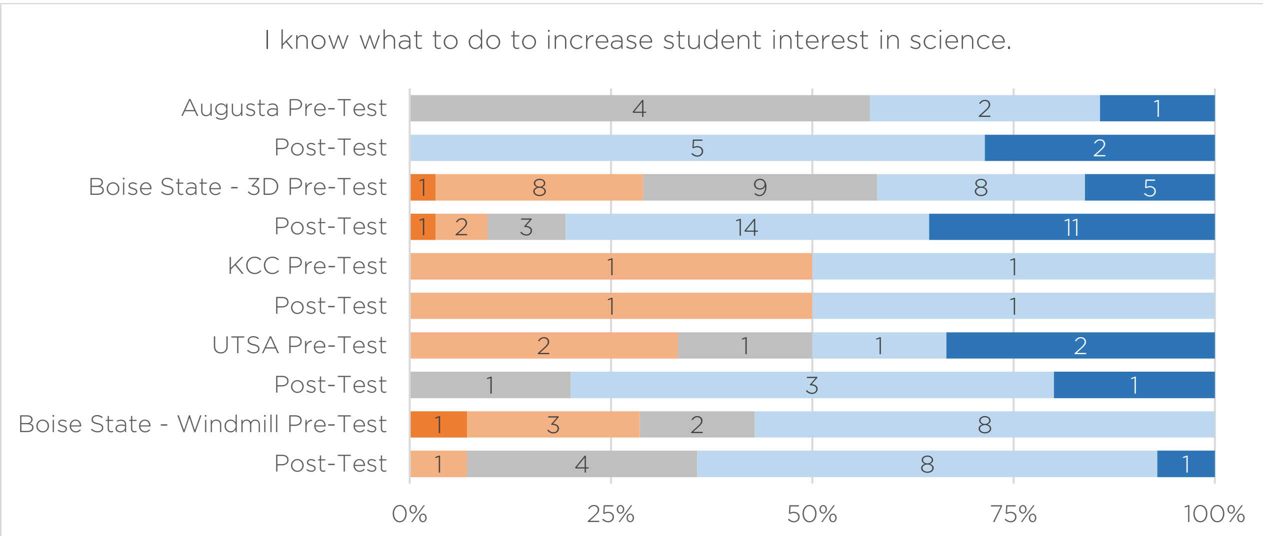
In addition to feeling more confident about teaching science effectively, PSETs also increased their confidence in their ability to answer students' science questions after participating in this course. PSETs participating in the Boise State 3D project had the largest increase in confidence. Before the course, nine students felt confident to answer student questions, but afterward, 18 did.

Figure 3



All universities increased PSET confidence in their ability to increase student interest in science. The largest increase was seen in Boise State PSETs participating in the 3D printing project. This group decreased PSETs feeling not confident from nine to three and increased the number of PSETs feeling confident from 13 to 25. Augusta also notably had all PSETs report feeling confident in their ability to increase student interest in science after participating in the course.

Figure 4



In the **final critical reflection**, PSETs were asked what they learned that is relevant to their future teaching. The most common response was that the course increased their math background and understanding (18 mentions). A majority of these responses (11 mentions) were from Boise State PSETs. The other common responses included the course providing relevant classroom strategies and activities (11 mentions), the value of learning about 3D printing (8 mentions), and learning how to engage students (7 mentions). Most PSETs finding 3D printing valuable were from UTSA, while most PSETs finding value in learning relevant classroom strategies were from Boise State.

Overall, PSETs felt they learned relevant and valuable skills to improve their ability to teach STEM in the future. PSETs also reported increased confidence in teaching STEM subjects. And this is true across all universities. This indicates the course is well-designed for improving PSETs' STEM teaching skills.

Research Question 2: To what extent does the ACE model influence PSETs' attitudes and beliefs towards math and STEM?

PSETs STEM Beliefs Entering the Course

During their **first critical reflection** when entering the course, PSETs were asked, "How have you applied your knowledge of STEM in your personal and/or professional life? For example, have there been situations that benefited, or you would have if you had more STEM knowledge?" Only 8 PSETs reported they do not feel they ever use STEM in their life while 41 PSETs reported using STEM to perform everyday tasks. Most of the PSETs who reported not using STEM were from Augusta and only 5 PSETs from

Augusta reported using STEM skills every day. Other notable responses include PSETs applying STEM when using and understanding technology (10 mentions) and using STEM-based critical thinking or problem-solving skills in life (8 mentions).

In the ME.ET survey at the beginning of the course, PSETs were also asked about general feelings toward STEM subjects. Most PSETs were willing to admit they were either good at math or at least sufficient at it. However, when asked if they liked math, more PSETs disagreed with the statement. This change seems to have happened among PSETs neither agreeing or disagreeing that they were good at math rather than PSETs feeling they are good at math but dislike it. The most notable instance was among UTSA PSETs.

Figure 5

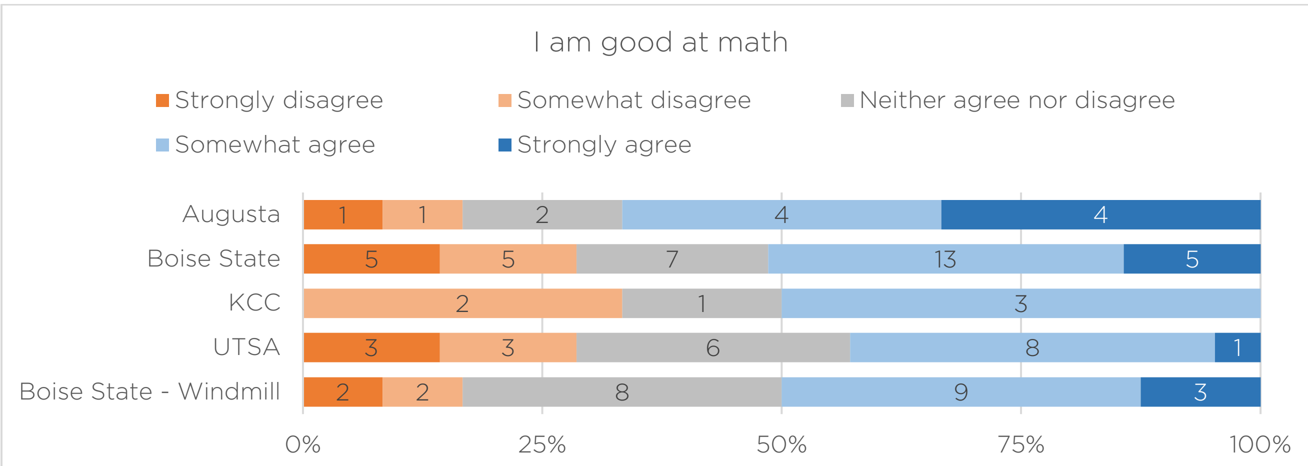
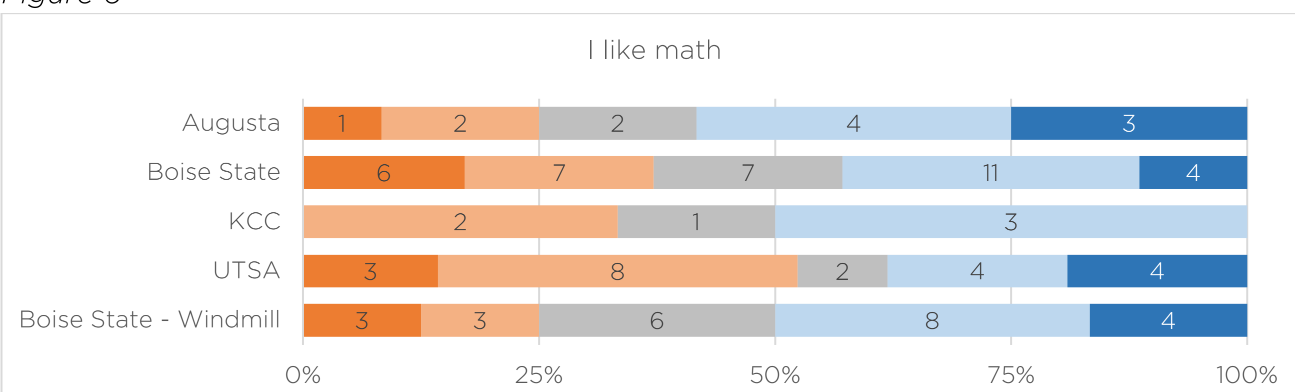


Figure 6



Most PSETs view math as characterized by abstraction and logic while also feeling there is more than one way to solve math problems, and that math is useful for everyday problems and in every profession. Most notably, at least a quarter of PSETs from each university strongly agree there is more than one way to solve math tasks and problems and math is useful for solving everyday problems.

Figure 7

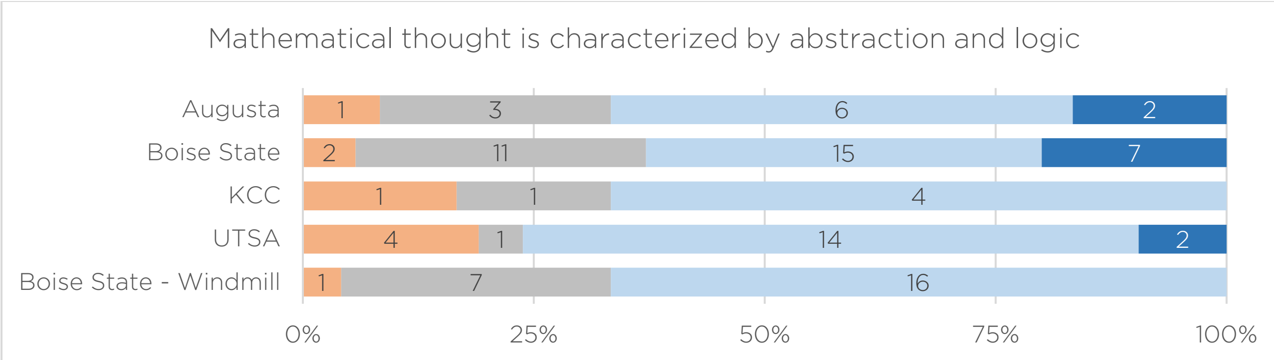


Figure 8

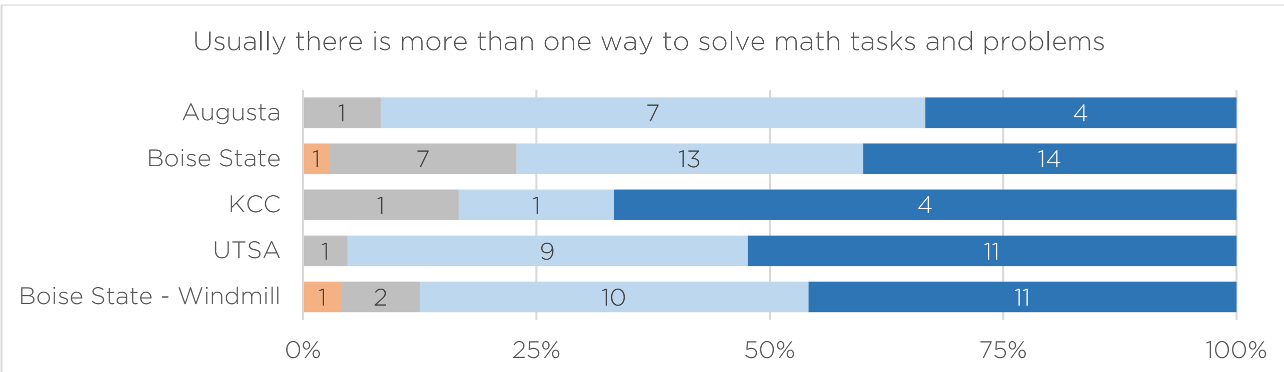


Figure 9

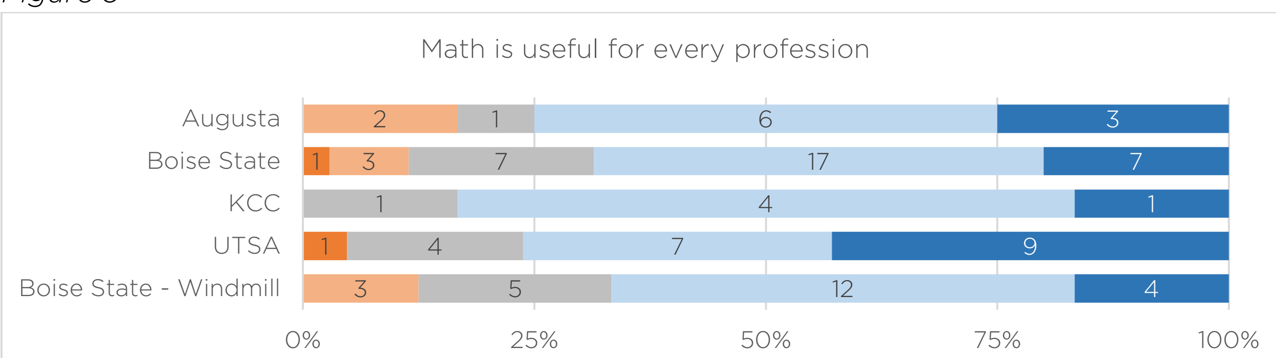
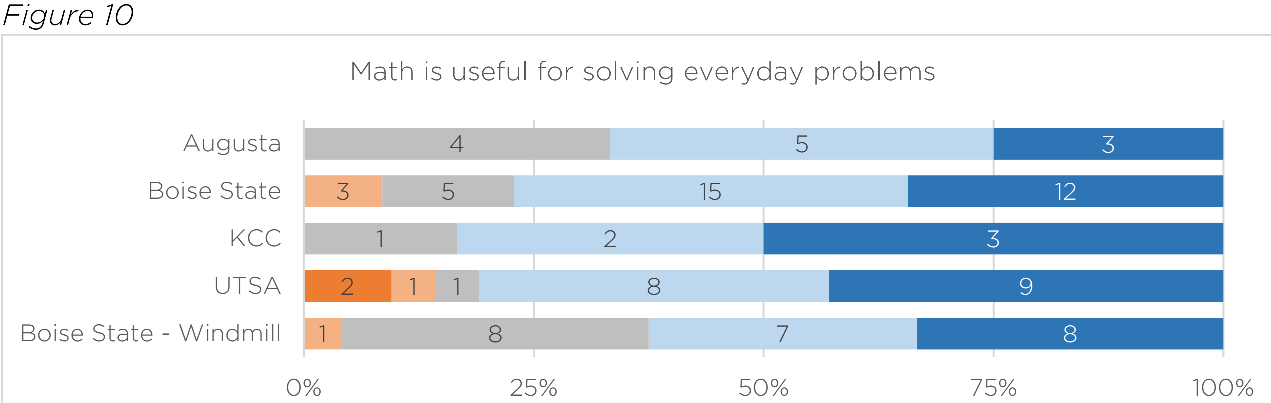


Figure 10



PSETs STEM Beliefs After the Course

In both T-STEM surveys, PSETs were asked about the impact a teacher can have on a student's ability to learn STEM concepts. This was measured by asking their level of agreement on the following statements:

- When a student does better than usual in mathematics, it is often because the teacher exerted a little extra effort
- When a student's learning in math is greater than expected, it is most often due to their teacher having found a more effective teaching approach
- Students' learning in math is directly related to their teacher's effectiveness in math teaching
- When a low achieving child progresses more than expected in math, it is usually due to extra attention given by the teacher
- If parents comment that their child is showing more interest in math at school, it is probably due to the performance of the child's teacher

Not all PSETs in all universities had the opportunity to answer these questions and s such the data is incomplete. For university specific data on the following analysis, please see Appendix A (Charts A6-10).

Almost half of all PSETs agreed that a teacher's extra effort can result in students doing better than usual in mathematics while nearly a third neither agreed or disagreed.

Even more PSETs, around two thirds, agree that when students' learning is greater than expected, it is because their teacher found a more effective teaching approach. Only seven students disagreed with this idea.

When asked, around 60% of PSETs agree that student's learning in math is directly related to their teacher's effectiveness in math teaching. Out of all the questions from this block, this was the only one to have PSETs to strongly disagree.

Most PSETs (60%) agreed when a low achieving child progresses more than expected in math, it is usually due to extra attention from the teacher. A little more than a quarter of PSETs neither agreed or disagreed. Only 13% disagreed.

Half of the PSETs agreed that if parents comment that their child is showing more interest in math at school, it is probably due to the performance of the child's teacher.

During the final reflection at the end of semester, PSETs were asked, "As a future educator, what will you do (be specific) to encourage your students to learn STEM?" The top three responses were to engage students in fun activities (32 mentions), engage students in real-world application activity (18 mentions), and allow students opportunities to experiment (9 mentions).

When taking all the data for this research question into account, only about half of PSETs reported liking math despite also reporting that they were good at math and that they use math in their everyday lives in the ME.ET survey. At the end of the course, at least half of all PSETs agreed that a teacher's effort could improve and change student performance in STEM subjects and reported learning strategies in the course they will take moving forward to encourage STEM. Though data for Fall 2022 is slightly incomplete for this question, it seems the course provides opportunities for PSETs to change their attitudes and beliefs toward STEM as it applies to their ability to increase student participation in STEM and their ability to teach STEM. Analysis for this question could be strengthened by asking some of the questions on the ME.ET survey at the end of the semester to make a pre- and post-course comparison of STEM attitudes.

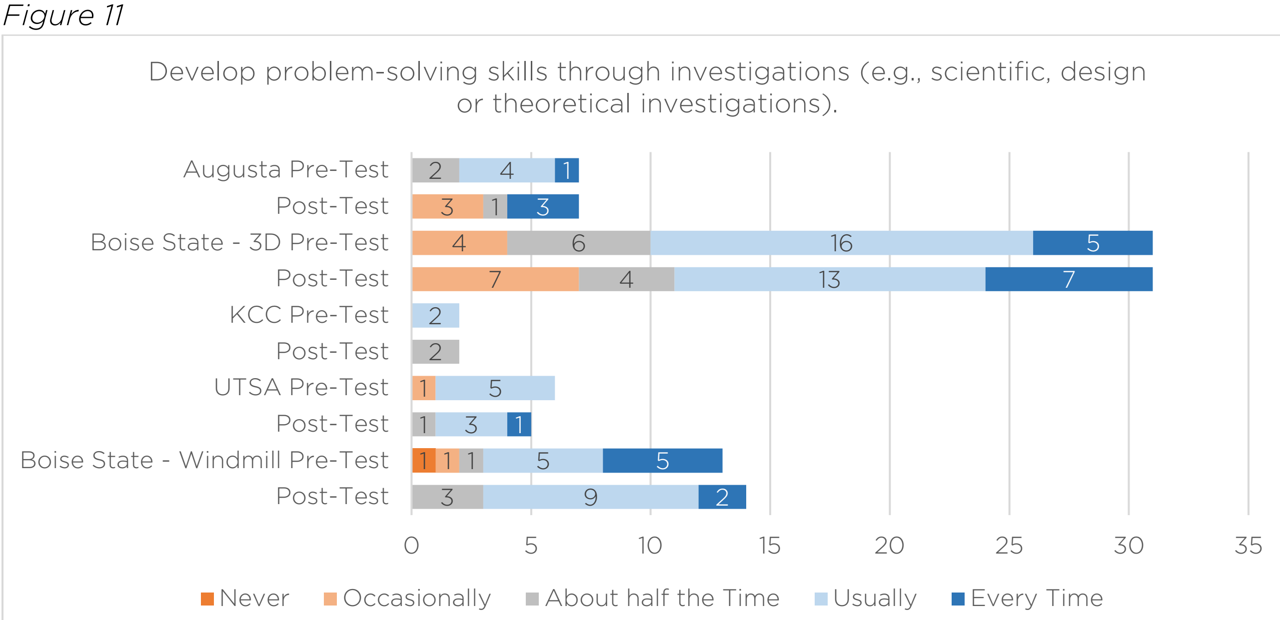
Research Question 3: What is the impact of integrated math-enhanced (IME) STEM inquiry in afterschool activity on PSETs' teaching practices?

In the reflection completed at the end of the CBEL activity, PSETs were asked, "How did your CBEL experience shape your thinking about teaching?" The most common responses were that it solidified their passion for teaching (16 mentions), they understood how students could benefit from IME STEM inquiry (15 mentions), and the importance of being flexible while teaching (10 mentions). There was no notable pattern or difference across universities.

In both T-STEM surveys, PSETs were asked both when entering and after participating in the CBEL activity about certain tasks and skills students should participate in and use during instructional time. These tasks and skills are directly related to the IME inquiry process and are listed below.

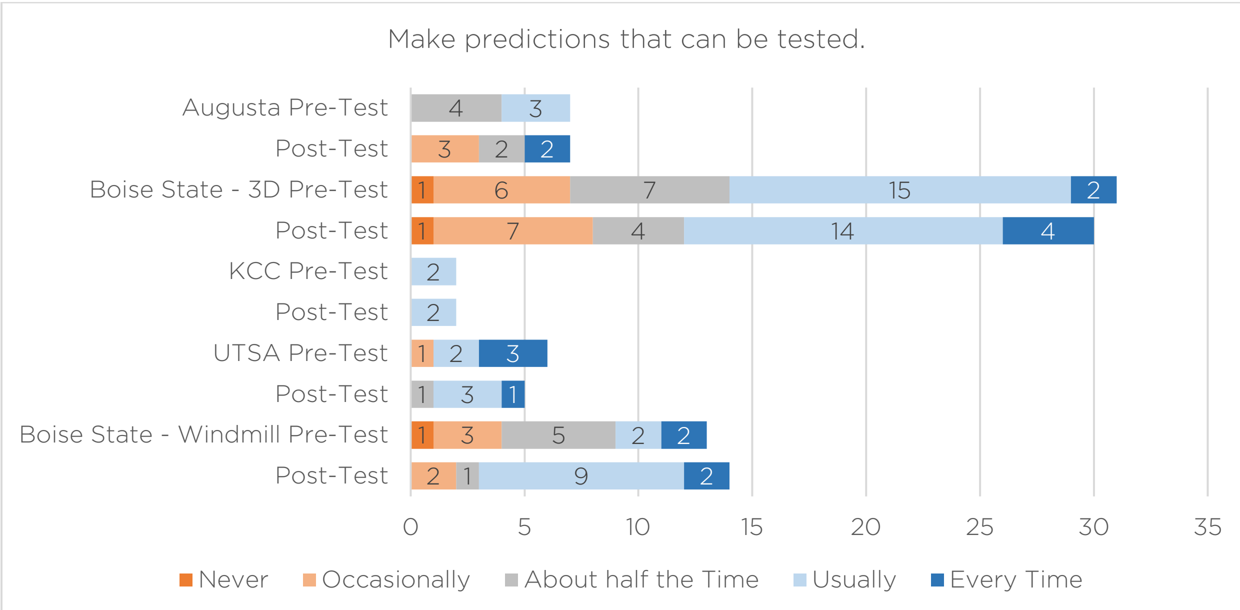
When asked how often students should develop problem-solving skills through investigations, the was no pattern across universities. At Augusta, KCC, and among Boise State PSETs participating in the 3D printing activity, the amount of time PSETs felt should be spent on this task decreased. However, at UTSA and among PSETs at Boise State participating in the Windmill activity, students increased the amount of time they thought should be spent doing this task.

Figure 11



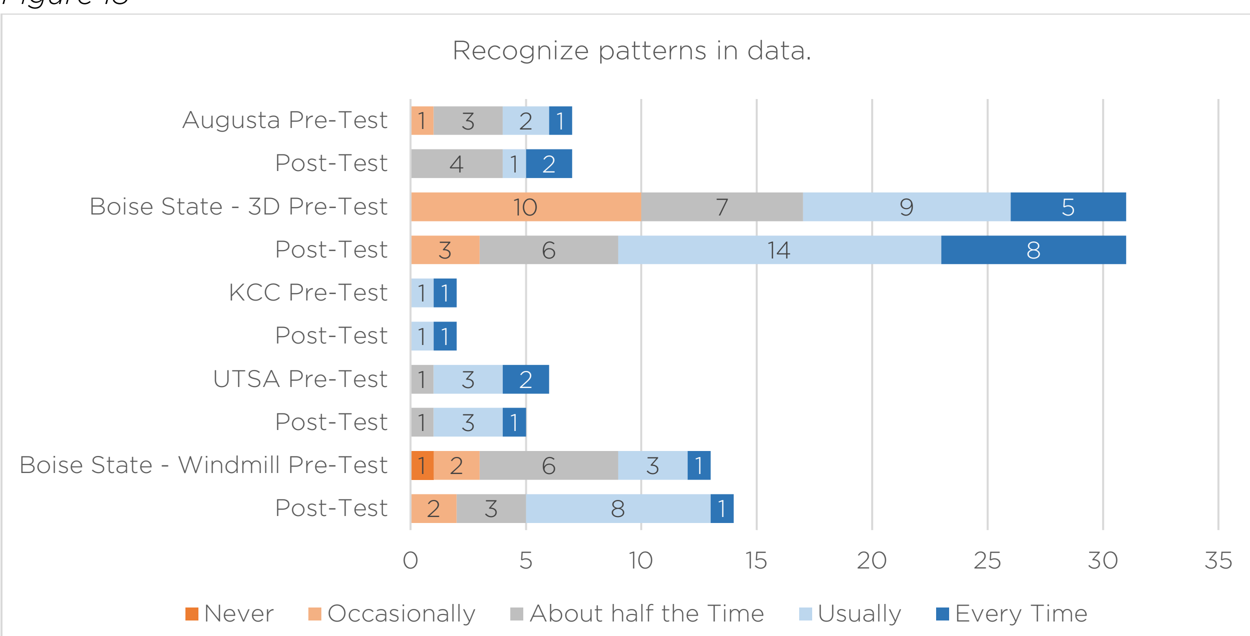
After participating in the course, PSETs generally increased the amount of time they believed students should spend on making predictions that can be tested. This is true across universities except for Augusta, where the overall time decreased slightly.

Figure 12



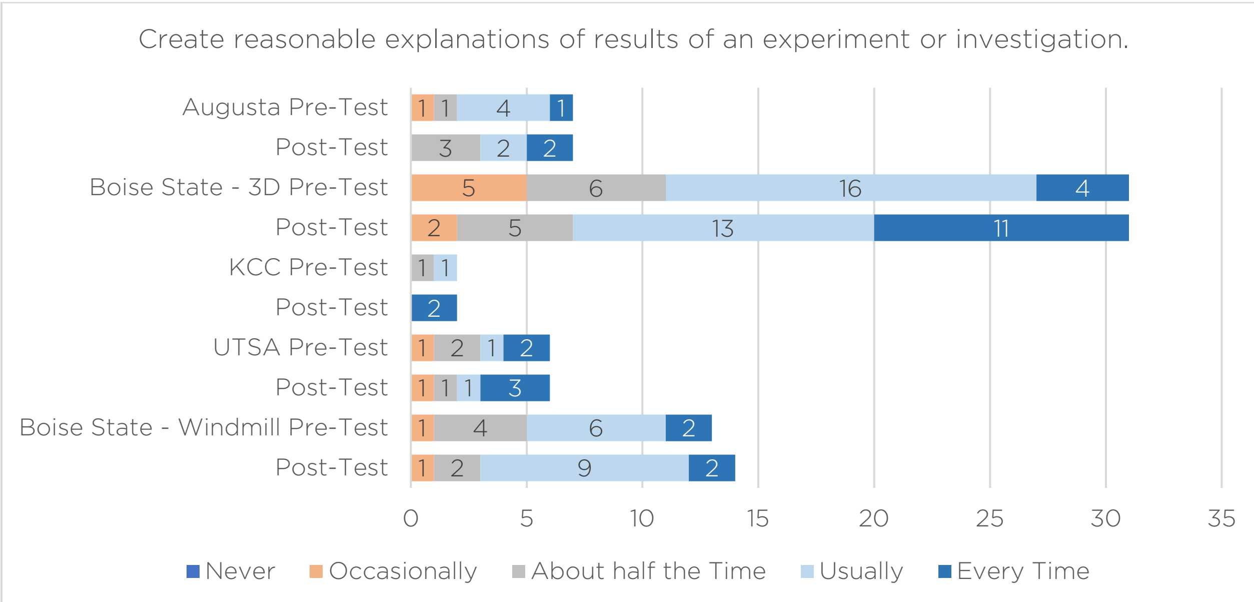
Across all universities, PSETs increased the amount of time they believed students should recognize patterns in data during the school day after participating in the course. Most notable is the increase among Boise State students participating in the 3D printing project. When entering the course, 14 PSETs believed students should perform this task more than half the time and after the course that increased to 22.

Figure 13



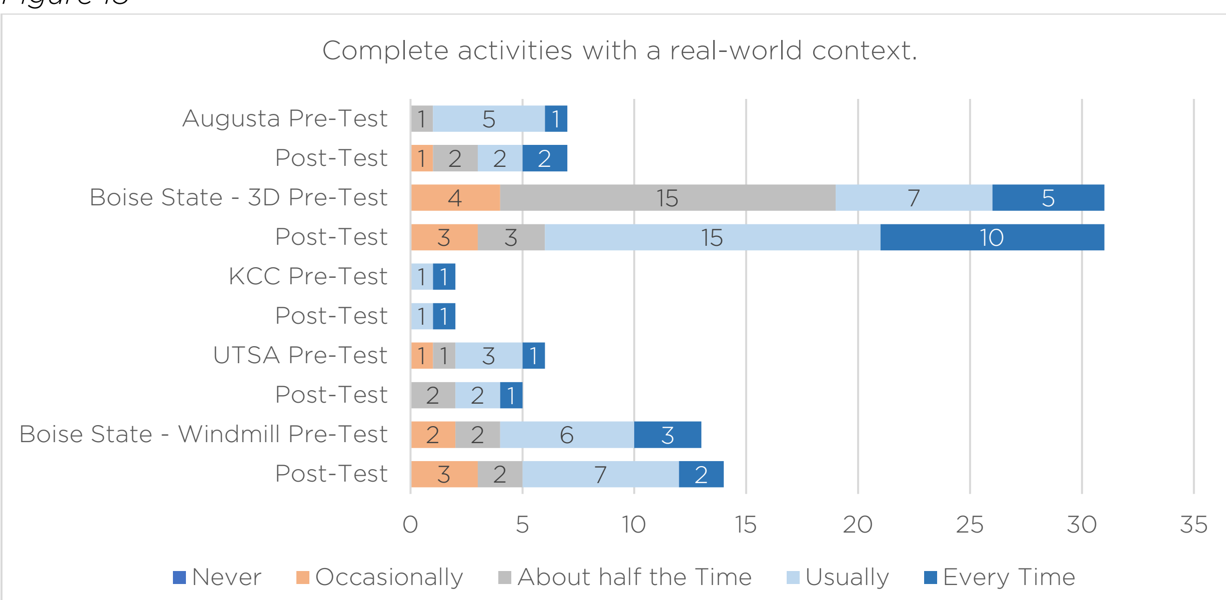
When asked how often students should create reasonable explanations of results of an experiment or investigation, PSETs across all universities increased the amount of time after participating in the course. There is no notable change at any university.

Figure 14



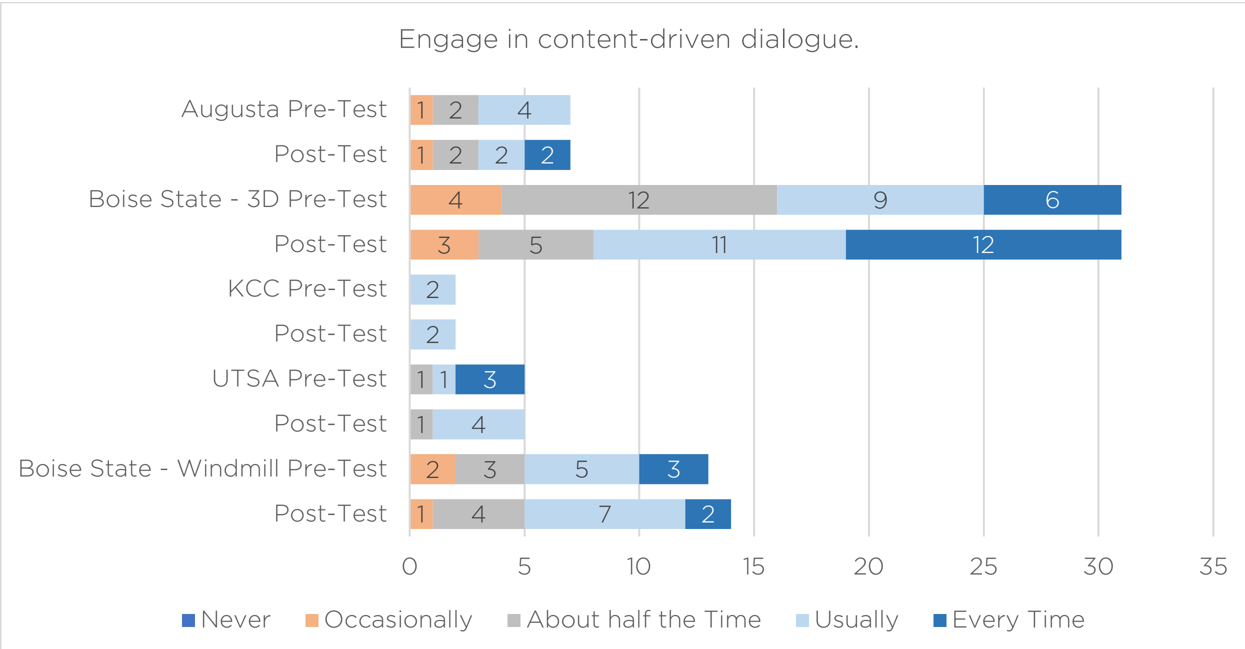
At Augusta and among students at Boise State participating in the Windmill activity, PSETs felt students should complete activities with a real-world context less after participating in the course. However, among students at Boise State participating in the 3D printing project, after completing the course 25 PSETs thought students should spend more than half the time completing activities with real-world context compared to 12 before the course.

Figure 15



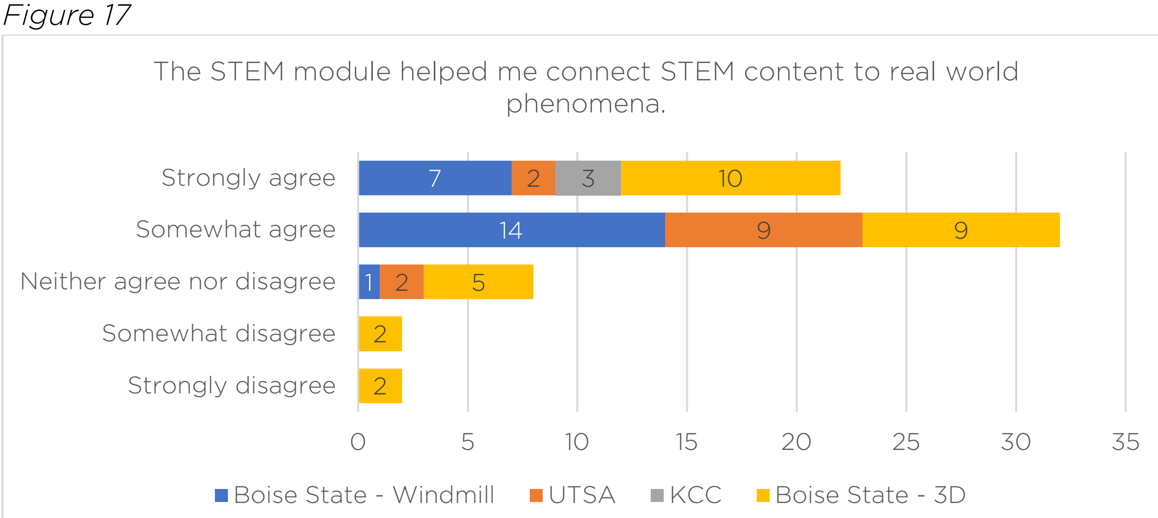
For the most part, PSETs felt students should engage in content-driven dialogue about half the time when entering the course and even more felt that way after participating in the course. Notably, among PSETs participating in the 3D printing project at Boise State, 12 students believed students should participate in content-driven dialogue every time compared to six when entering the course.

Figure 16



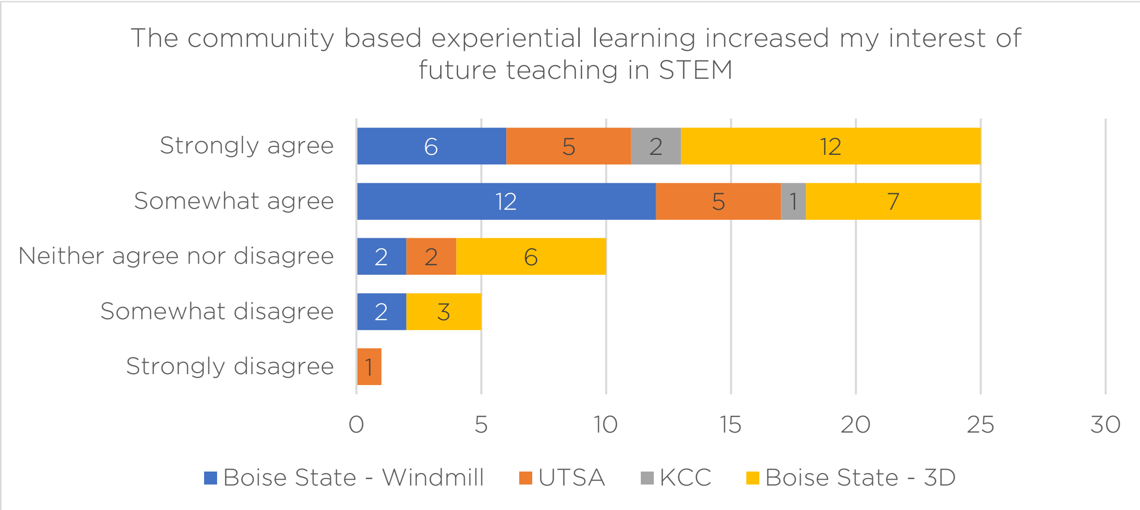
In the ACE Course Evaluation at the end of the semester, PSETs were asked to evaluate the course overall. In Fall 2022, PSETs from Augusta did not respond to this evaluation. One question asked if they felt the STEM module helped them connect STEM content to real world phenomena. All but 12 PSETs across all universities agreed the STEM module helped, all of the PSETs disagreeing were Boise State students participating in the 3D printing activity.

Figure 17



Students were also asked if they felt the community based experiential learning increased their interest of future teaching in STEM. Out of students across all universities, 76% agreed the module increased their interest in teaching STEM.

Figure 18



Using IME STEM inquiry in afterschool activities appears to mostly have positively impacted PSET teaching practices. Many reported the value of the project to increase their passion for teaching, increase student interest in STEM, and learning strategies for teaching such as being flexible and patient. Almost all participating PSETs felt the experience helped them better connect STEM content to real world phenomena and the activity increased their interest in teaching STEM as a whole.

When looking at specific IME skills, such as recognizing patterns in data, creating reasonable explanations of results, and making predictions that can be tested, PSET interest in implementing these tasks varied. This implies that though the course is designed well to increase interest in STEM and in teaching STEM with the IME inquiry activity, it may not be connecting the different concepts and skills related to IME inquiry to the process of the activity.

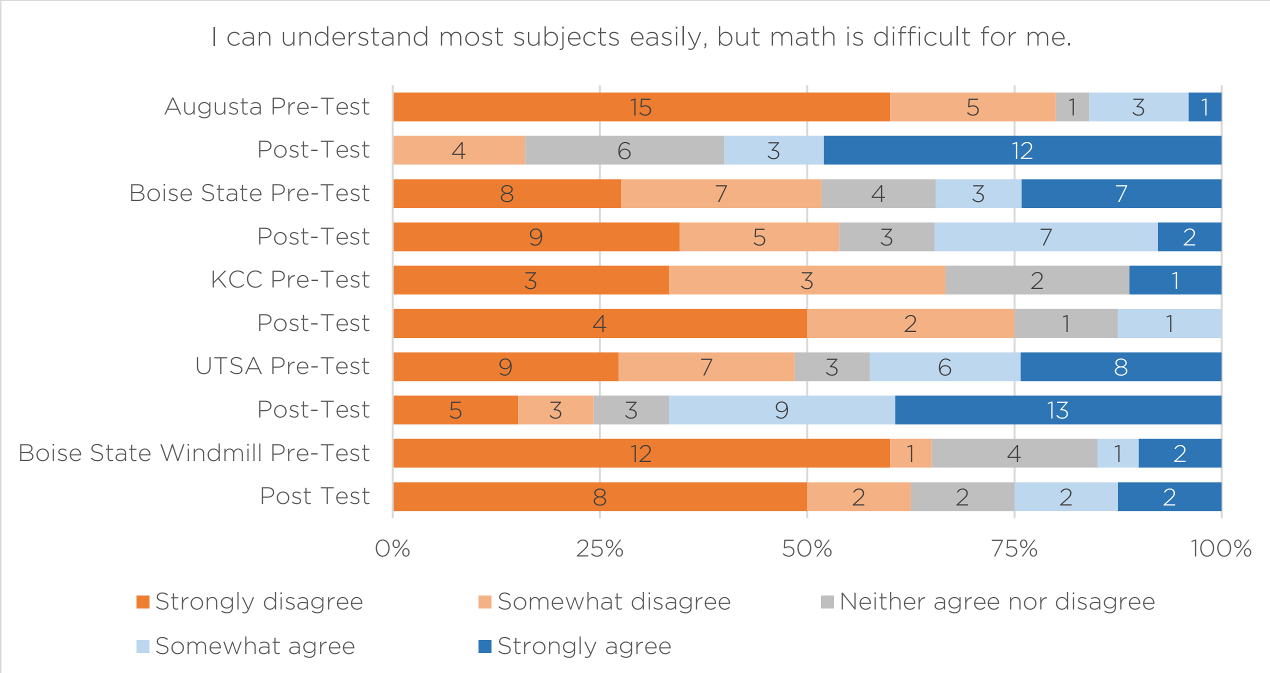
PROGRAM IMPACT ON PRE-SERVICE ELEMENTARY STUDENTS

Research Question 4: How does participating in ACE math course IME inquiry activities influence elementary school students' beliefs or perceptions in STEM?

Elementary students participating in the IME inquiry activities participated in a survey both before and after completing the activity. The survey asked them to rate their agreement to statements relating to their affinity toward STEM subjects.

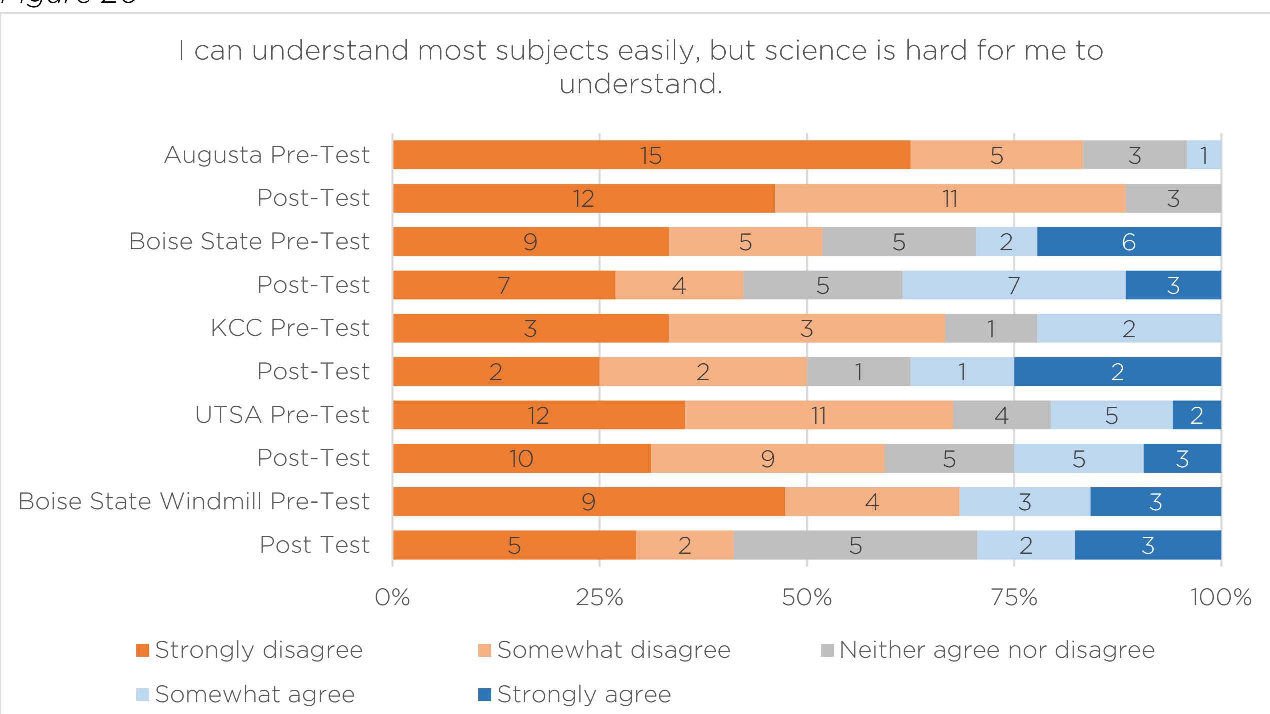
In the pre-test (S-TEM) taken when entering the activity, most elementary students disagreed that math is difficult for them. However, after the activity, many universities saw an increase in students agreeing the math is difficult for them. This most notably happened at Augusta and USTA. Numbers for KCC and both Boise State groups remained similar.

Figure 19



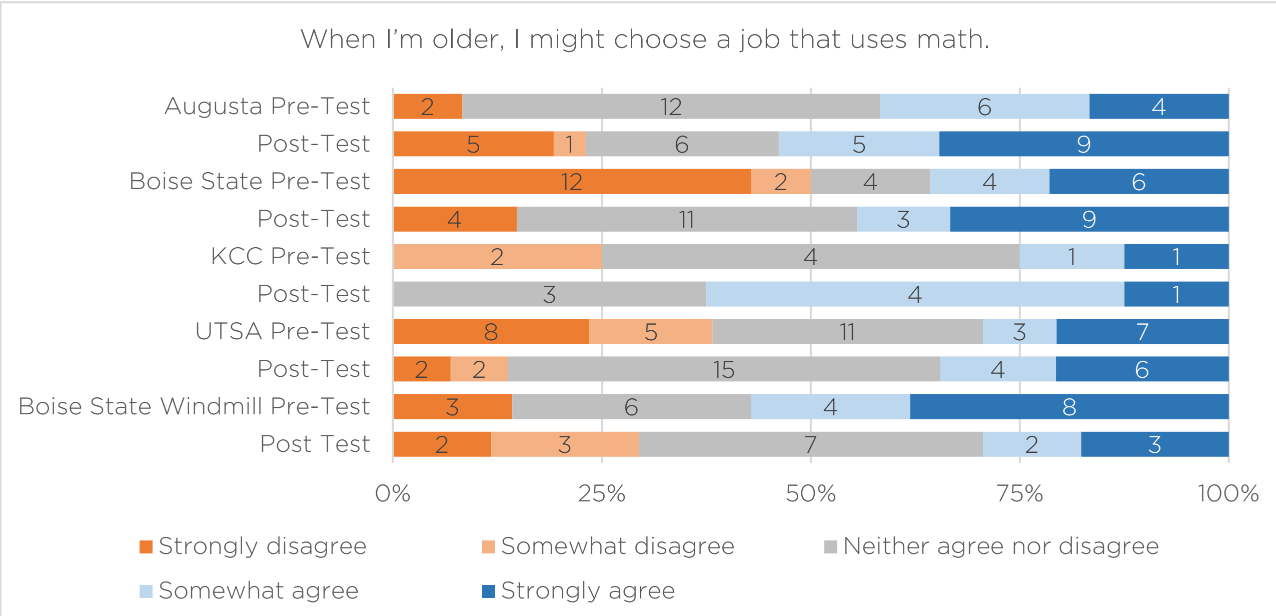
Comparatively, when asked if science is difficult for them, there was not as big of a change in agreement between before and after the activity. The biggest differences were seen among both Boise State groups where after the activity, both groups were more likely to agree that science is hard for them to understand.

Figure 20



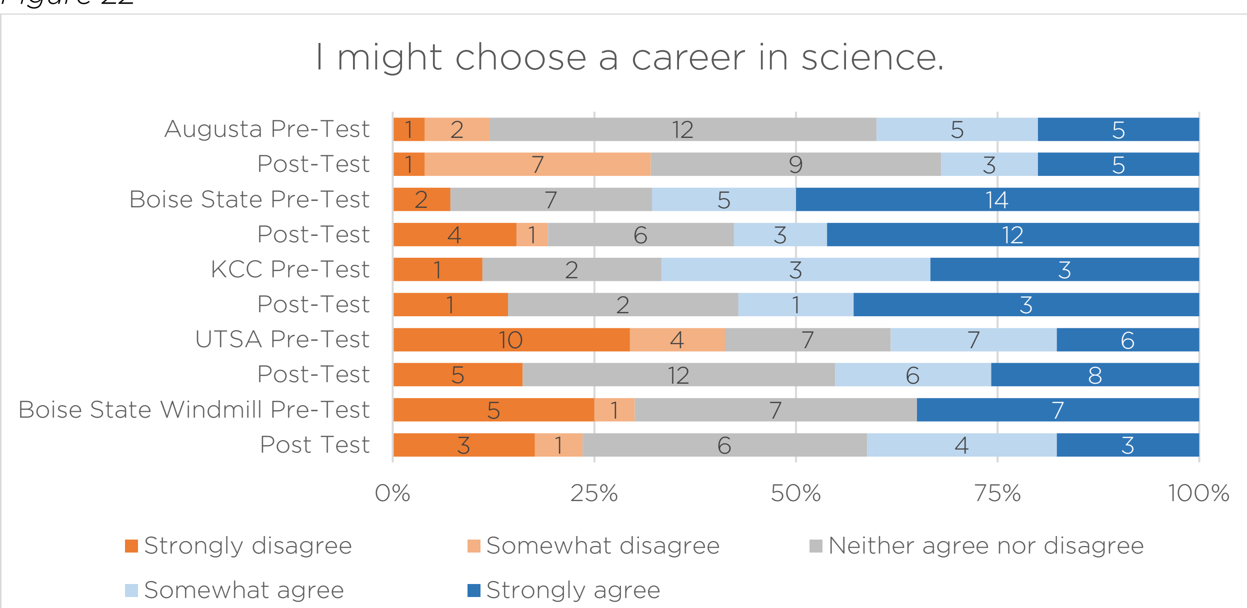
Students were asked about their desire to pursue a career in STEM. For all universities participating in the 3D printing activity, more students agreed they might choose a career in math after the activity. However, among students participating in the windmill activity, seven less students agreed they would choose a math career after the activity.

Figure 21



There was no real pattern between pre- and post-test responses asking if students would choose a career in science. The most notable changes were among Augusta students, where more students disagreed they would choose a career in science after the activity and UTSA where less students were likely to disagree.

Figure 22



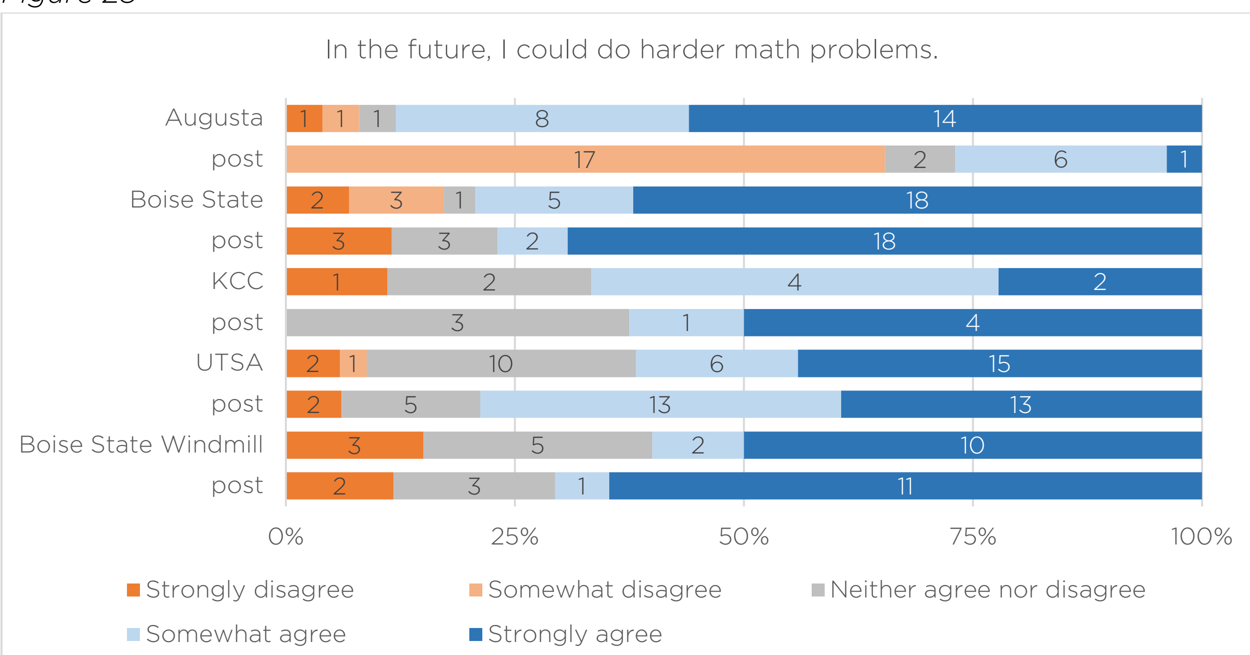
Overall, elementary students were less likely to believe they were good at science or math and also less likely to want to pursue science or math as a career after participating in the activity. Though sample sizes are too small to calculate a correlation, the pattern is consistent enough to consider ways to improve attitudes toward STEM during the IME inquiry activities. It is possible the activities may be overwhelming students or limiting their view of what careers in STEM may look like. For example, having the windmill activity fresh in their minds could make students think of the math and science they did during the activity specifically and use that to decide if they want a job in STEM.

Research Question 5: To what extent does the ACE model promote mathematics learning in elementary school students?

In the pre- and post-surveys, students were also asked to rate their level of agreement with statements relating to their ability to do math and science work, including their desire to learn about STEM topics out of school.

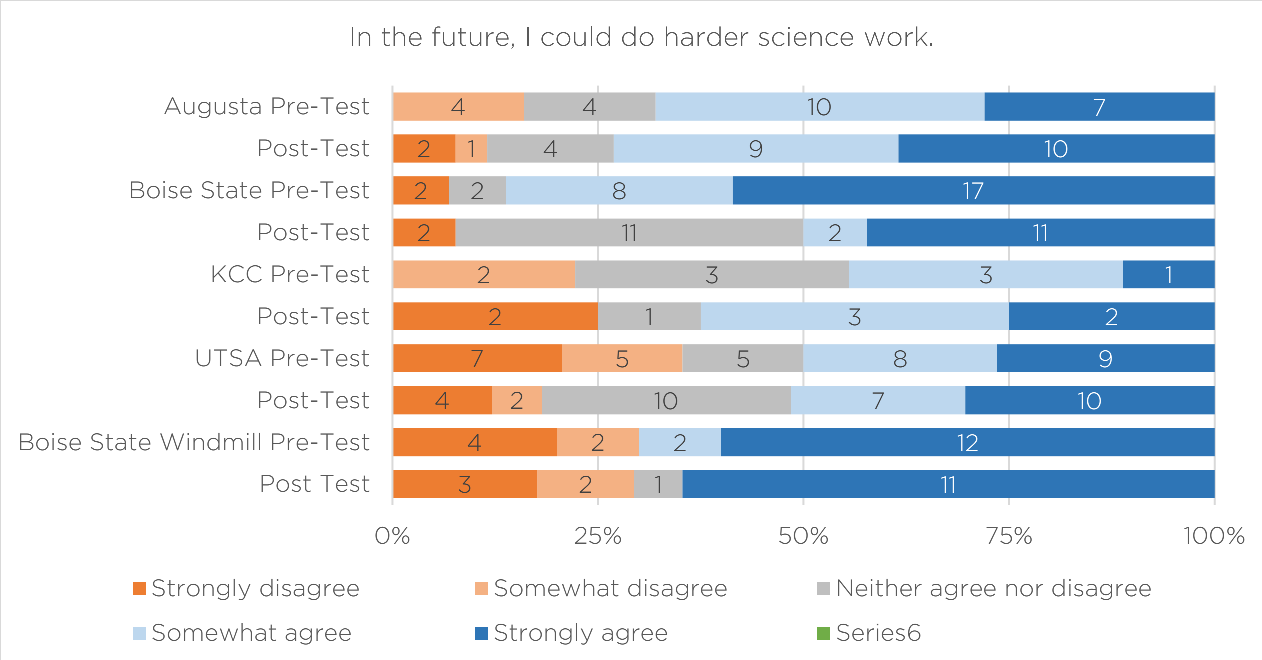
When asked if, in the future, students could do harder math problems, most students replied somewhat similarly before and after the activity. The biggest change was seen at Augusta, where after the activity, 17 students disagreed they could do harder math problems compared to only two before the activity. Alternately, UTSA went from 21 to 26 students agreeing they could do harder math problems after the activity.

Figure 23



However, when asked about their ability to do more difficult science problems, very little change was seen across universities. The exception is among students participating in the Boise State 3D printing activity where 25 students agreed they could do harder science work in the future before the activity and then only 13 agreed after.

Figure 24



Students were also asked about their agreement to the following statements regarding using STEM outside of the classroom:

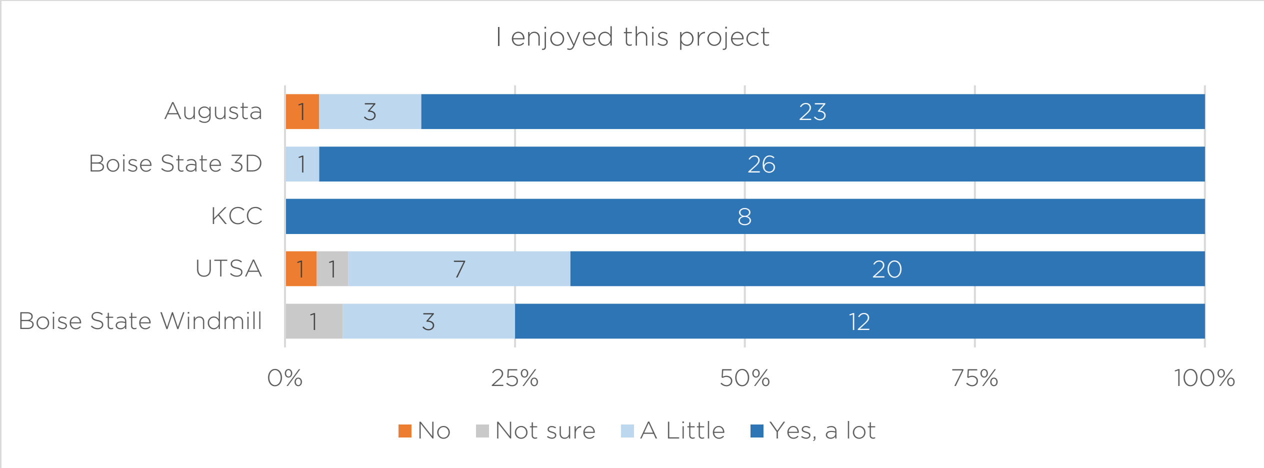
- If I learn engineering, then I can improve things that people use every day
- I am interested in what makes machines work
- I am curious about how electronics work
- I want to be creative in my future jobs

Students' agreement with these statements did not change much between the pre- and post-test for any universities and the breakdown can be found in Appendix A (Charts A11-14). The exception was at Augusta for three out of the four statements. Before the activity, 12 students agreed that learning engineering could improve daily life. This number increased to 20 after the activity.

Before the activity, only two students at Augusta were curious about how electronics work and after, 20 students were curious. However, when asked about creativity, the amount of student interested in creative jobs in the future decreased from 22 to eight.

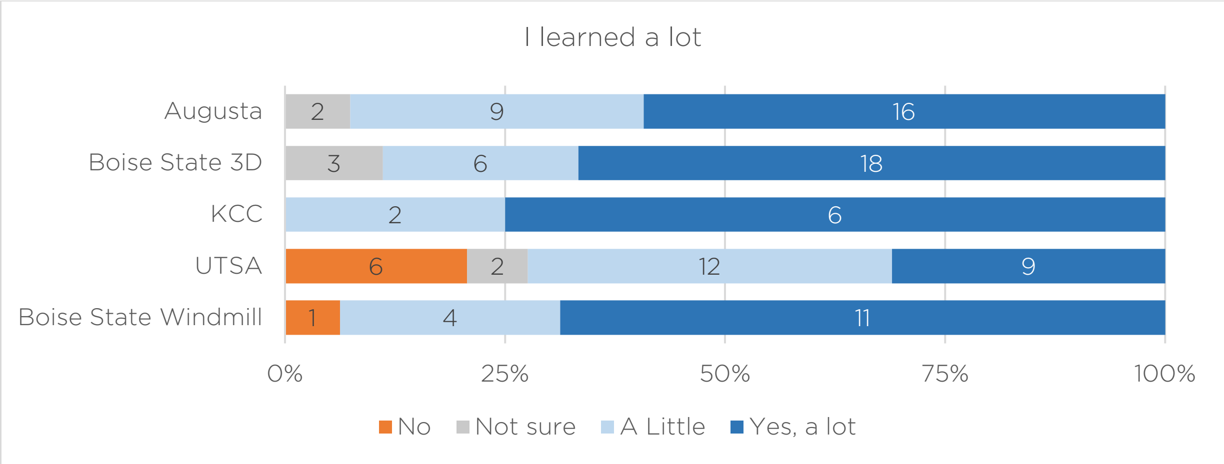
After the activity, students were also asked outright if they enjoyed the project and if they felt like they learned a lot. All but four students across all universities agreed they enjoyed the project at least a little. Out of all the students, 83% agreed enjoying the project a lot.

Figure 25



Only seven students across all universities believed that no, they did not learn a lot. The majority of these students were at UTSA. More students enjoyed the project than reported learning a lot, but over half (56%) of students across universities did.

Figure 26



Based on these survey responses, it's clear that students learned a lot from the activity. For most students, the activity did not change their feelings about their ability to perform in STEM subjects or their desire to participate in STEM outside of the classroom.

PROGRAM IMPACT ON PRE-SERVICE ELEMENTARY TEACHER INSTRUCTORS

Research Question 6: What are the beliefs and perceptions of ACE math course instructors on the effectiveness of the designed course materials in teaching PSETs and in altering teaching processes?

Instructor Perception of the Course

And the end of the semester, instructors were interviewed about their experiences with the course. Since there were only five instructors, there were few common themes expressed, rather individual experiences.

Instructors were asked, "How did the design of the STEM module relate to the PSETs' learning of basic content?" Overall, instructors agreed the module helped students apply previously taught content and helped them integrate theoretical knowledge to real-world applications. Though one instructor noted that not all students have the same prior knowledge around STEM topics when entering the course and there is an opportunity to build a solid foundation of relevant concepts.

Instructors were also asked if the ACE course changed their understanding of PSET learning. Instructors identified the value of providing PSETs with opportunities to actively engage in STEM lessons themselves. Specifically, by participating in this project, PSETs gained a deeper understanding of the content, pedagogical strategies, and practical challenges associated with teaching STEM. It also enabled them to make connections across STEM disciplines, recognize the relevance of STEM education, and develop the confidence and skills needed to create engaging and meaningful learning experiences for their future students.

Another instructor mentioned the ACE Course model allowed them to see the need for PSETs to learn classroom management skills and gain practical teaching experience. Noting that by gaining hands-on teaching experience, pre-service teachers can better understand the nuances of working with students, develop rapport, and employ effective classroom management strategies.

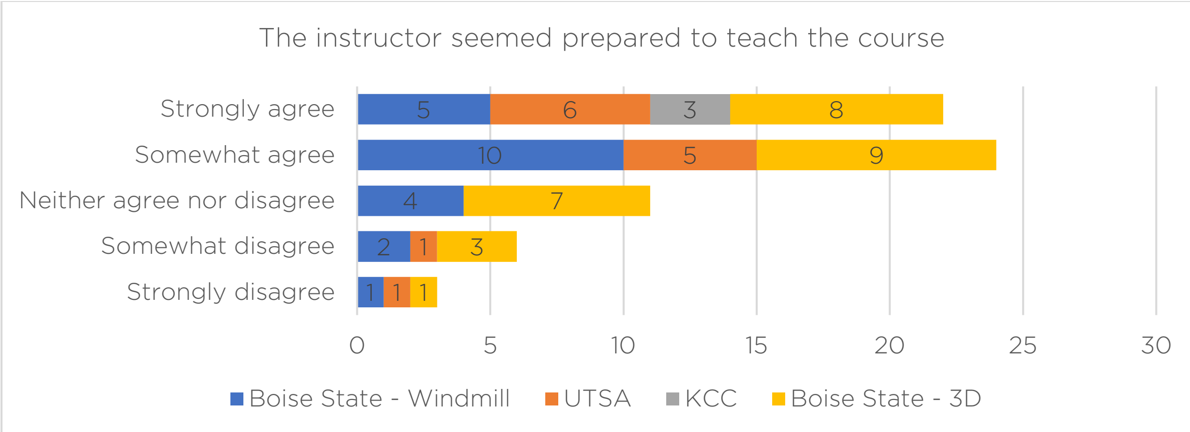
When asked if the ACE course model will influence their future teaching, instructors noted that PSETs need to have real-world teaching experiences that allow them to work directly with elementary school students to help them understand the realities of the classroom. One instructor noted that the course made them want to collaborate more with other instructors to provide PSETs with more hands-on STEM learning experiences.

Instructors also shared issues with implementing the STEM activity. Some problems listed included having technological problems with the module, needing more training on how to implement the project and course model, and trying to manage different levels of student engagement in the project.

PSET Perceptions of the Instructor

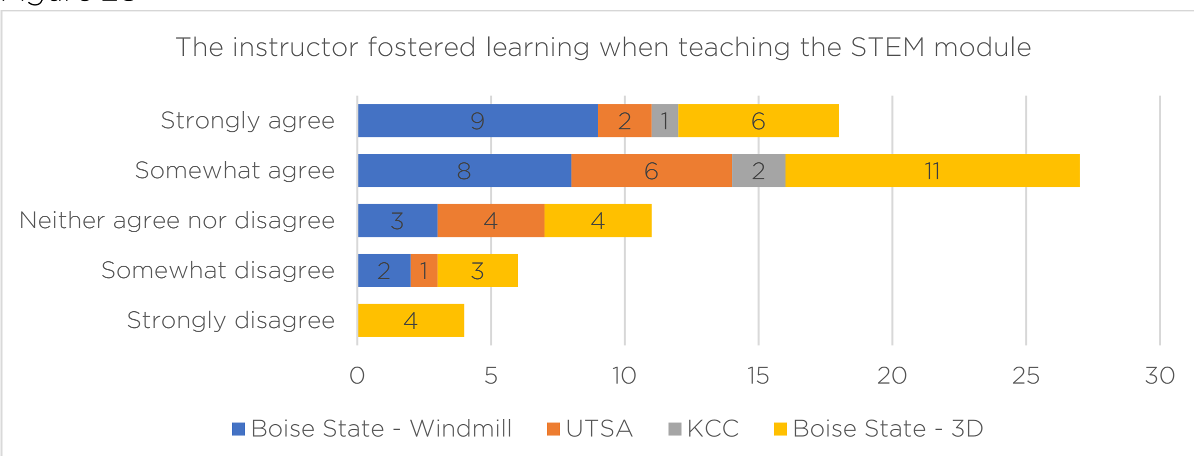
In the ACE Course Evaluation, PSETs were asked to evaluate their instructor's performance. A majority of PSETs (67%) across universities agreed their instructor seemed prepared to teach the course. There was no pattern across universities and Augusta did not participate in this survey in Fall 2022.

Figure 27



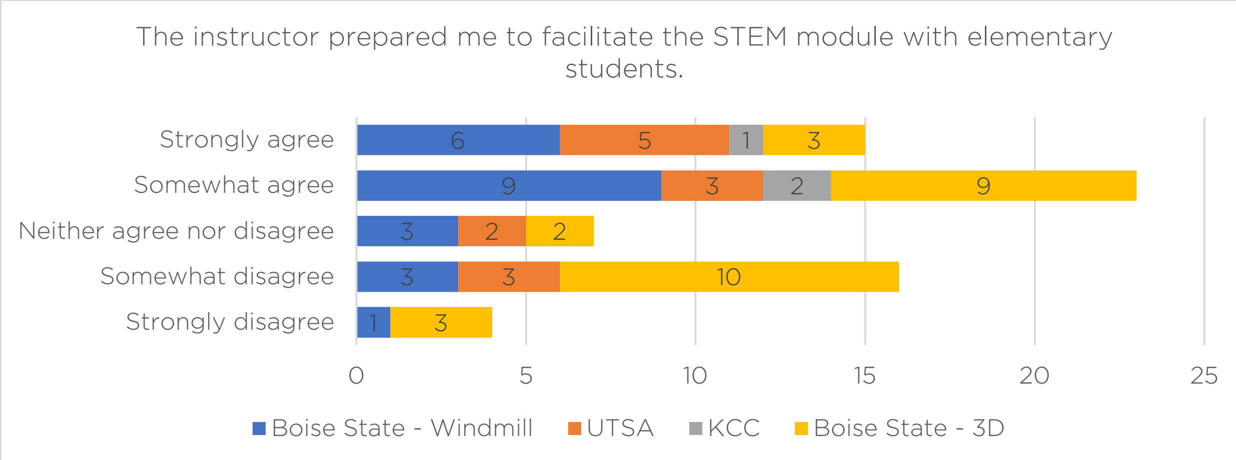
When asked if the instructor fostered learning when teaching the STEM module, 68% of PSETs agreed. Boise State PSETs participating in the 3D printing project were the only PSETs to strongly disagree with this statement.

Figure 28



Boise State PSETs participating in the 3D printing project were much more likely to disagree to the statement, "The instructor prepared me to facilitate the STEM module with elementary students." UTSA PSETs were less likely to agree with this statement compared to the other statements. This increased disagreement could indicate an opportunity to improve strategies used to prepare PSETs for working with elementary students.

Figure 29



PSETs were asked to provide detailed feedback about their experiences with their instructors. Augusta did not participate in these questions. Across universities, PSETs most commonly reported instructors were able to enhance their learning through instructional support and engagement. This includes responsiveness to PSET needs by answering questions, providing examples, being approachable, and creating a supportive learning environment.

When asked about areas of improvement for instructors, PSETs most commonly reported a need for clarity in communication. This includes a need for better understanding of expectations, more explicit directions, and improved explanations of concepts.

Instructors feel the course is impactful on PSET learning and see the importance of implementing the ACE course model. PSETs feel the instructors are mostly impactful in teaching the course but see room for growth in explaining the concepts of the course and the expecations.

SPRING 2023 ANALYSIS

PROGRAM IMPACT ON PRE-SERVICE ELEMENTARY TEACHERS

Research Question 1: To what extent does the ACE model promote PSETs' mathematics learning and increase their teaching abilities?

PSET Math Skills Attainment

High School Math Courses

The ME.ET survey indicated that before entering university, most of the PSETs took math courses through Grade 12 of high school (about 80%). Almost all PSETs across universities took a Geometry and an Algebra 2 course, with most students completing Geometry before Grade 11 and Algebra 2 before Grade 12.

When looking at higher level math courses, only 20% of PSETs took a calculus class though 53% reported taking precalculus. The most commonly reported class taken in Grade 12 was statistics, followed closely by precalculus.

Table 3: Percent of PSETs from a university taking each course

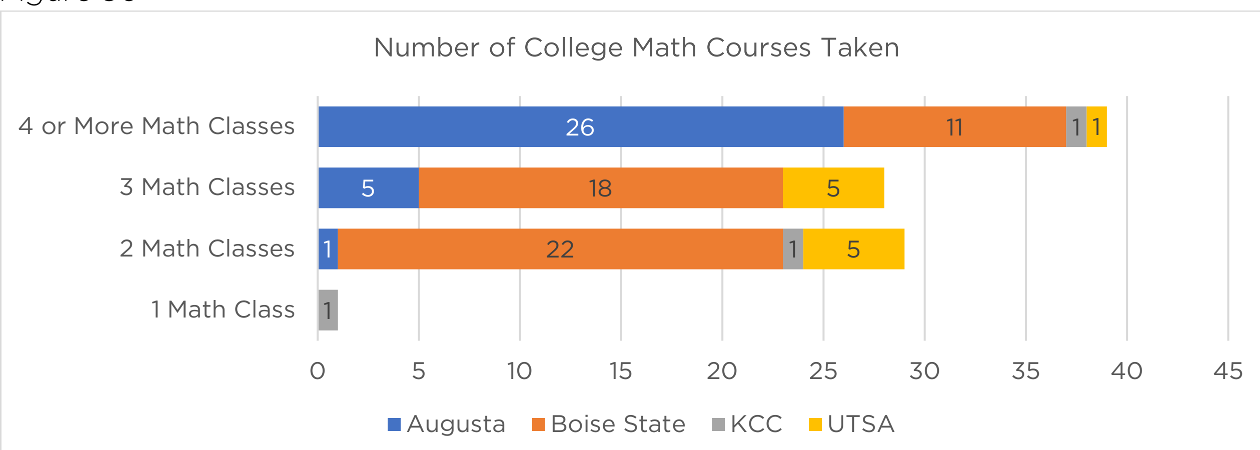
Course*	Augusta (n=33)	Boise State (n=51)	KCC (n=3)	UTSA (n=11)
Calculus	6	13	0	1
Statistics	16	18	0	2
Precalculus	18	28	2	4

* See Appendix B (Charts B1-4) for more details

College Math Courses

When asked **on the ME.ET survey** how many college math classes PSETs took, 96 out of 97 PSETs took at least two. All but six Augusta students (81%) completed four or more, and Boise State and UTSA students varied in their experience. About half of UTSA students took only two math courses, and half took three. Across all universities, 69% of students completed three or more courses. As 75% of the PSETs were either juniors or sophomores, the number of classes taken indicates that more students were recently in a math learning environment before taking this course.

Figure 30



* Math courses include statistics and computer science courses

Course Learning

During **the first reflection**, PSETs were asked, "Was there a unique experience (either positive or negative) that influenced your interest/perception in STEM?" The most common positive experiences were those that made STEM fun (15 mentions), STEM experiences with good teachers (11 mentions), and experiences that connected STEM concepts to their importance in the future (10 mentions).

The most common reported negative experiences were those that siloed STEM subjects (18 mentions), those that were not presented in an interesting way (11 mentions), and general anxiety toward math (8 mentions). There is not a notable pattern or difference across universities for these responses.

At the end of the course, **in the ACE Course Evaluation**, PSETs were asked what aspects of the course were most valuable to their learning experience. Overwhelmingly, PSETs reported the hands-on experience of working with students

(45 mentions) was the most valuable aspect of the course. This encompasses the value placed on working directly with students and engaging in CBEL activities. PSETs expressed the importance of being able to apply their knowledge in real-world settings, work with elementary students, collaborate in teams to teach lessons, and interact with students to enhance their learning.

When looking at the whole of this data, it is clear that coming into the course, PSETs in this group had some math experience but not likely in higher level math courses. At the outset of the course, it is not clear if the course increased their ability to learn STEM subjects as they did not mention it in their final reflections. It does seem clear that PSETs felt what they did learn was relevant to their desired outcomes and they gained valuable experience.

PSETs Math Teaching Ability

In the initial written reflection at the beginning of the course, PSETs asked what they most wanted to learn about teaching STEM during the course. The five more common responses were:

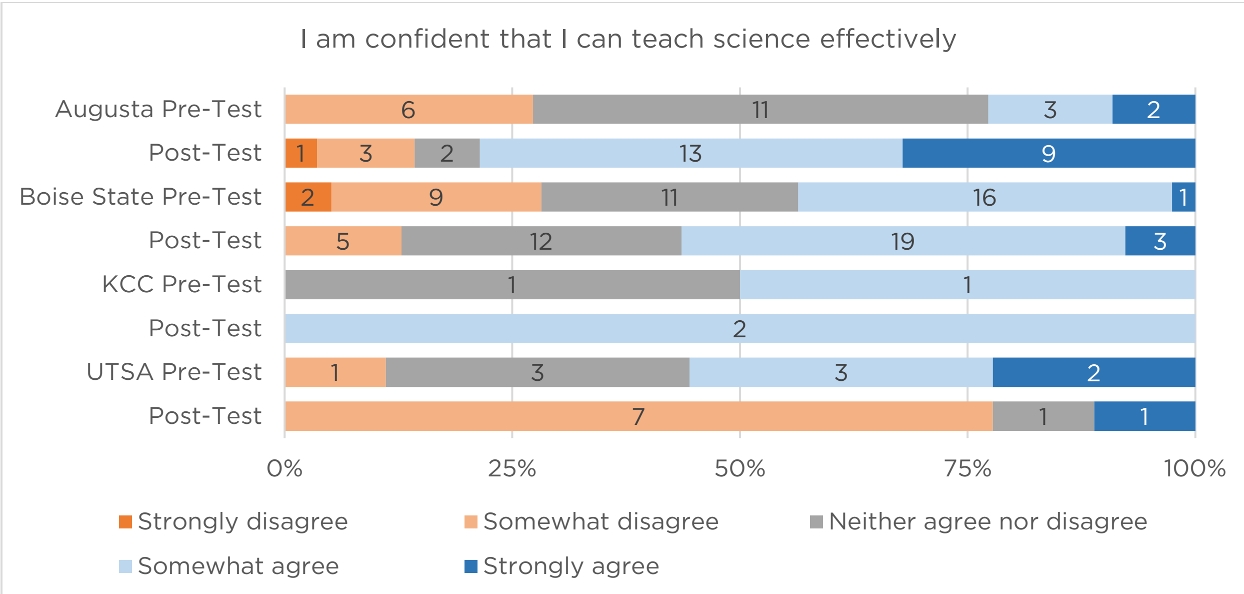
- Knowing how to apply what they learn in the course in the future (26 mentions)
- Gathering STEM teaching resources (21 mentions)
- Learning how to make STEM fun for students (16 mentions)
- Learning how to foster student passion in STEM (15 mentions)
- Knowing how to make STEM easier to understand (14 mentions)

Augusta PSETs were most interested in gaining teaching resources (14 mentions) while Boise State PSETs were most interested in knowing how to apply what they learn in the future (17 mentions). Too few PSETs responded from KCC and UTSA to identify any patterns.

Some lesser mentioned but notable objectives of the course included wanting to gain more knowledge in how to teach math (11 mentions), learning about different types of projects (7 mentions), and learning age appropriate STEM lessons (5 mentions).

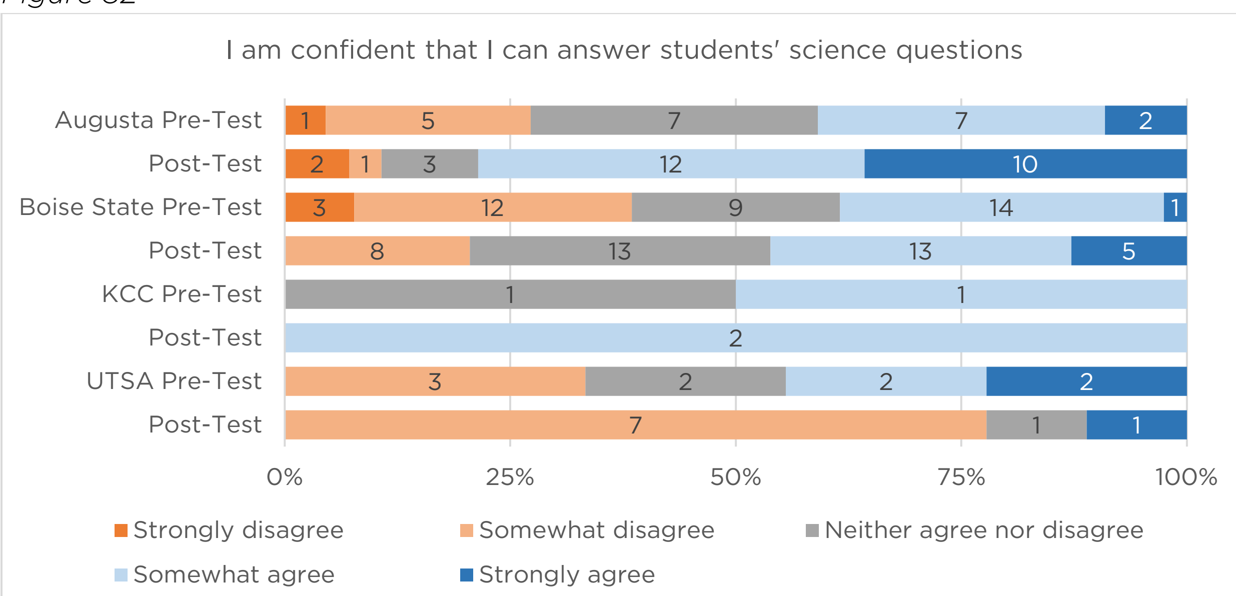
Figures 31-33 demonstrate data from PSETs pre- and post-T-STEM surveys. At the end of the course, the confidence of PSETs to teach science effectively increased at all universities except for UTSA. UTSA notably went from one student not feeling confident to teach science to seven students not feeling confident to teach science. Alternately, Augusta when from five students feeling confident to 22 students feeling confident to teach science effectively.

Figure 31



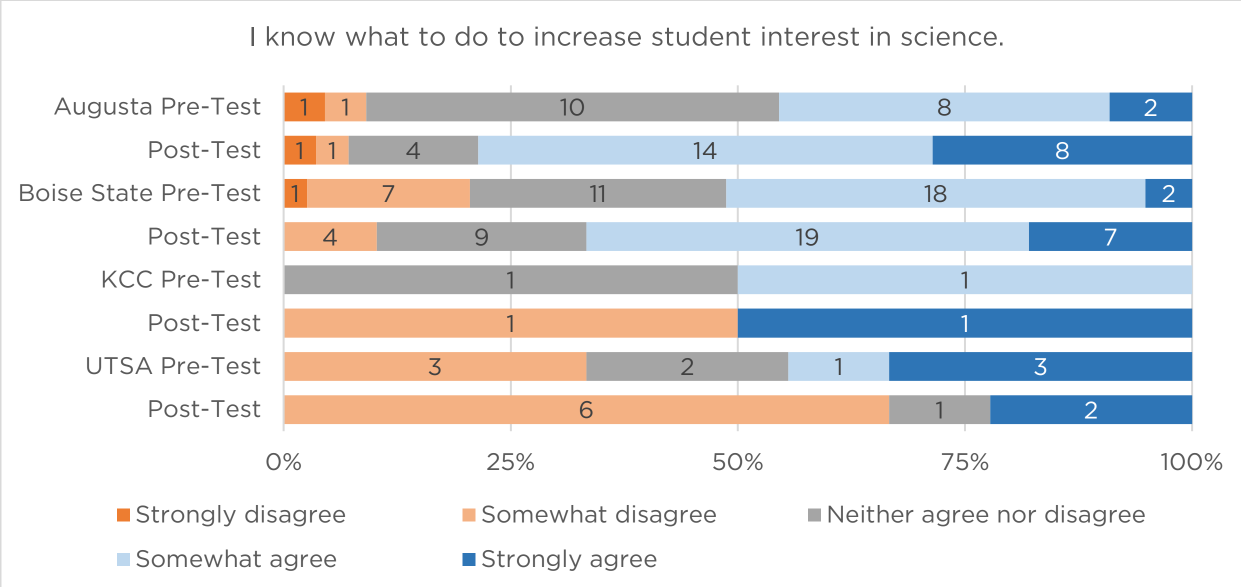
Universities saw similar changes in PSET confidence in their abilities to answer students' science questions. Again, UTSA saw a notable increase of PSETs not feeling confident while Augusta had a notable increase of PSETs feeling confident.

Figure 32



When asked if they know what to do to increase student interest in science, more UTSA PSETs again did not feel confident after taking the course than before. All other universities saw an increase of confidence among PSETs.

Figure 33



During **the final reflection**, PSETs were asked what they learned that is relevant to their future teaching. The most common response was the course increased their math background and understanding (25 mentions). A majority of these responses (17 mentions) were from Boise State PSETs and only one PSET at UTSA reported this outcome. The other common responses included learning how to engage students (14 mentions), a better understanding of how students learn at different paces (13 mentions), and learning teaching strategies to use in the classroom (13 mentions).

Overall, PSETs felt they learned relevant and valuable skills to improve their ability to teach STEM in the future. With the exception of PSETs at UTSA, PSETs reported increased confidence in teaching STEM subjects. This indicates the course is well-designed for improving PSETs STEM teaching skills but these outcomes may be dependent on the instructor of the course.

Research Question 2: To what extent does the ACE model influence PSETs' attitudes and beliefs towards math and STEM?

PSETs STEM Beliefs Entering the Course

During **the first critical reflection** when entering the course, PSETs were asked how they felt about STEM by asking them how they apply STEM to their personal or professional life. While 14 PSETs reported not ever applying STEM to their lives, 39 PSETs reported using STEM to perform everyday tasks. Other notable responses include PSETs using STEM concepts when working with students (20 mentions), applying STEM when using and understanding technology (14 mentions), and using STEM-based critical thinking and problem-solving skills in life (12 mentions).

In **the ME.ET survey** at the beginning of the course, most PSETs at each university were willing to admit they were either good at math or at least sufficient at it. When asked if they like math, PSETs were more likely to strongly agree with the statement.

Figure 34

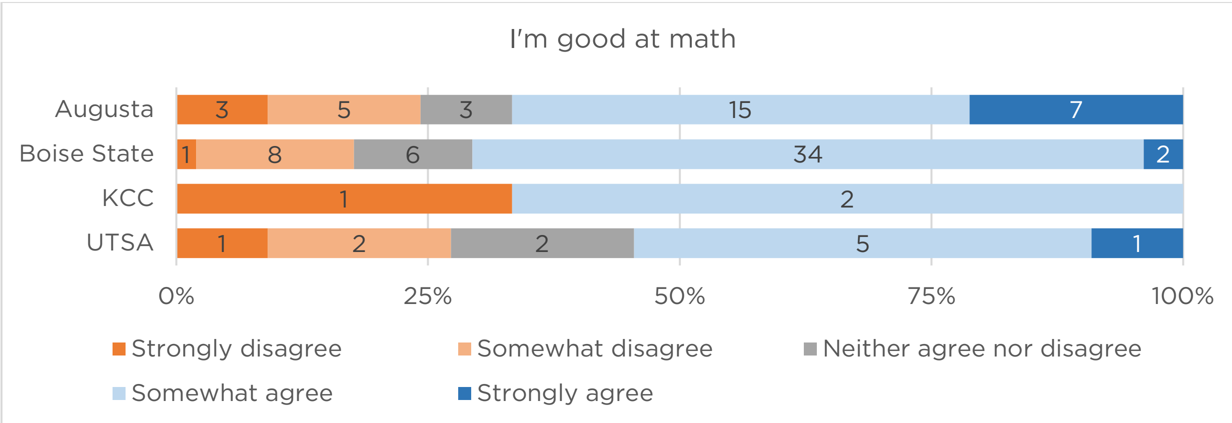
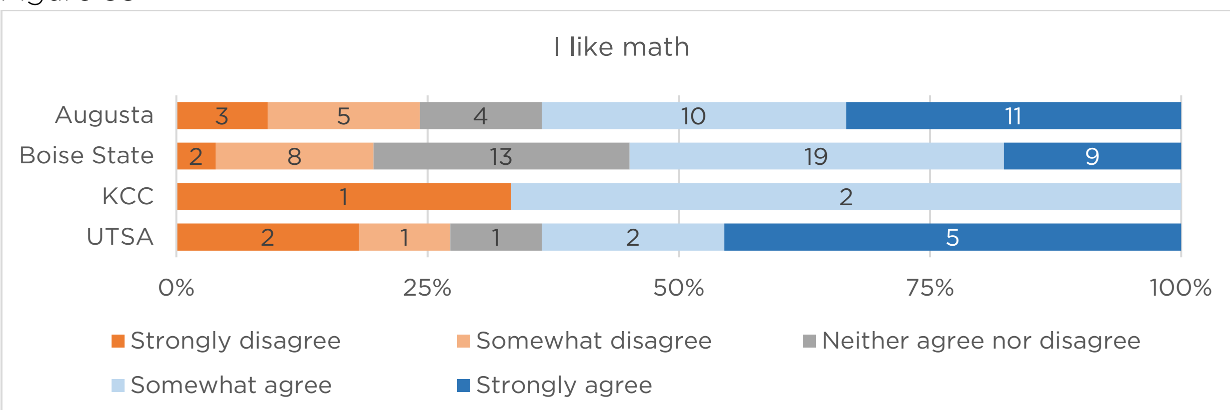


Figure 35



Most PSETs at Augusta and Boise State view math as characterized by abstraction and logic though much fewer agreed from KCC and UTSA. More than half of PSETs agreed there is usually more than one way to solve math tasks and problems, that math is useful for solving everyday problems and in every profession. Most notably, half of PSETs from each university strongly agree there is more than one way to solve math tasks and problems.

Figure 36

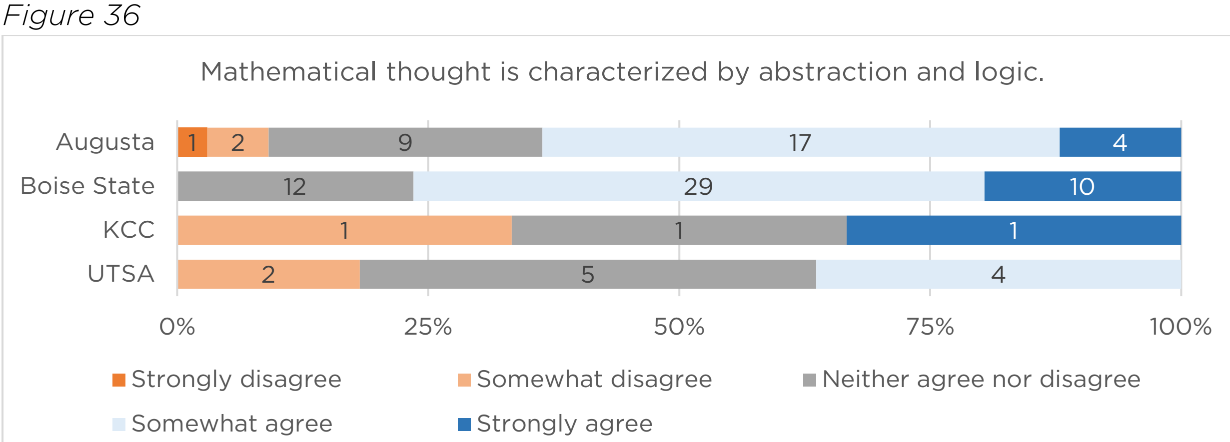


Figure 37

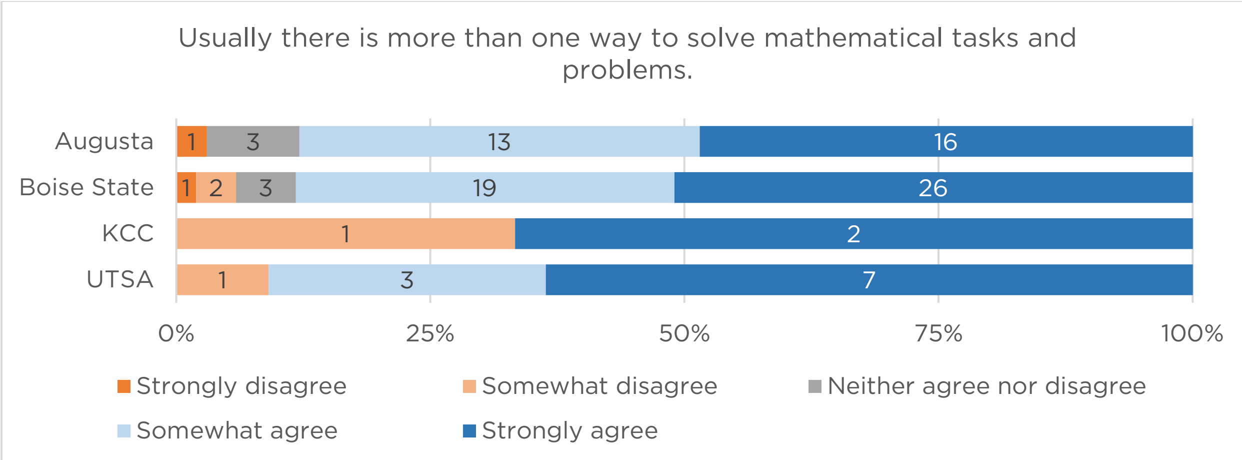


Figure 38

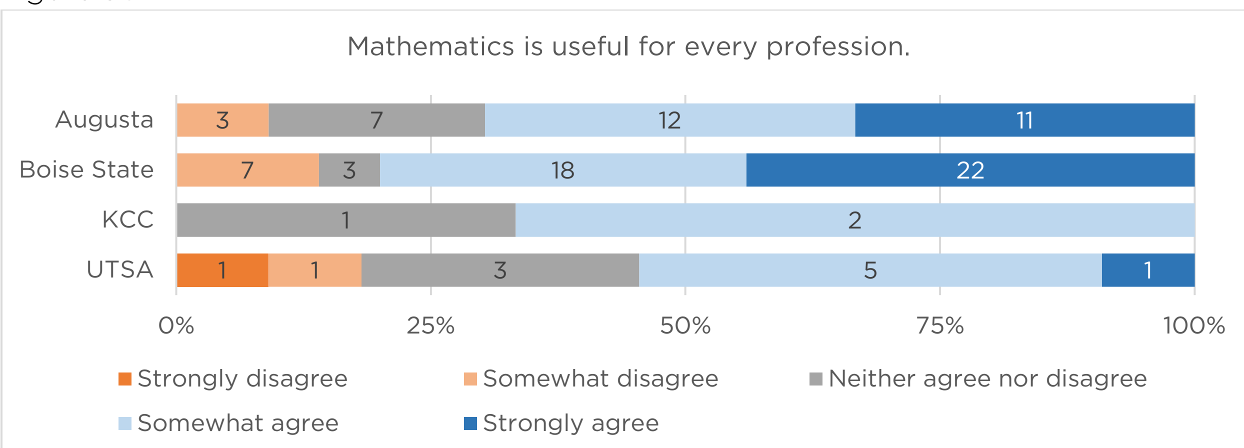
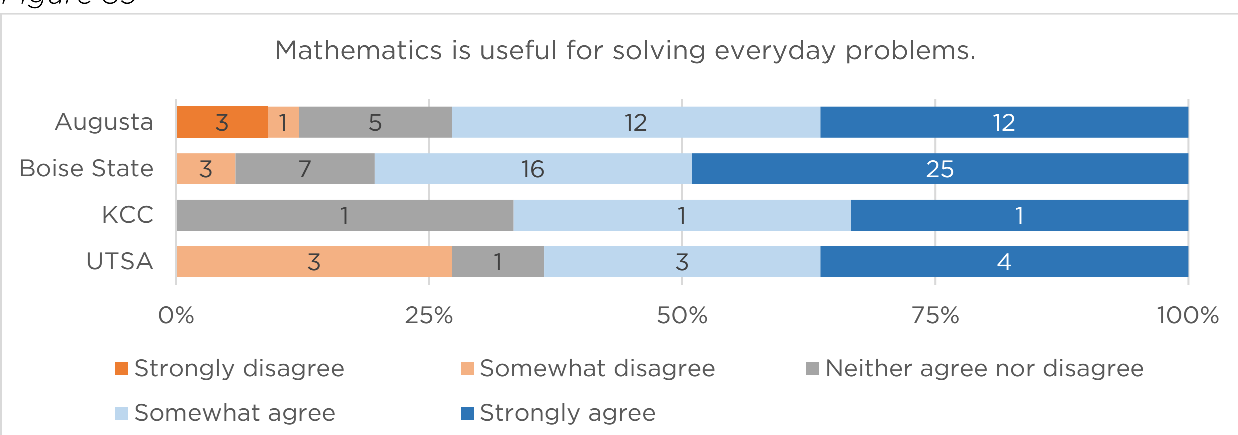


Figure 39



PSETs STEM Beliefs After the Course

In both T-STEM surveys, PSETs were asked about the impact a teacher can have on a student's ability to learn STEM concepts at the beginning and the end of the course. This was measured by asking their level of agreement on the following statements:

- When a student does better than usual in mathematics, it is often because the teacher exerted a little extra effort
- When a student's learning in math is greater than expected, it is most often due to their teacher having found a more effective teaching approach
- Students' learning in math is directly related to their teacher's effectiveness in math teaching
- When a low achieving child progresses more than expected in math, it is usually due to extra attention given by the teacher
- If parents comment that their child is showing more interest in math at school, it is probably due to the performance of the child's teacher

For university specific data on the following analysis, please see Appendix B (Charts B5-10).

At the end of the course, 60% of all PSETs agreed a teacher's extra effort can result in students doing better than usual in math while 28% neither agreed nor disagreed. Almost all PSETs who disagreed with the statement were from Boise State.

A similar distribution of all PSETs agreed when a student's learning in math is greater than expected, it is most often due to their teacher having found a more effective teaching approach. Six fewer PSETs disagreed with this statement, again, all from Boise State.

About 55% of all PSETs agreed students' learning in math is directly related to their teacher's effectiveness in math teaching. Slightly more PSETs disagreed with this statement compared to the previous two, with 13 PSETs disagreeing.

Half of all PSETs agreed when a low achieving child progresses more than expected in math, it is usually due to extra attention given by the teacher while 41% neither disagreed nor agreed.

When asked if parents comment that their child is showing more interest in math at school, it is probably due to the performance of the child's teacher, 58% of all PSETs agreed while 10% disagreed.

During their final reflection, PSETs reported what they plan to do to encourage more students to learn STEM topics. The top three responses were to engage students in fun activities (50 mentions), engage students in real-world application activities (32 mentions), and allow students opportunities to experiment (13 mentions).

When taking all the data for this research question into account, most PSETs had positive feelings toward math and reported using STEM concepts in their everyday lives entering the course. In the post-T-STEM survey, at least half of all PSETs agreed a teacher's effort could improve and change student performance in STEM subjects and reported strategies learned in the course they will take moving forward to encourage STEM. It is clear this course provides opportunities for PSETs to change their attitudes and beliefs toward STEM as it applies to their ability to increase student participation in STEM and their ability to teach STEM. Analysis for this research question could be strengthened by asking some of the questions on the ME.ET survey at the end of the semester to make a pre- and post-course comparison of STEM attitudes.

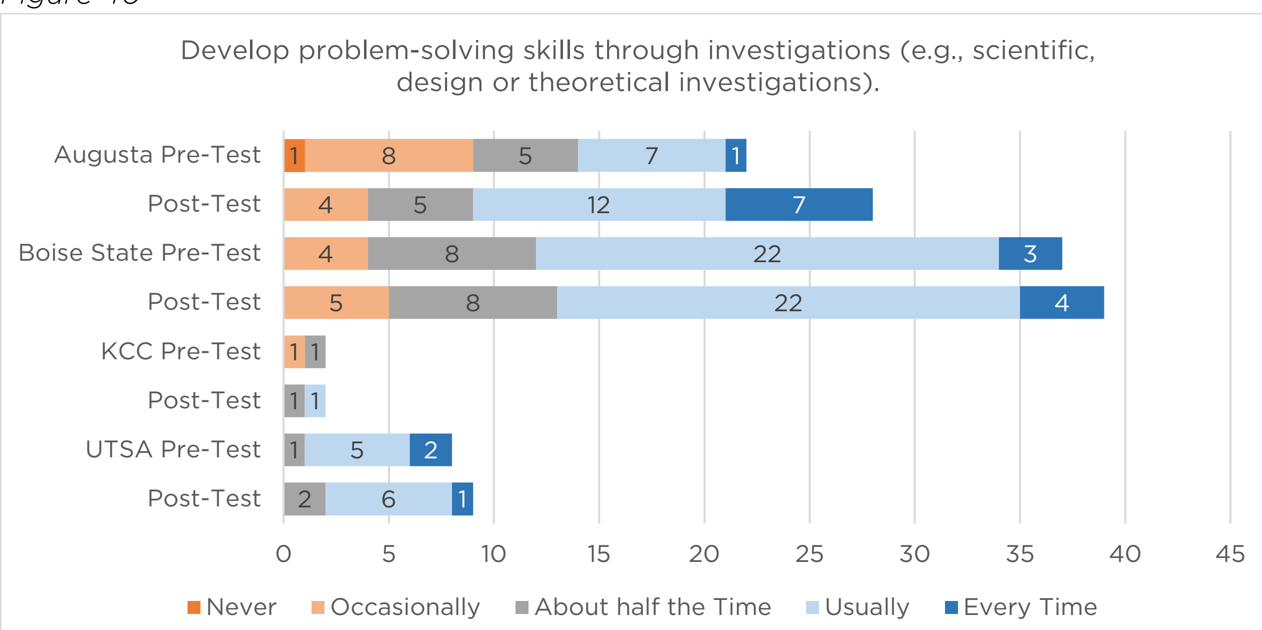
Research Question 3: What is the impact of integrated math-enhanced (IME) STEM inquiry in afterschool activity on PSETs' teaching practices?

In the reflection completed at the end of the CBEL activity, PSETs were asked directly how the CBEL experience shaped their thinking about teaching. The most common responses were that it solidified their passion for teaching (29 mentions), it provided valuable exposure to students (28 mentions), and taught them new instructional strategies (12 mentions). Most of the PSETs (21) that felt the experience solidified their passion for teaching were from Boise State.

In both T-STEM surveys, PSETs were asked both when entering and after participating in the CBEL activity about certain tasks and skills students should participate in and use during instructional time. These tasks and skills are directly related to the IME inquiry process and listed below.

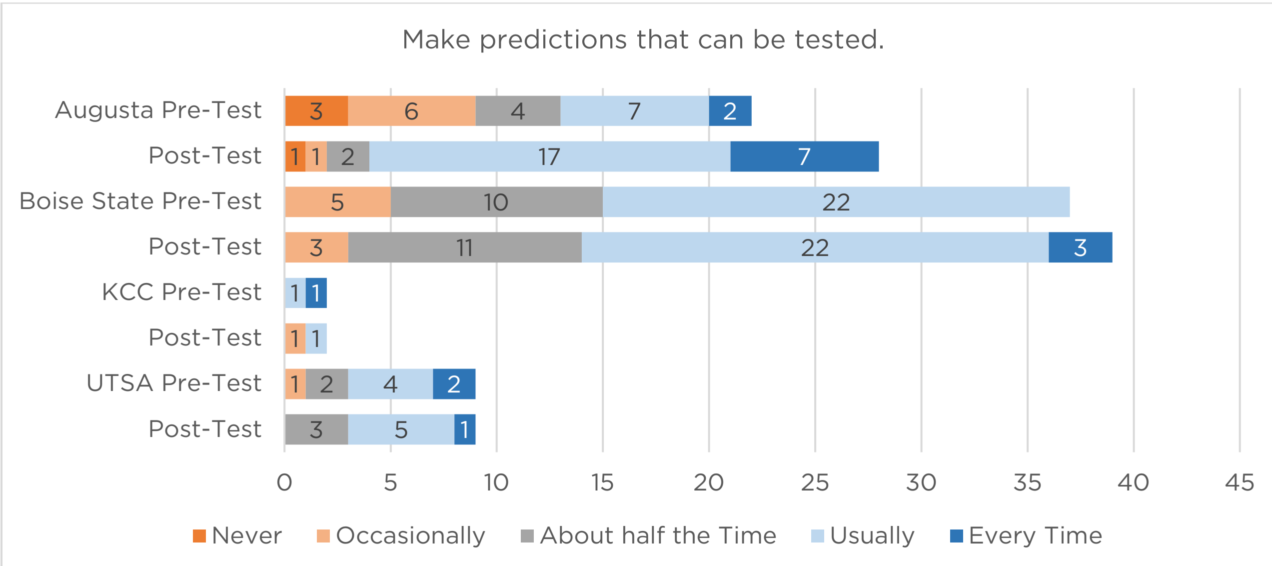
When asked how often students should develop problem-solving skills through investigations, most PSETs across universities believed students should practice this at least half of the time. Beliefs on this did not seem to change much before and after the course except at Augusta, where PSETs increased the amount of time they recommended.

Figure 40



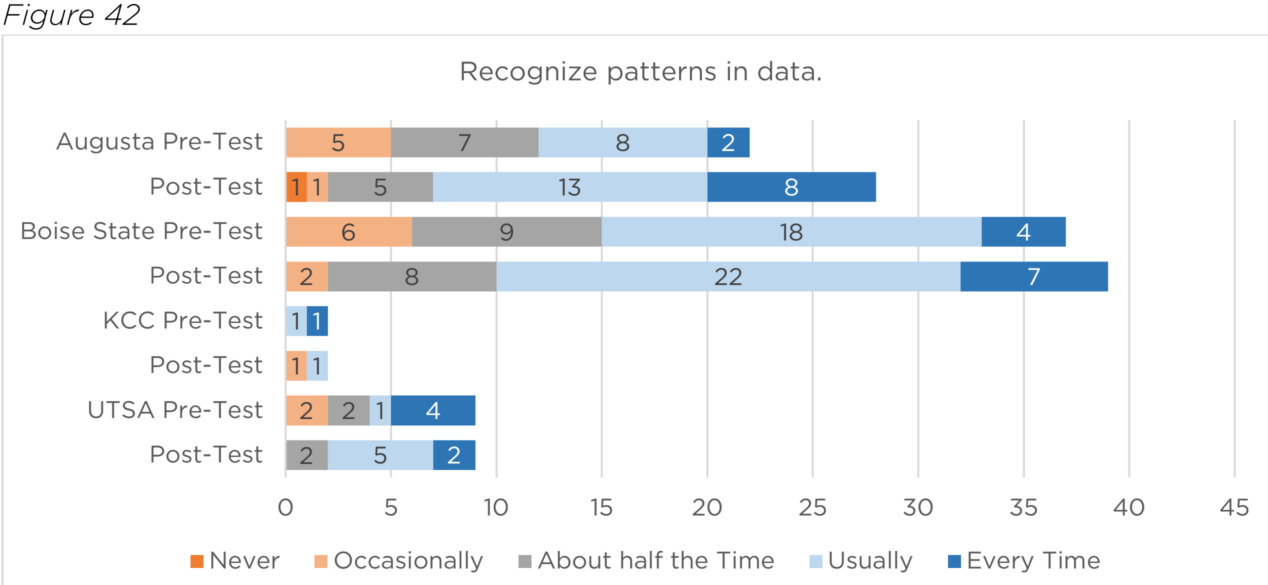
Opinions on the amount of time that should be spent making predictions that can be tested did not change before and after the course, the exception was among PSETs at Augusta where after the course, more than half of PSETs believed this should happen more than half of the time.

Figure 41



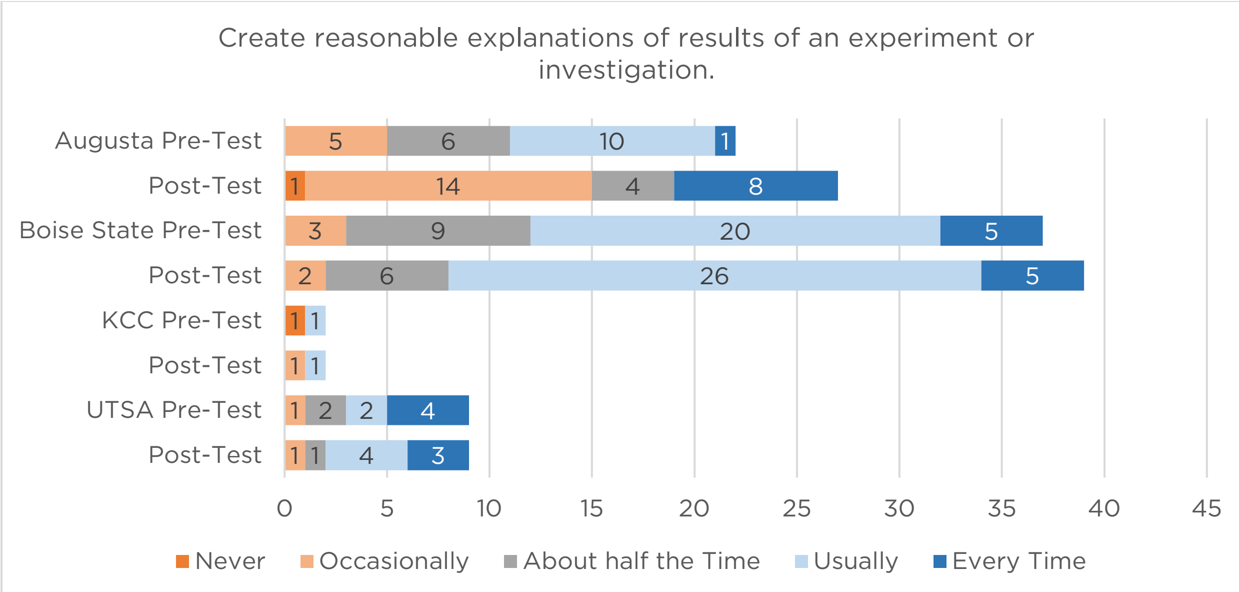
Across all universities, almost all PSETs believed students should spend at least half the time recognizing patterns in data, this was a slight increase from when entering the course. There were no notable changes at any university.

Figure 42



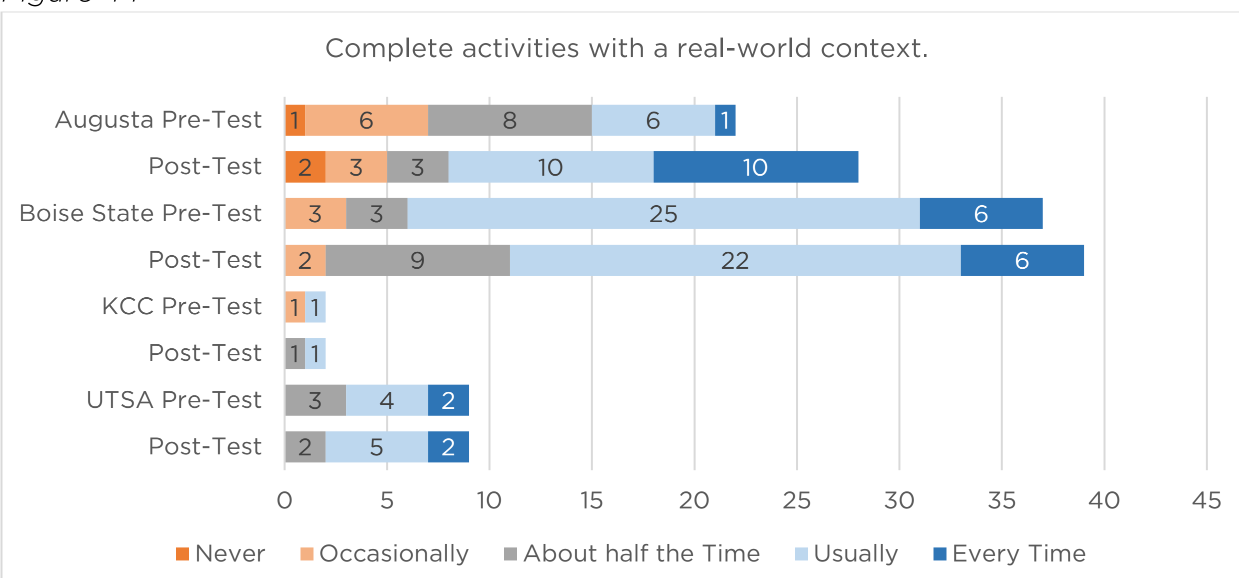
Most PSETs feel students should spend at least half the time creating reasonable explanations of results of an experiment or investigation. This was different at Augusta where most PSETs believed students should spend less than half the time on this, especially after the course.

Figure 43



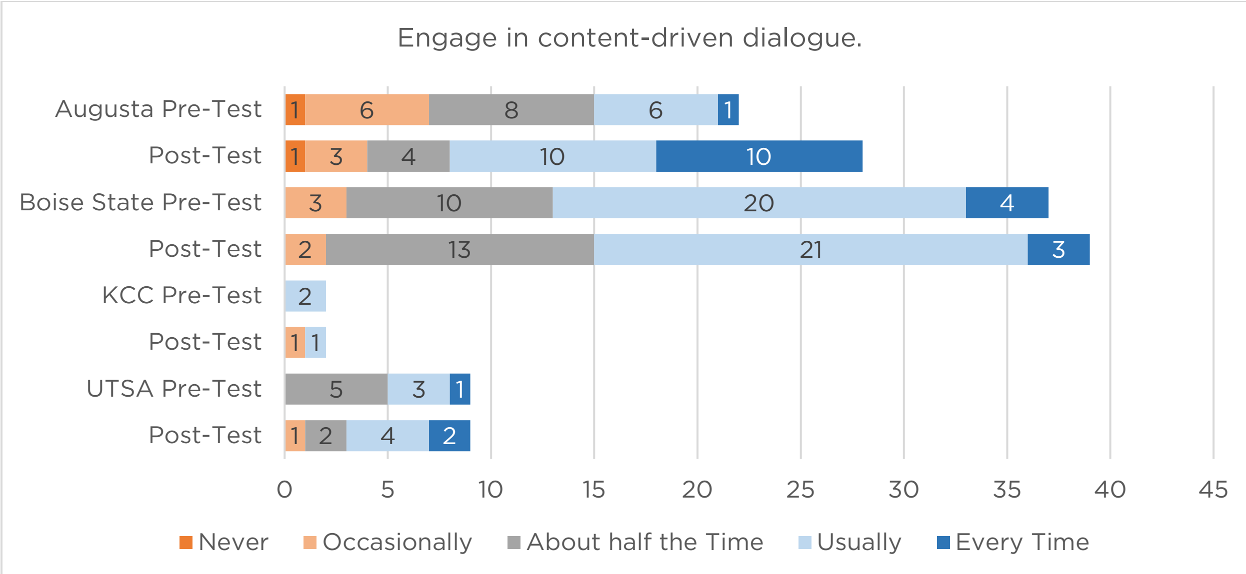
At the end of the course, almost all PSETs believed students should complete activities with a real-world context at least half of the time. The biggest change from before to after the course was at Augusta.

Figure 44



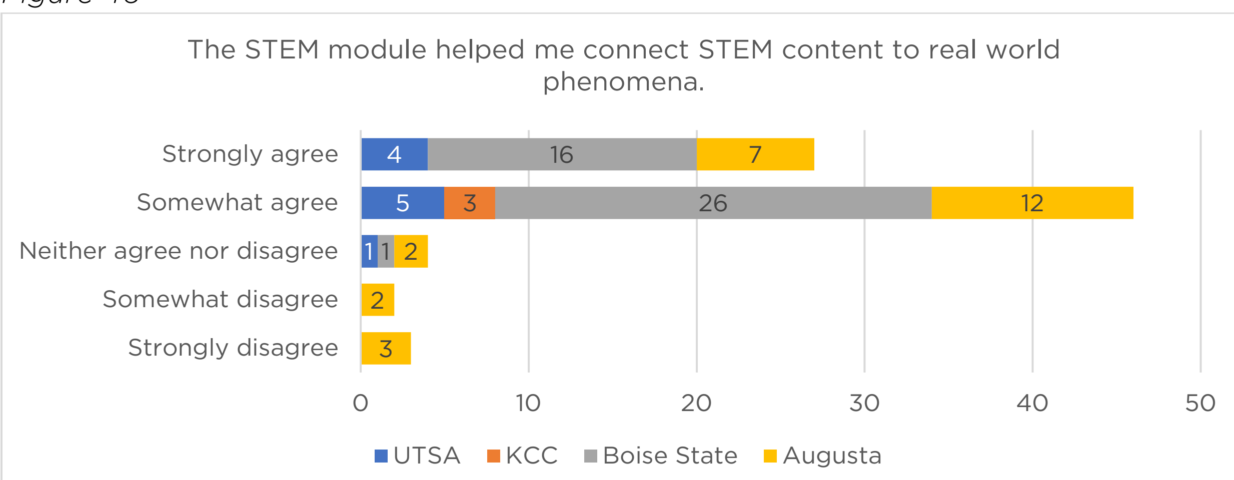
Similar patterns were seen when PSETs were asked about engaging in content-driven dialogue.

Figure 45



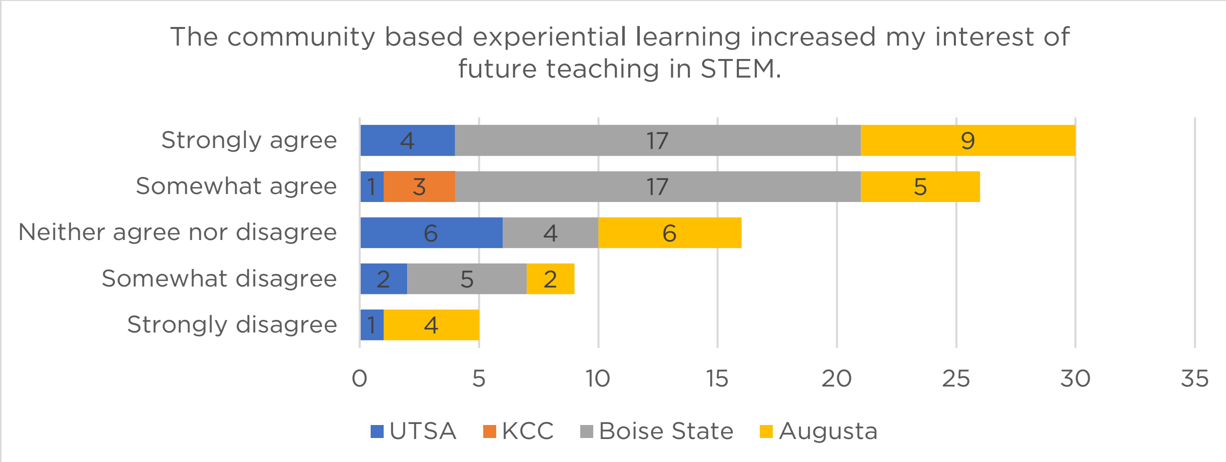
At the end of the semester, PSETs were asked to evaluate the course overall in the ACE course evaluation. One question asked if they felt the STEM module helped them connect STEM content to real world phenomena. All but nine PSETs across all universities agreed the STEM module helped, all of the PSETs disagreeing were Augusta students.

Figure 46



Students were also asked if they felt the community based experiential learning increased their interest of future teaching in STEM. Across all universities, 65% of PSETs agreed the module increased their interest while 16% disagreed.

Figure 47



Using IME STEM inquiry in afterschool activities appears to have mostly positively impacted PSET teaching practices. Many reported the value of the project to increase their passion for teaching, increase student interest in STEM, and learning strategies for teaching such as being flexible and patient. Almost all participating PSETs felt the experience helped them better connect STEM content to real world phenomena and the activity increased their interest in teaching STEM as a whole.

When looking at specific IME skills, such as recognizing patterns in data, creating reasonable explanations of results, and making predictions that can be tested, PSET interest in implementing these tasks varied. This implies that though the course is designed well to increase interest in STEM and in teaching STEM with the IME inquiry activity, it may not be connecting the different concepts and skills related IME inquiry to the process of the activity.

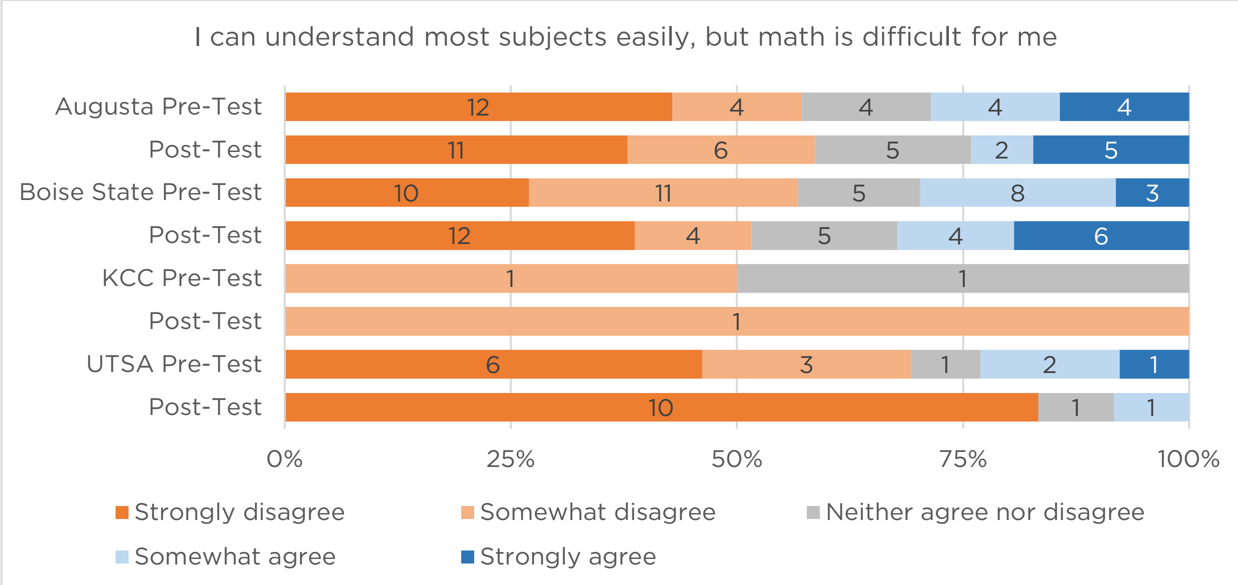
PROGRAM IMPACT ON PRE-SERVICE ELEMENTARY STUDENTS

Research Question 4: How does participating in ACE math course IME inquiry activities influence elementary school students' beliefs or perceptions in STEM?

Elementary students participating in the IME inquiry activities participated in the S-STEM survey both before and after completing the activity. The survey asked them to rate their agreement to statements relating to their affinity toward STEM subjects.

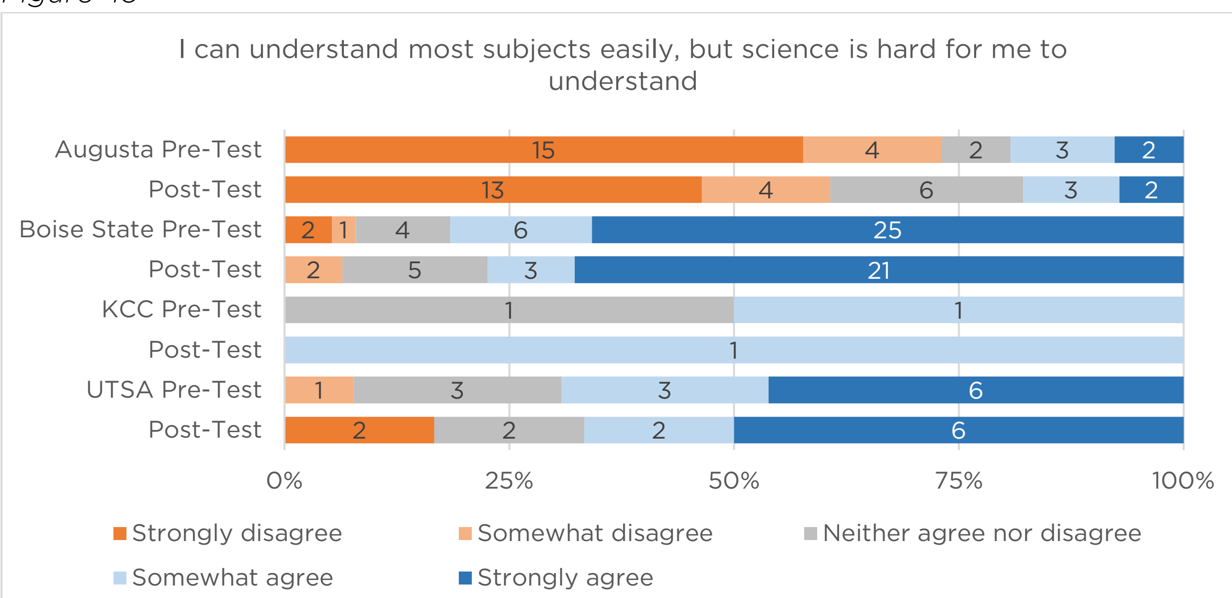
Prior to the activity, most elementary students disagreed that math is difficult for them. After the activity, most universities did not experience a change in number of students feeling confident in math. The most notable change happened at UTSA where students went from somewhat disagreeing that math was difficult for them to strongly disagreeing.

Figure 48



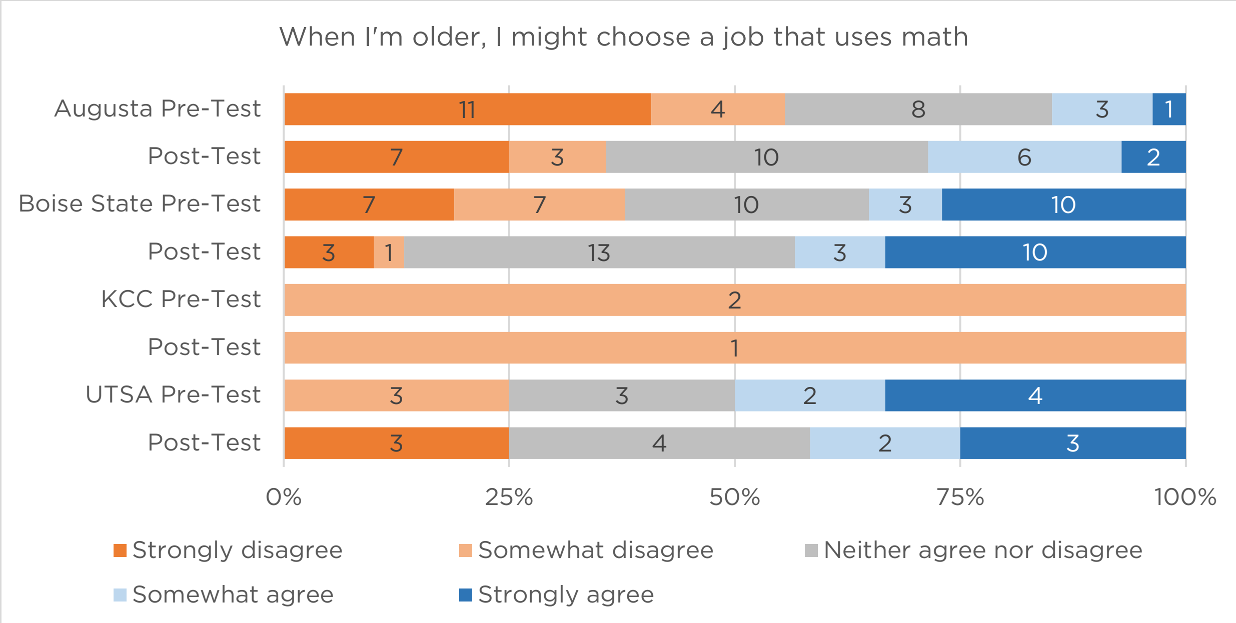
When asked if science is difficult for them, students from both Boise State and UTSA were much more likely to agree than with math. At Augusta more students disagreed to the statement than when asked if math is difficult for them. After participating in the activity, opinions remained mostly unchanged, students at Boise State and UTSA mostly agreed that science is difficult while students at Augusta mostly did not.

Figure 49



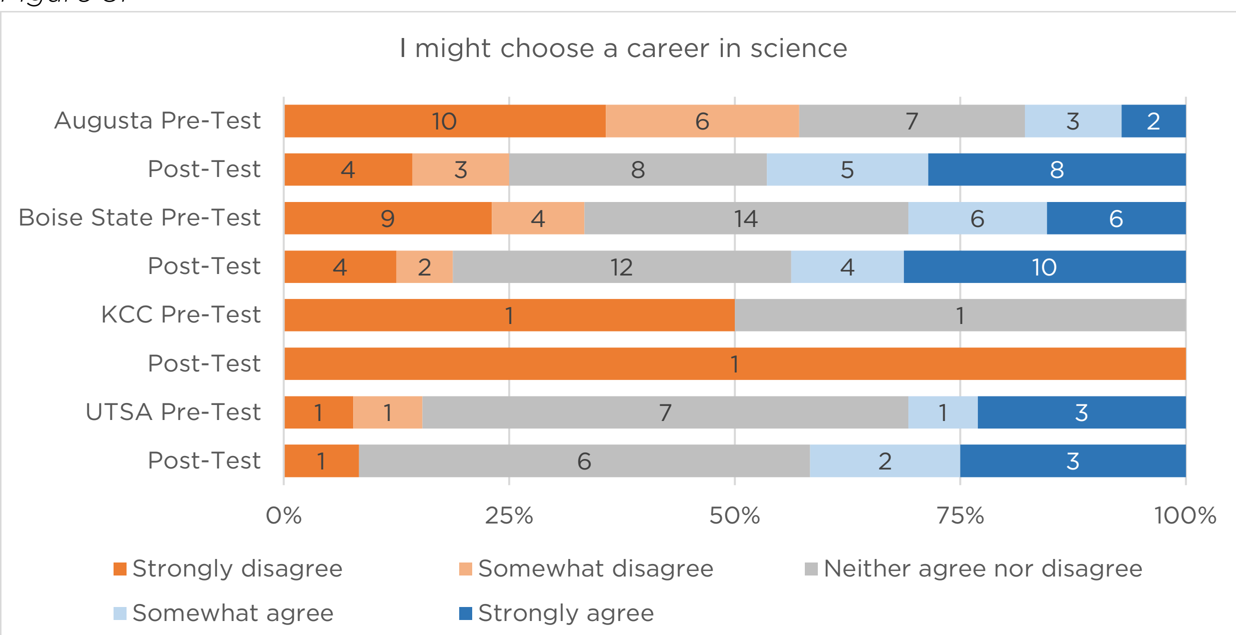
Students were asked about their desire to pursue a career in STEM. Before participating in the activity, students were fairly split in their desire to choose a career that uses math though most students disagreed or were neutral to the idea. After the activity, less students disagreed with the statement. At Augusta, more students agreed and at Boise State, more students felt neutral to the idea.

Figure 50



Much like math, fewer students were interested in pursuing a career in science at the beginning of the activity. After the activity, more students at Augusta, Boise State, and UTSA agreed to wanting to choose a job that uses science. The biggest change occurred at Augusta.

Figure 51



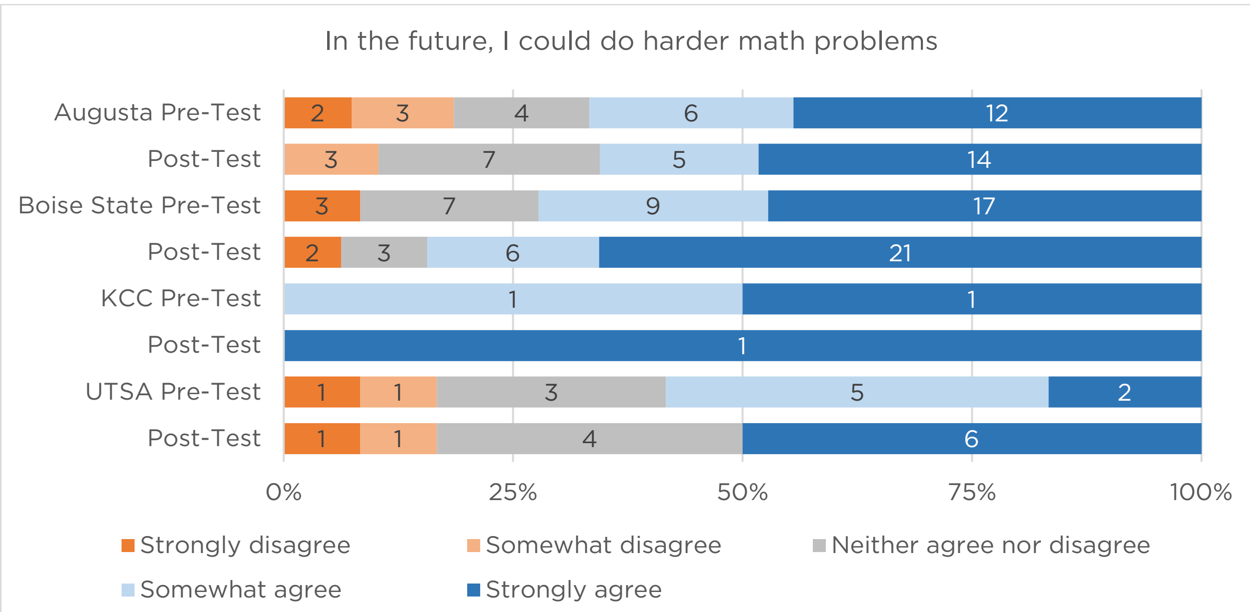
Overall, participating in the activity did not have much of an impact on student perception of their abilities in math and science. This group of students specifically came into the activity feeling confident in math but not science and did not experience much of a change in confidence after the activity. The activity did seem to change student interest in pursuing math and science jobs at each university. This could mean that though the activity may not be designed to help students improve their STEM skills, it is encouraging more interest in STEM.

Research Question 5: To what extent does the ACE model promote mathematics learning in elementary school students?

In the pre- and post-S-STEM surveys, students were also asked to rate their level of agreement with statements relating to their ability to do math and science work, including their desire to learn about STEM topics outside of school.

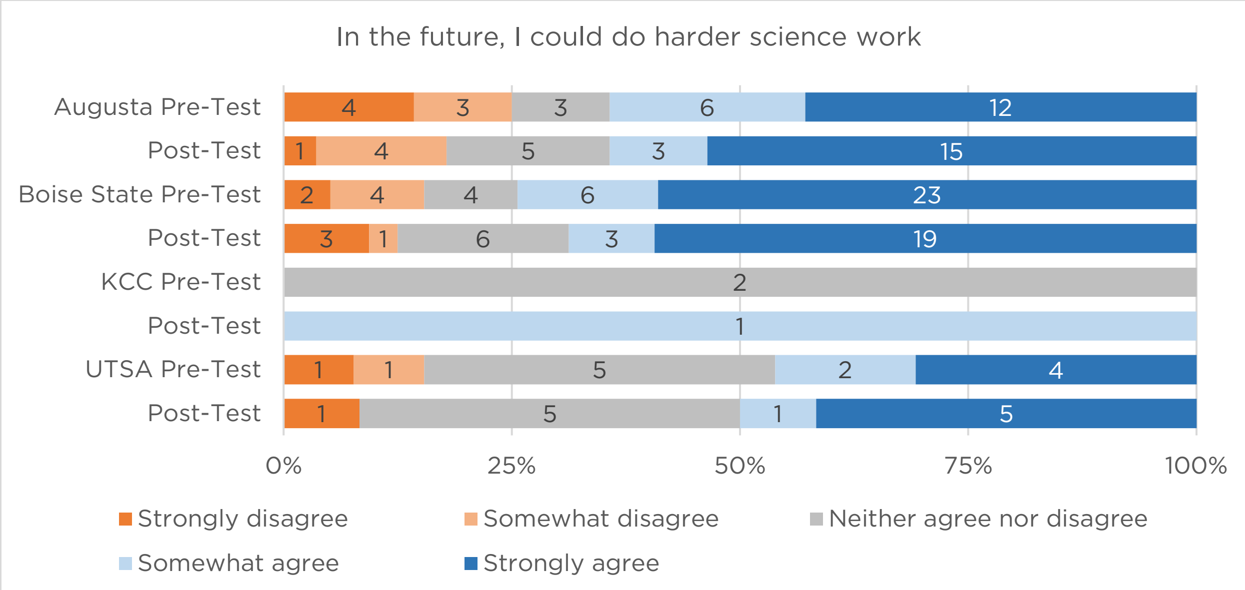
When asked if in the future, students could do harder math problems, most students replied similarly before and after the activity. There were no significant changes across universities. This could be because more than half of students at each university already felt confident in their ability to do harder math when entering the activity.

Figure 52



When asked about their ability to do harder science problems in the future, more than half of all students agreed before the activity. The only real change after the activity is slightly more students strongly agreed rather than somewhat agreed. The was no real notable change across universities.

Figure 53



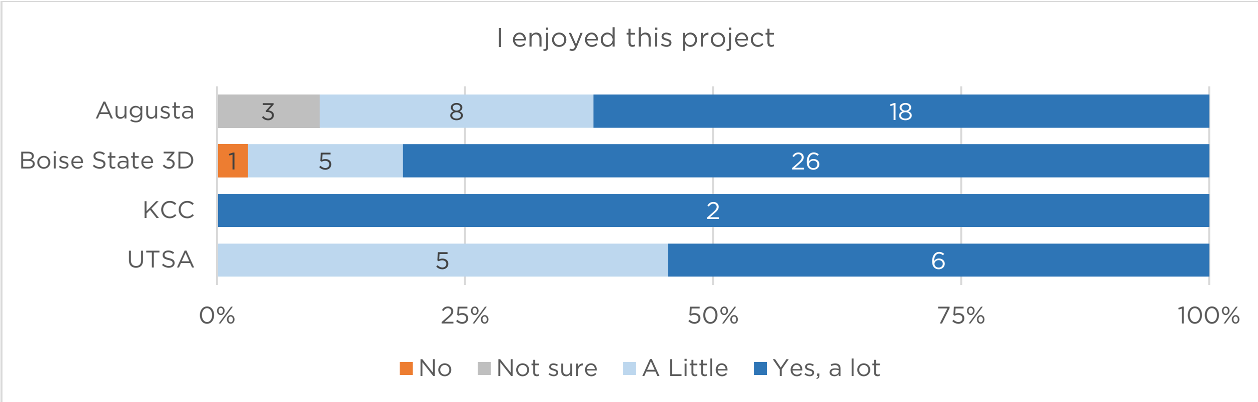
Students were also asked about their agreement to the following statements regarding using STEM outside of the classroom:

- If I learn engineering, then I can improve things that people use every day
- I am interested in what makes machines work
- I am curious about how electronics work
- I want to be creative in my future jobs

Students' agreement with these statements did not change much between the pre- and post-test for any universities and breakdowns can be found in Appendix B (Charts B11-13). The exception was at Augusta for the statement "I want to be creative in my future jobs." Before the activity, 20 students at Augusta agreed they wanted to be creative in their future job and after only six students agreed, with 16 disagreeing. This change could be a result of how the activity was presented.

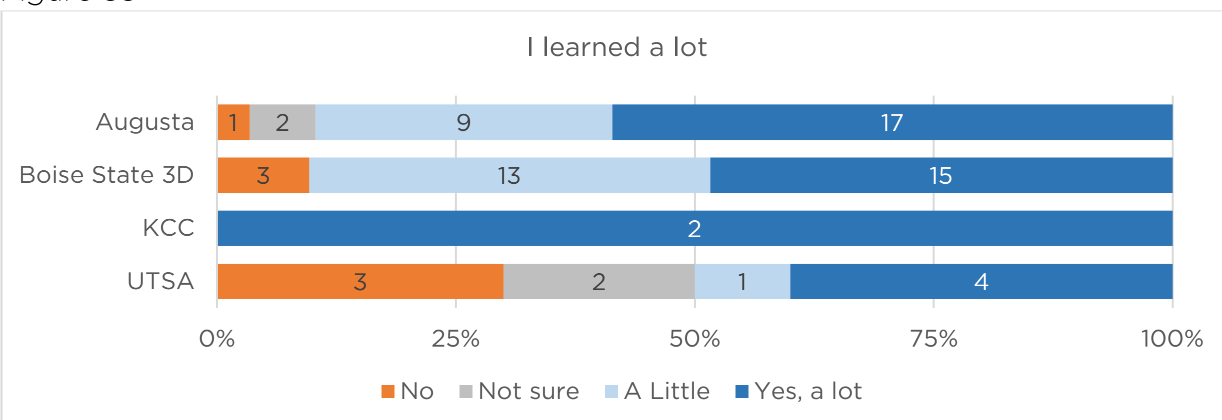
After the activity, students were also asked outright if they enjoyed the project and if they felt like they learned a lot. All but four students across all universities agreed they enjoyed the project at least a little. Out of all the students, 73% agreed to enjoying the project a lot.

Figure 54



Only seven students across all universities believed that no, they did not learn a lot. The majority of these students were at either Boise State or UTSA. About half of all students agreed to yes, learning a lot.

Figure 55



Based on these survey responses, it's clear students learned a lot from the activity. For most students, the activity did not change their feelings about their ability to perform in STEM subjects or their desire to participate in STEM outside of the classroom.

PROGRAM IMPACT ON PRE-SERVICE ELEMENTARY TEACHER INSTRUCTORS

Research Question 6: What are the beliefs and perceptions of ACE math course instructors on the effectiveness of the designed course materials in teaching PSETs and in altering teaching processes?

Instructor Perception of the Course

At the end of the semester, instructors were interviewed about their experiences with the course. Since there are only five instructors, there were few common themes expressed, rather individual experiences.

Instructors were asked if the STEM module related to PSETs' learning of basic content. Three instructors feel the module helped students apply previously taught content and helped them connect math concepts to real-world applications which overall increased their ability to teach STEM. One instructor did note that the siloed learning of STEM topics throughout PSETs education before entering the course made it difficult to introduce the content.

Instructors were also asked if the ACE course model changed their understanding of PSET learning. Two instructors found positive impacts of the model on PSET learning, naming the importance of PSETs participating in active learning, the importance of PSETs having practical teaching experiences, and the importance of teaching STEM concepts together. One instructor admitted to relying on prior teaching practices rather than implementing the ACE model.

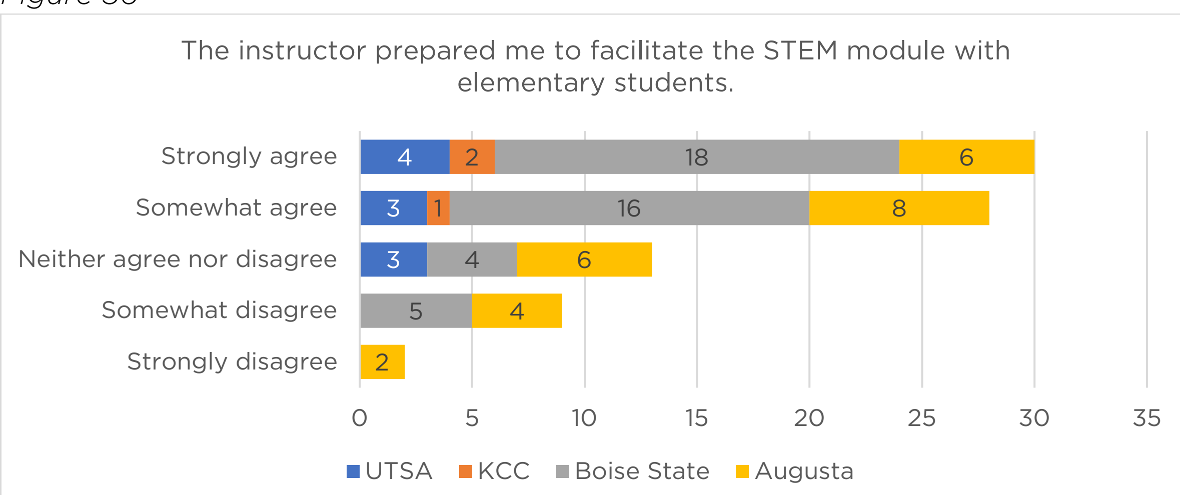
When asked if the ACE course model will influence their future teaching, three instructors noted the importance of PSETs having the real-world teaching experiences as outlined in the model and integrating STEM concepts. However, some instructors were unsure if they would use the whole ACE course model again. One mentioned the course model does not align with the course outline and another mentioned that the course model is too much work for them as an instructor.

Instructors also shared issues with implementing the STEM activity. Some problems listed were having technical problems, needing more training on how to implement the project, and trying to manage different levels of student interest in the content.

PSET Perceptions of the Instructor

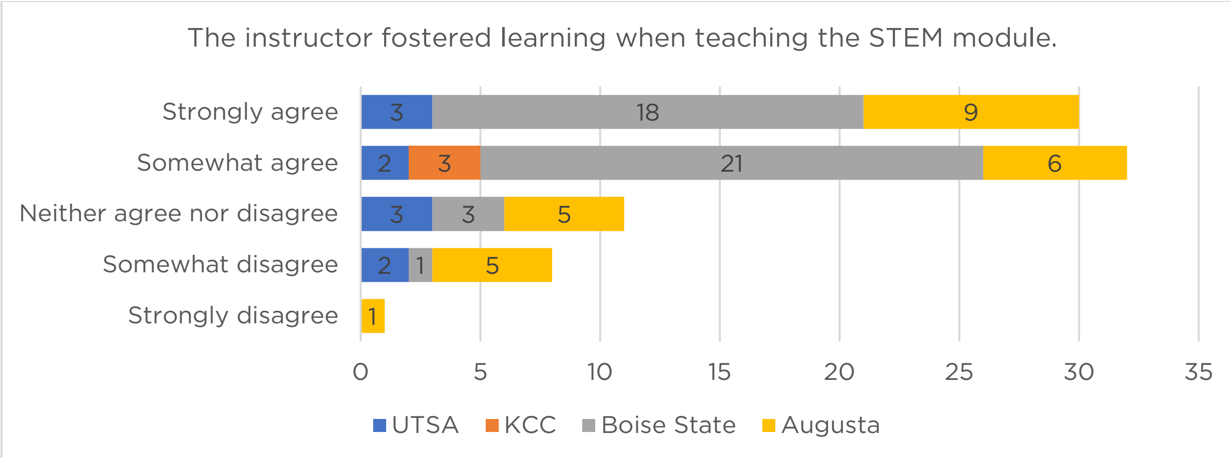
In the ACE Course Evaluation, PSETs were asked to evaluate their instructor's performance. A majority of PSETs (67%) across universities agreed their instructor seemed prepared to teach the course. Boise State and Augusta PSETs were the only ones to disagree with the statement.

Figure 56



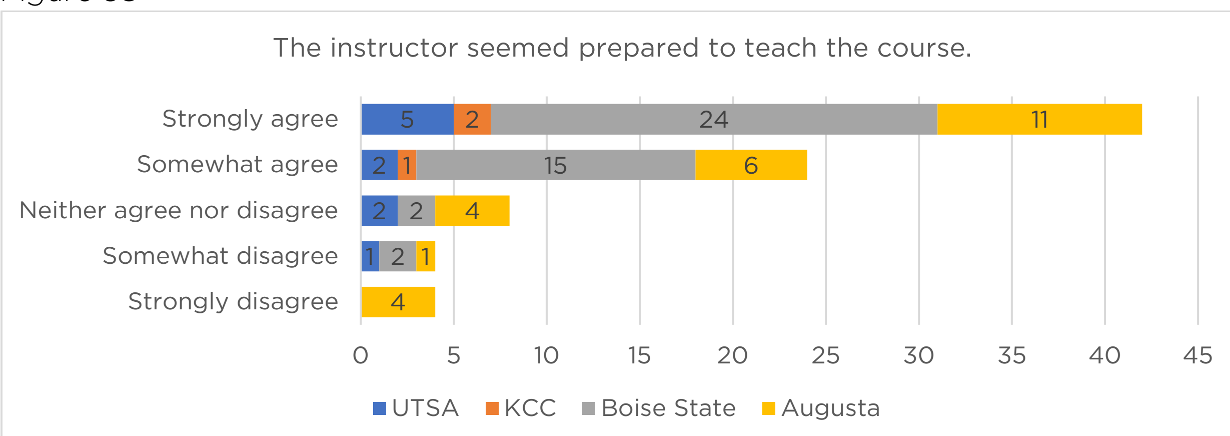
When asked if the instructor fostered learning when teaching the STEM module, 72% of PSETs agreed. Students from almost all universities disagreed with this statement.

Figure 57



Almost half of all PSETs strongly agreed the instructor was prepared to teach the course in general. Augusta students were the only ones to strongly disagree.

Figure 58



PSETs were asked to provide feedback on their experiences with their instructors. Across universities PSETs most commonly reported instructors enhanced their learning through appropriately explaining the lessons, being available to answer questions, and providing ample opportunities to practice using the technology before the activity.

When asked about areas of improvement for instructors, PSETs most commonly reported needing to be more prepared for the practicality of teaching students in the activity, and improving instructional techniques to account for different learning needs and different levels of prior STEM knowledge.

Instructors in Spring 2023 did not agree on the value of the ACE course model, some exhibited exemplary buy-in while some had no buy-in to the model at the end of the course. However, PSETs found value in the ACE course model. This indicates the model is valuable but instructors may need more instruction or better reasons for implementation to continue its use.

CONCLUSION

There is room for growth in implementation of the course model, namely providing more training to instructors, including more practical teaching strategies to the course, and improving data collection methods. However, all participating parties report benefitting from the model.

In year two of the project, PSETs benefitted from participating in the ACE course model and the CBEL activity. In both semesters almost all PSETs found value in the opportunity to work with real students in a learning environment and found that the course provided valuable insights into how to teach STEM in a way that increases student interest.

Elementary students participating in the activity mostly agreed that the activity was fun and that they learned a lot. However, it is not clear if the activity had a direct impact on their beliefs and attitudes toward STEM.

Instructors using the ACE model in year two mostly appreciated the model, specifically the opportunities to provide PSETs with experiences with real students. Most instructors could see using many aspects of the ACE model in the future.

APPENDIX A: Fall 2022 Tables

Chart A1: ME.ET Survey – Did you take any of the following courses from eighth grade through graduation from high school?

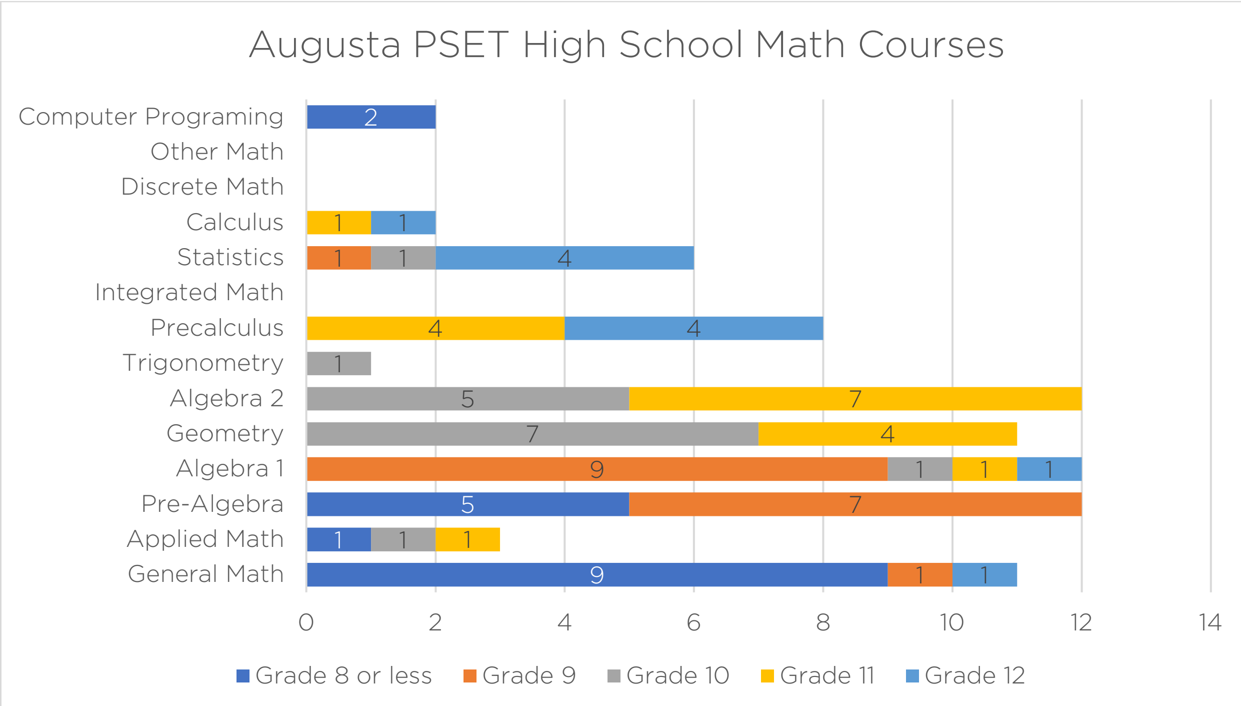


Chart A2: ME.ET Survey – Did you take any of the following courses from eighth grade through graduation from high school?

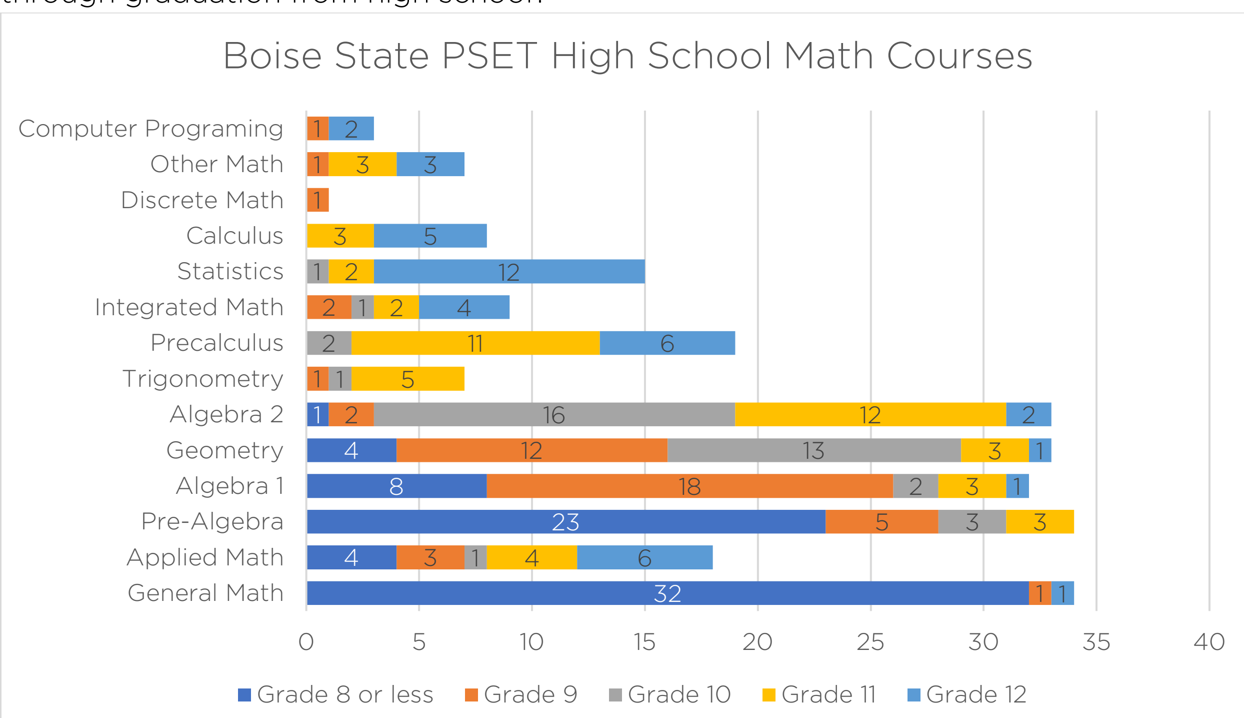


Chart A3: ME.ET Survey – Did you take any of the following courses from eighth grade through graduation from high school?

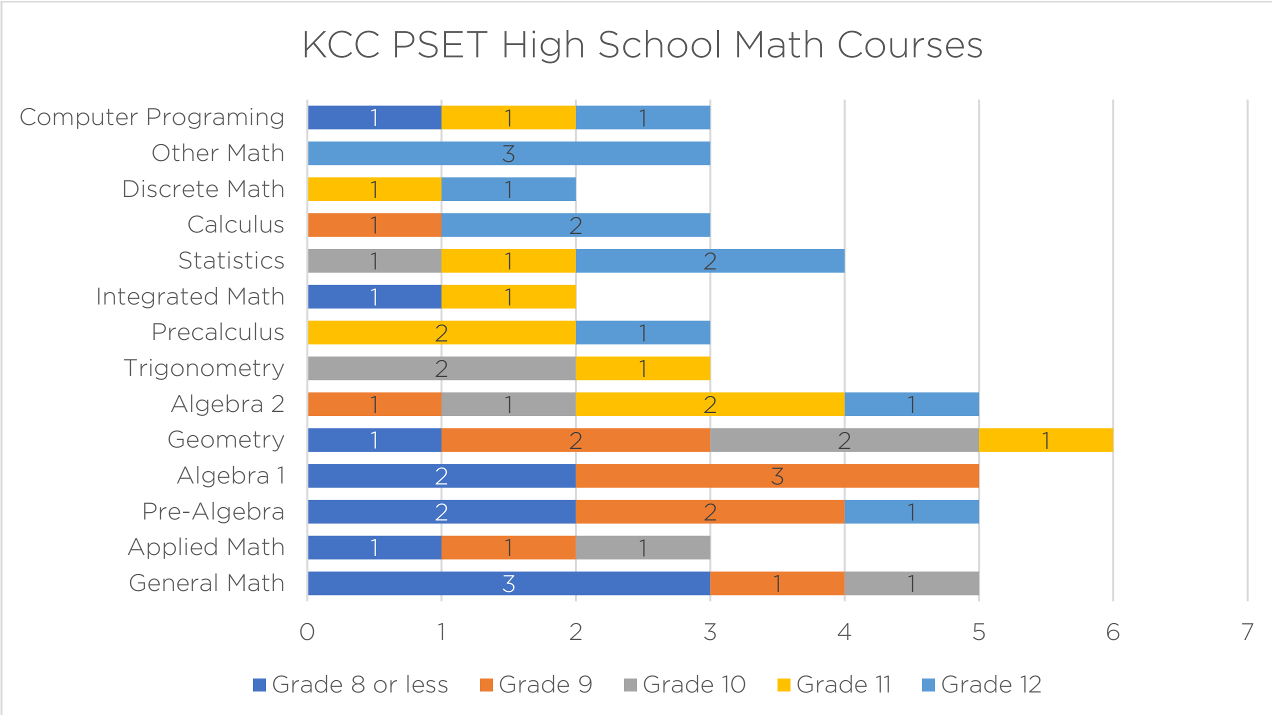


Chart A4: ME.ET Survey – Did you take any of the following courses from eighth grade through graduation from high school?

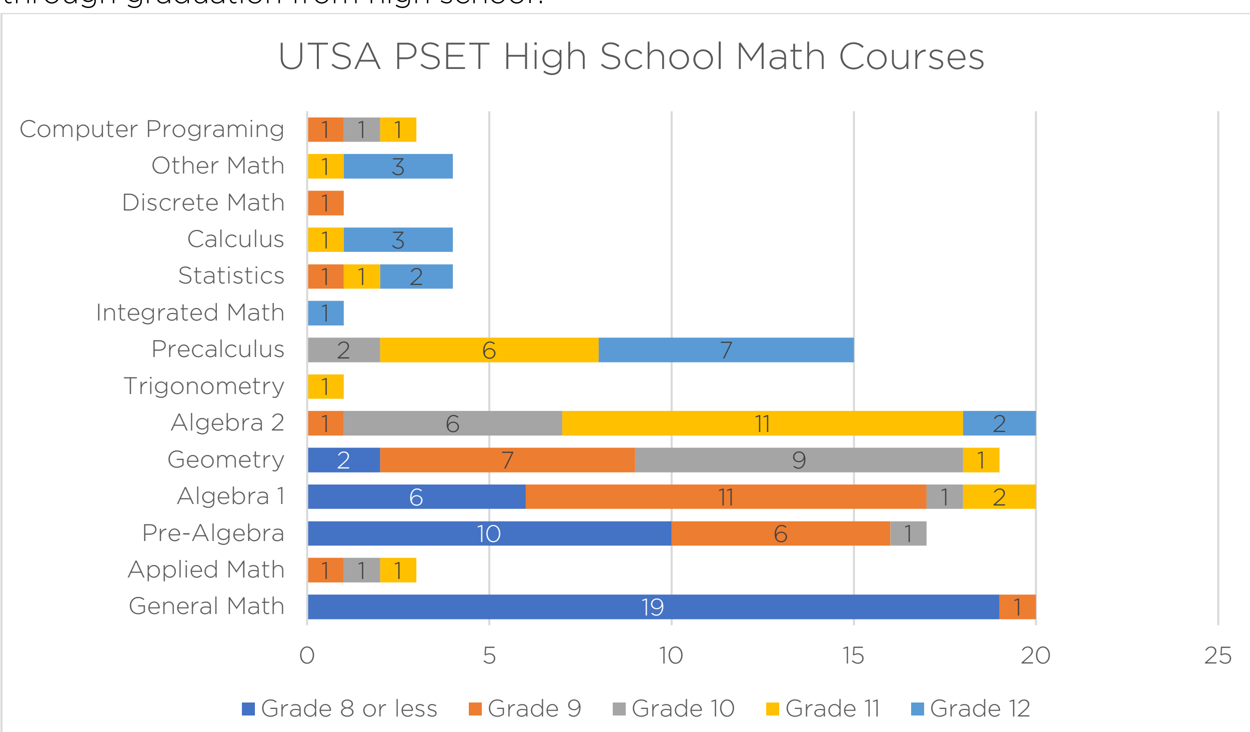


Chart A5: ME.ET Survey – Did you take any of the following courses from eighth grade through graduation from high school?

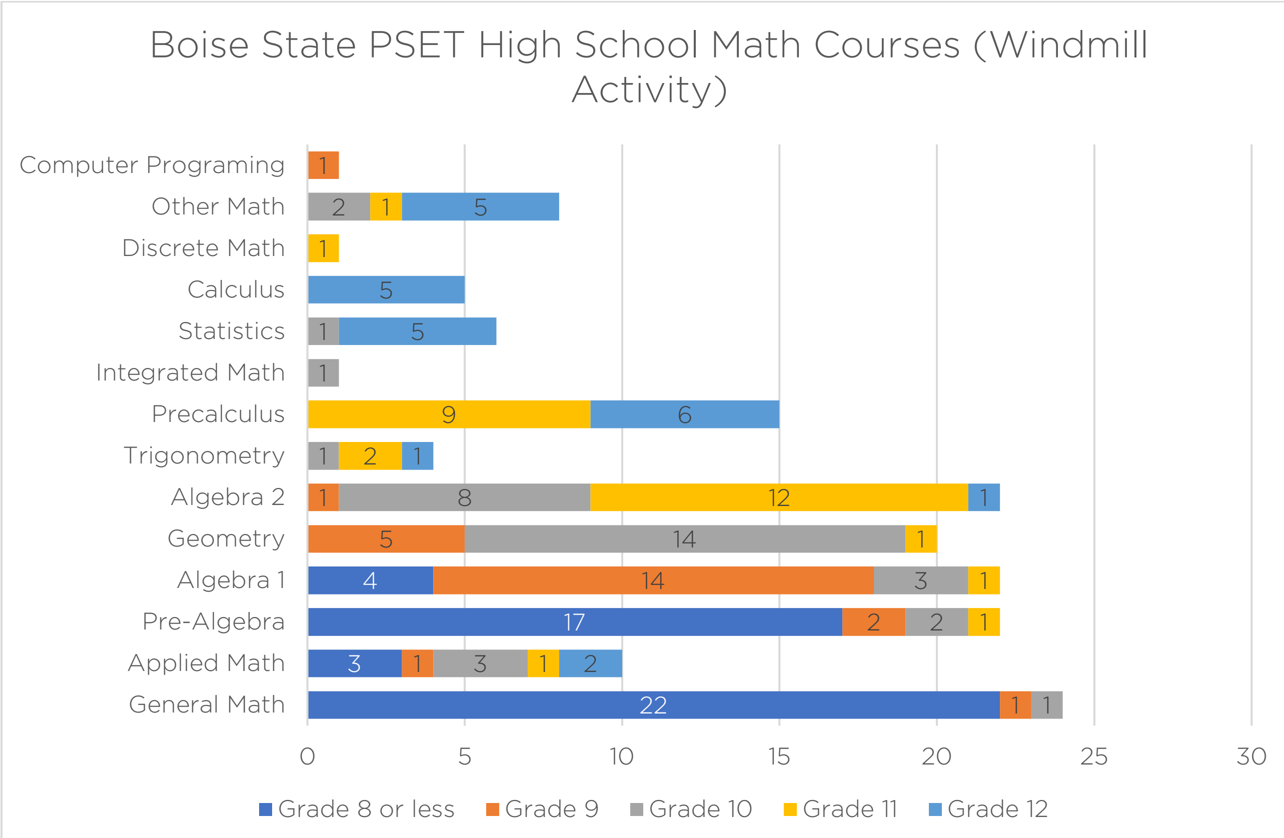


Chart A6: T-STEM Pre-Test – Level of agreement with statements related to teaching STEM

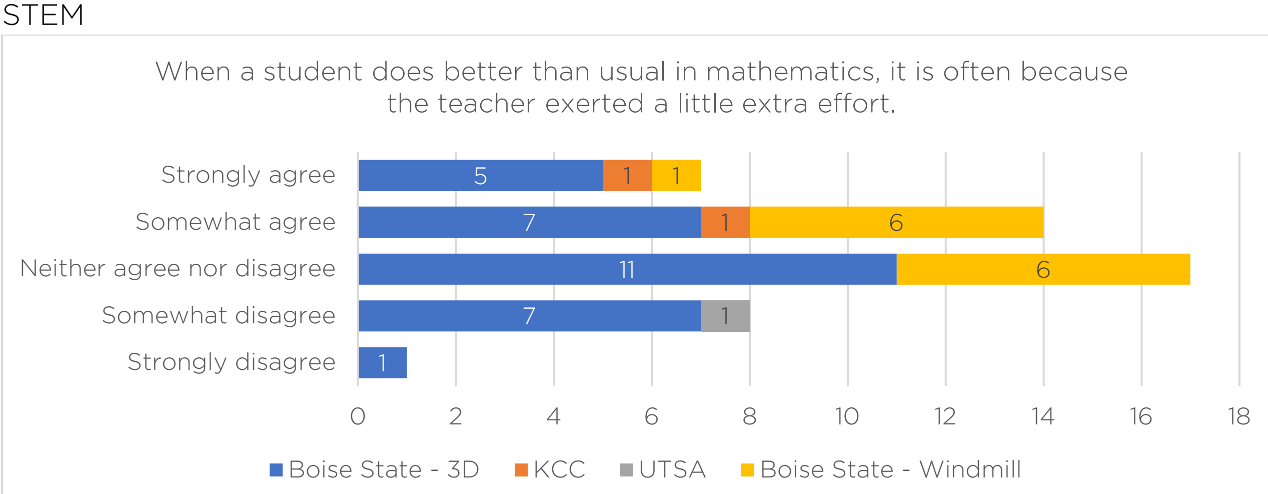


Chart A7: T-STEM Pre-Test – Level of agreement with statements related to teaching STEM

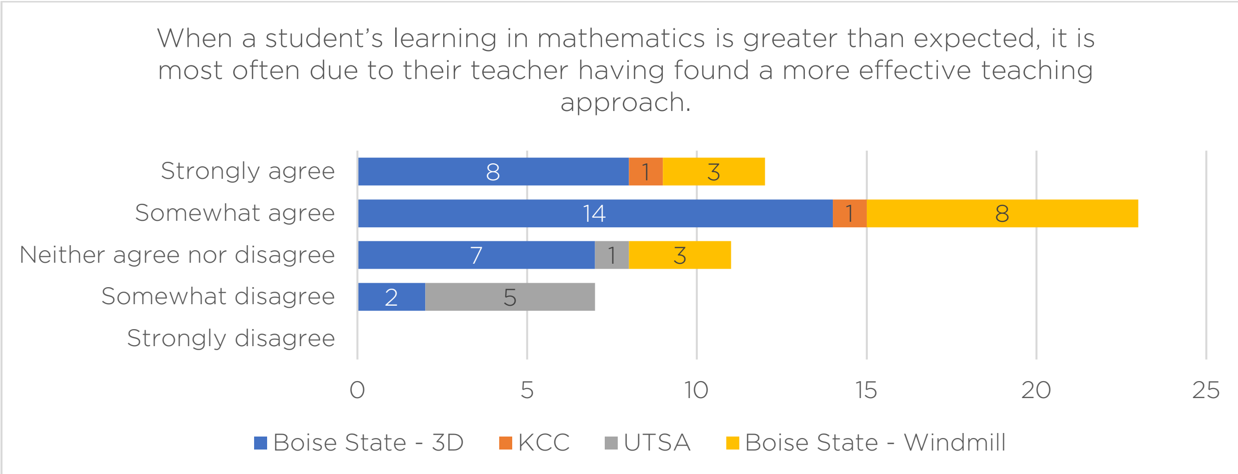


Chart A8: T-STEM Pre-Test – Level of agreement with statements related to teaching STEM

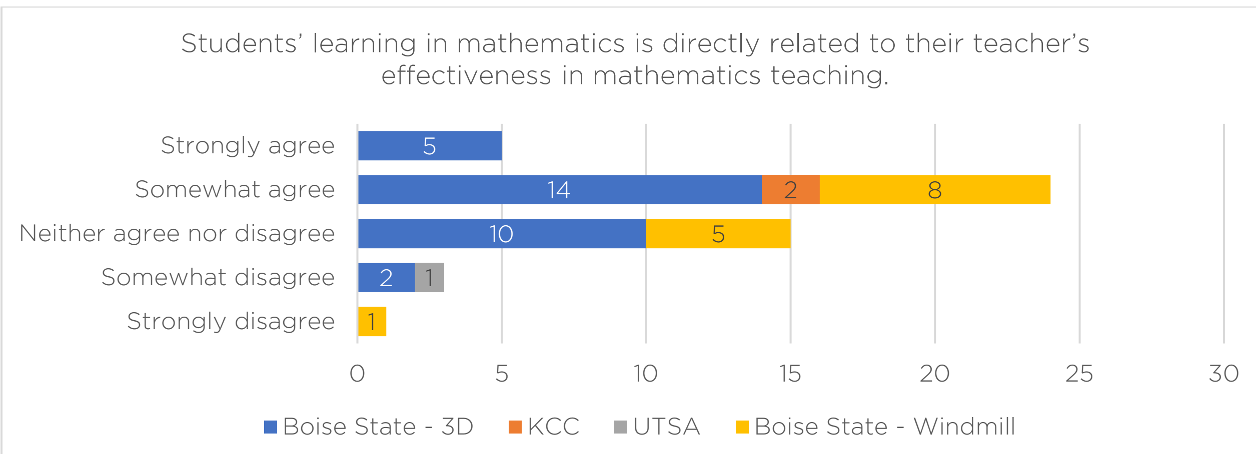


Chart A9: T-STEM Pre-Test – Level of agreement with statements related to teaching STEM

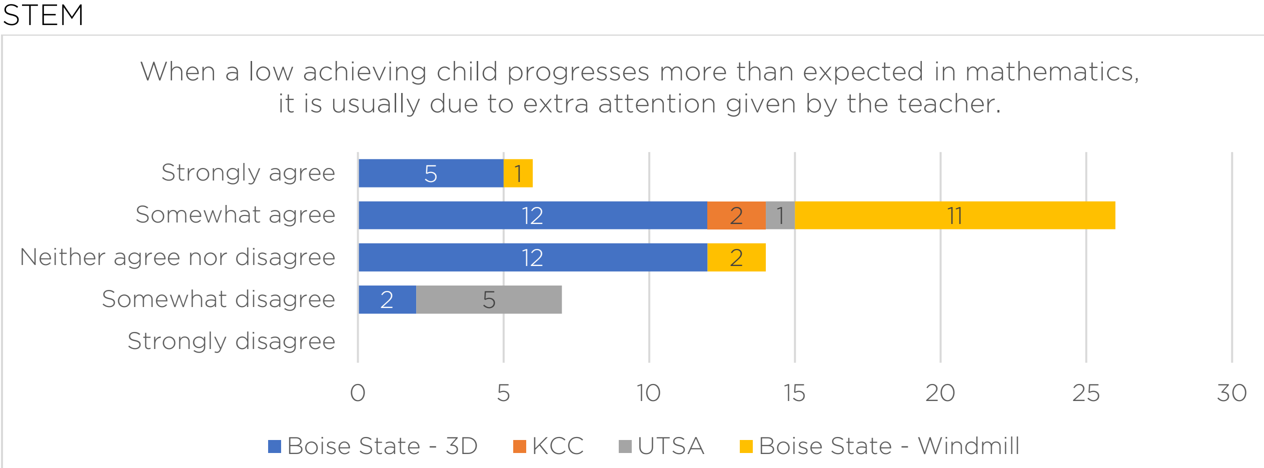


Chart A10: T-STEM Pre-Test – Level of agreement with statements related to teaching STEM

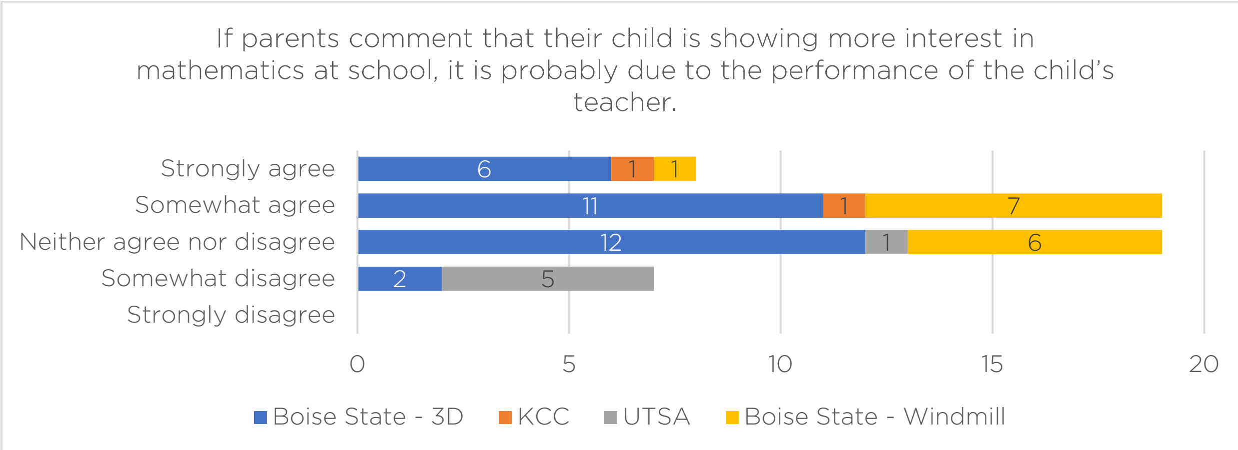


Chart A11: S-STEM Pre- and Post-Test – Level of agreement with statements related to STEM interest

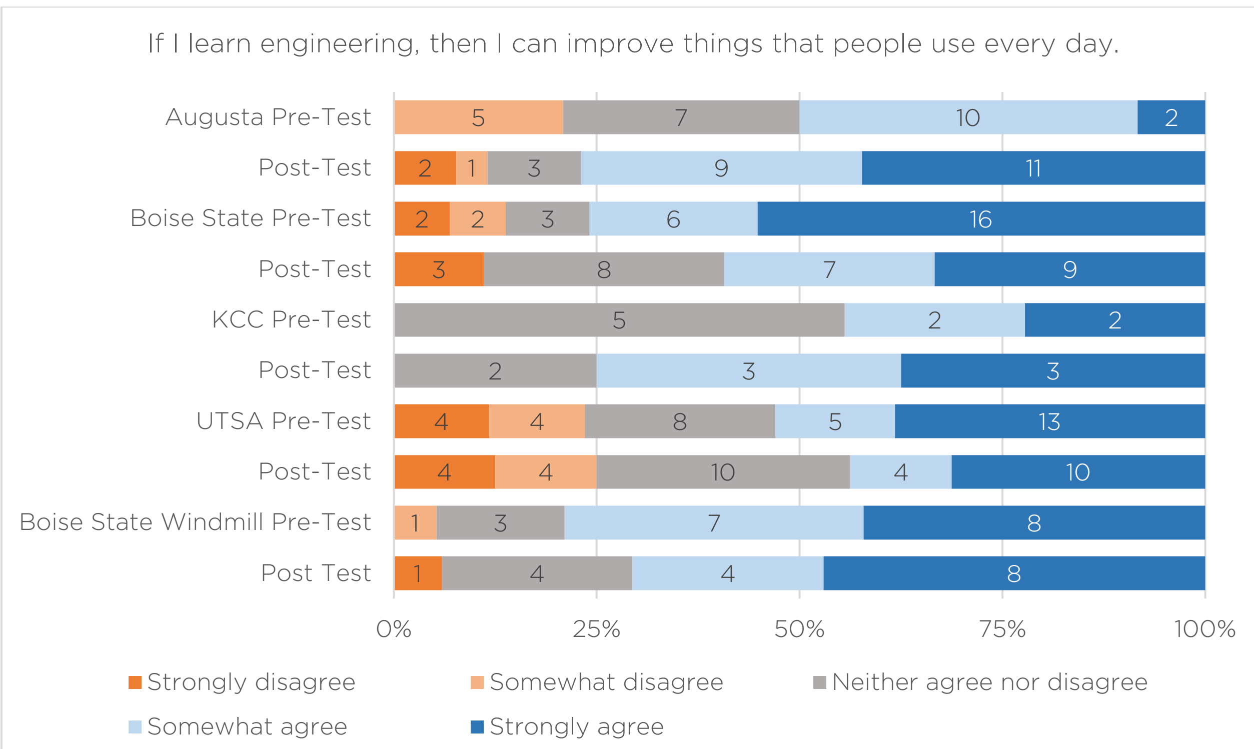


Chart A12: S-STEM Pre- and Post-Test – Level of agreement with statements related to STEM interest

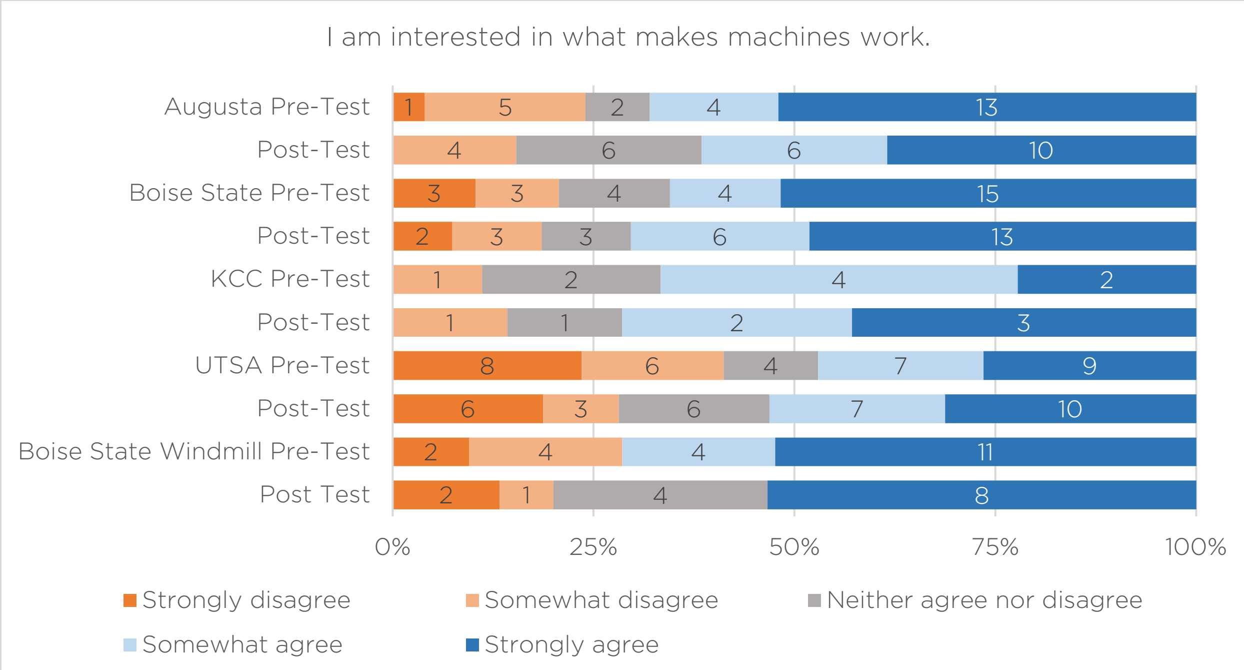


Chart A13: S-STEM Pre- and Post-Test – Level of agreement with statements related to STEM interest

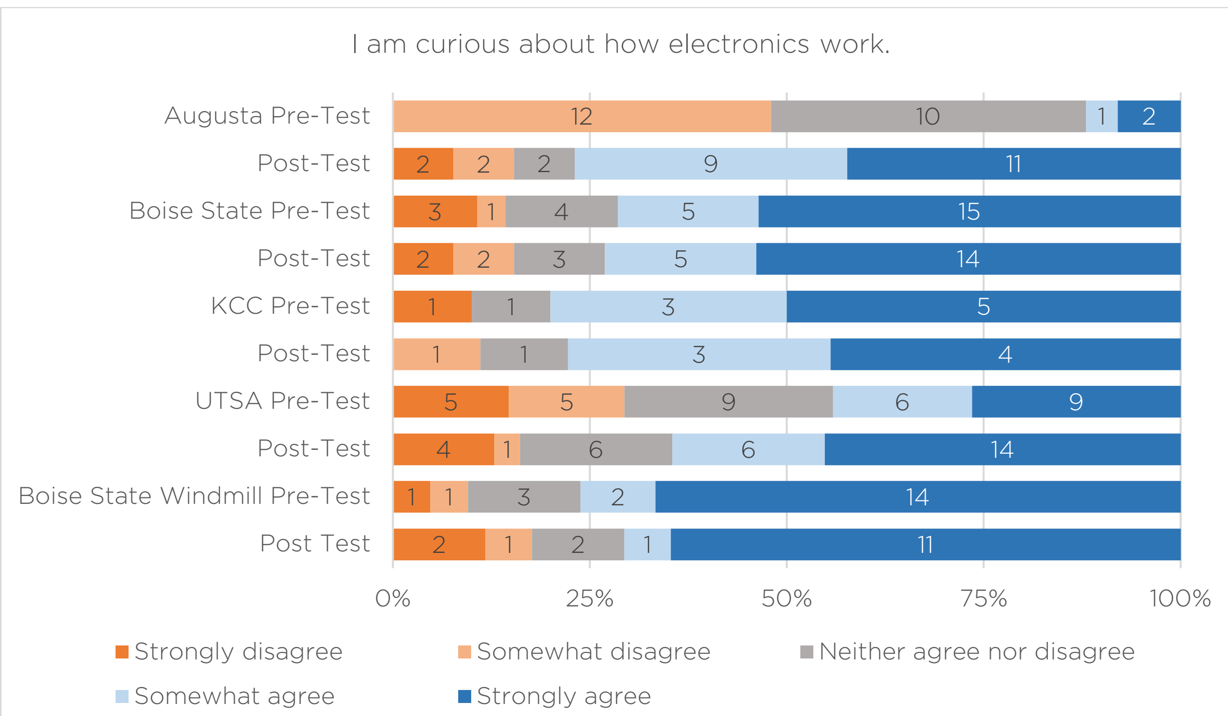
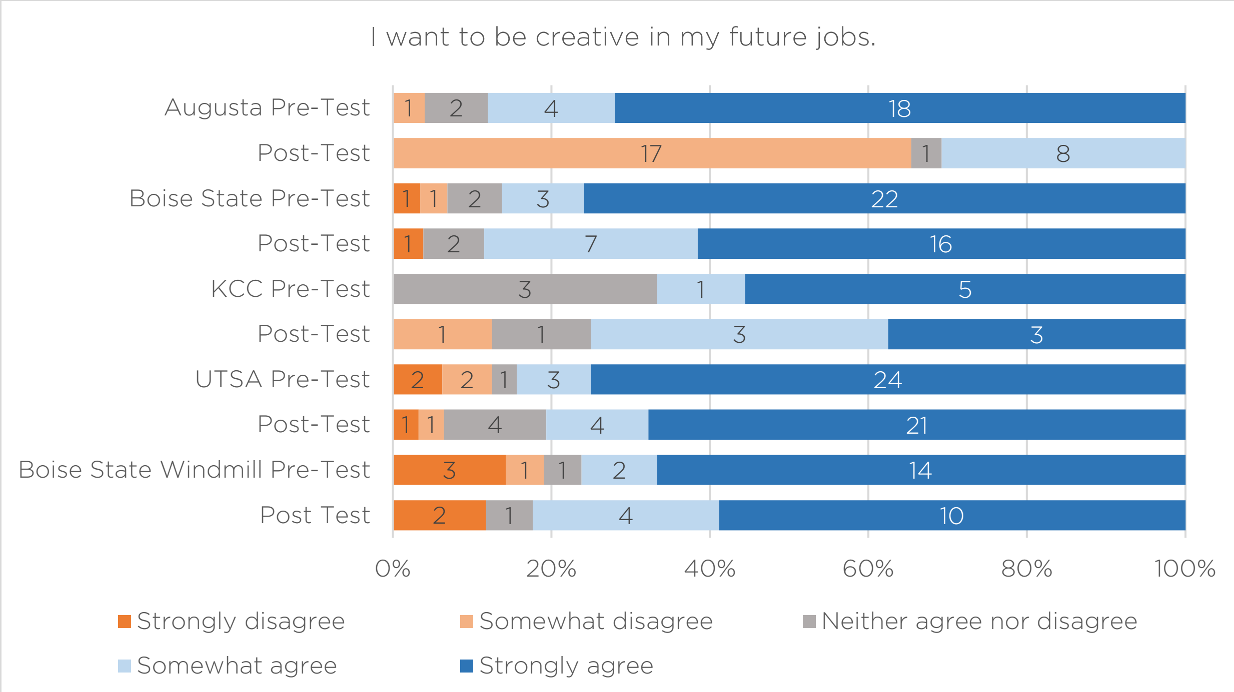


Chart A14: S-STEM Pre- and Post-Test – Level of agreement with statements related to STEM interest



APPENDIX B: Spring 2023 Tables

Chart B1: ME.ET Survey – Did you take any of the following courses from eighth grade through graduation from high school?

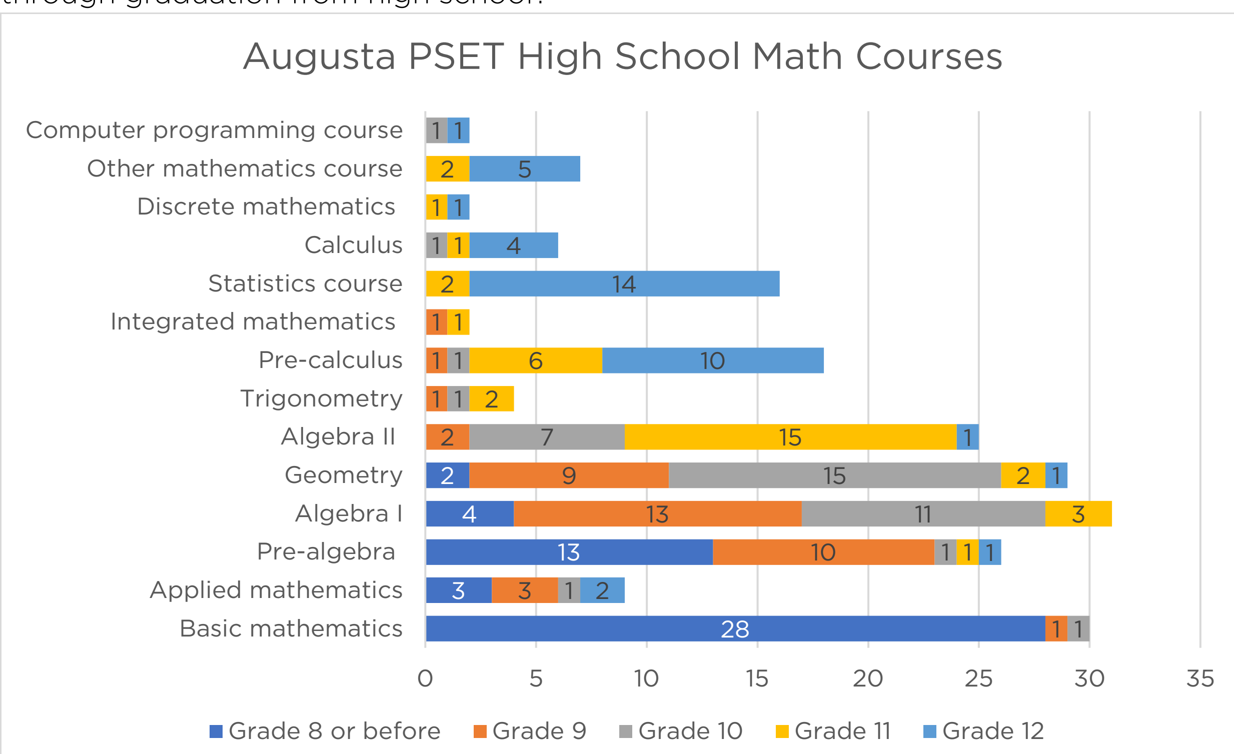


Chart B2: ME.ET Survey – Did you take any of the following courses from eighth grade through graduation from high school?

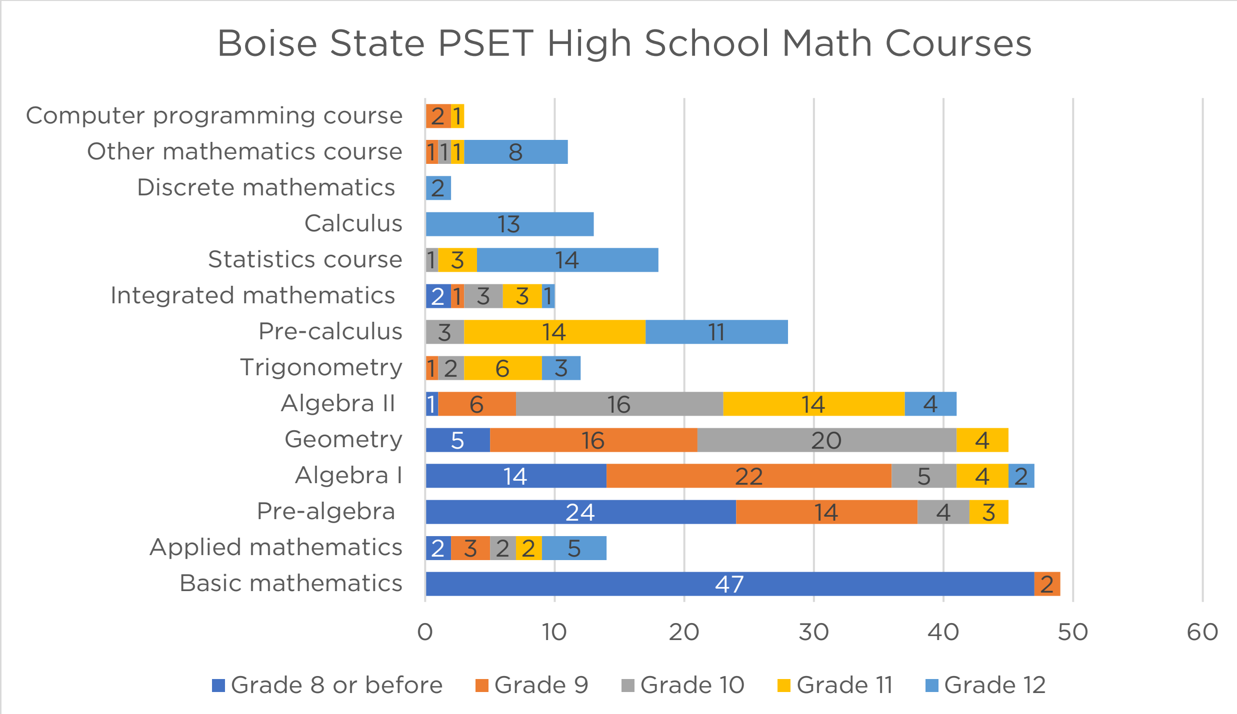


Chart B3: ME.ET Survey – Did you take any of the following courses from eighth grade through graduation from high school?

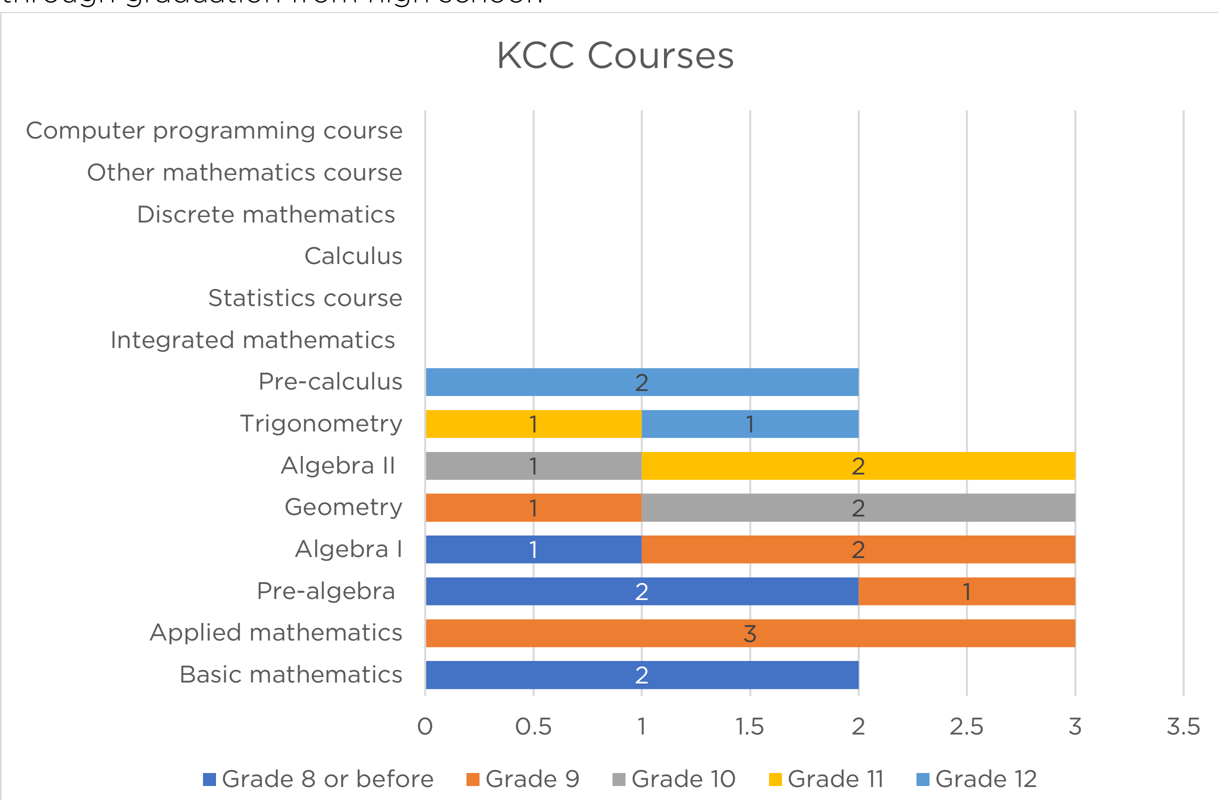


Chart B4: ME.ET Survey – Did you take any of the following courses from eighth grade through graduation from high school?

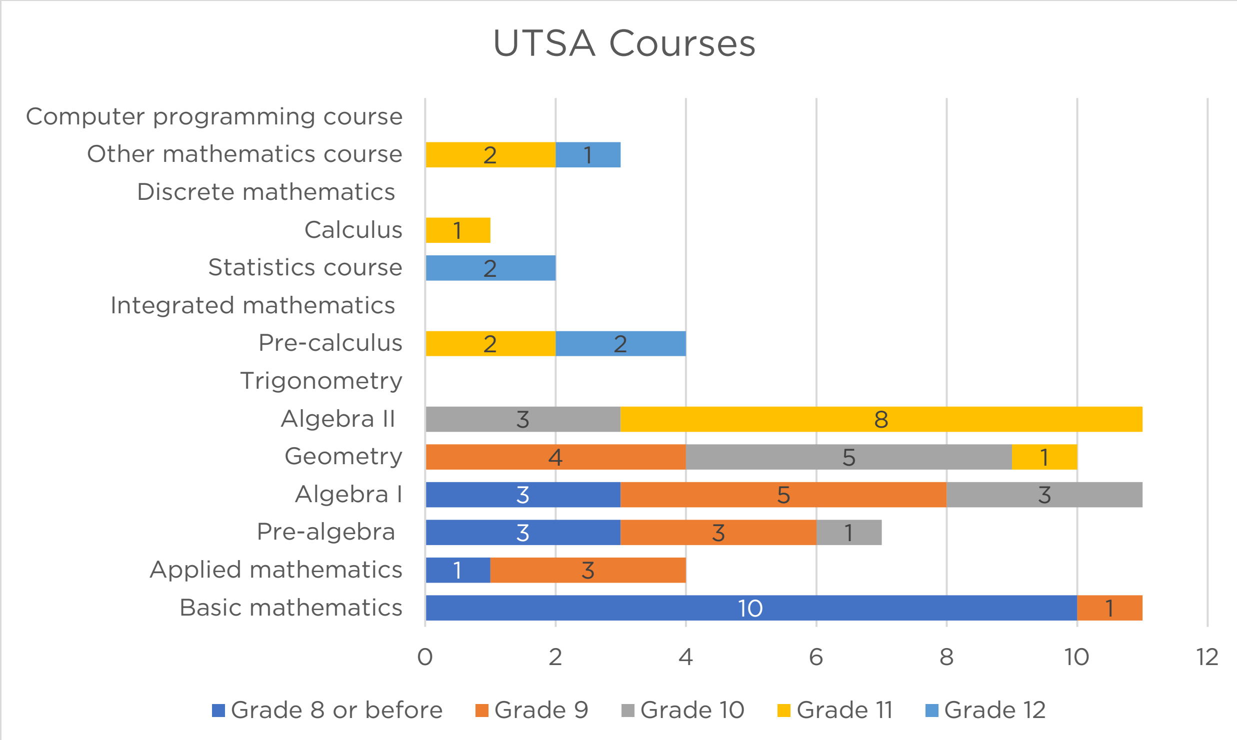


Chart B5: T-STEM Pre-Test – Level of agreement with statements related to teaching STEM

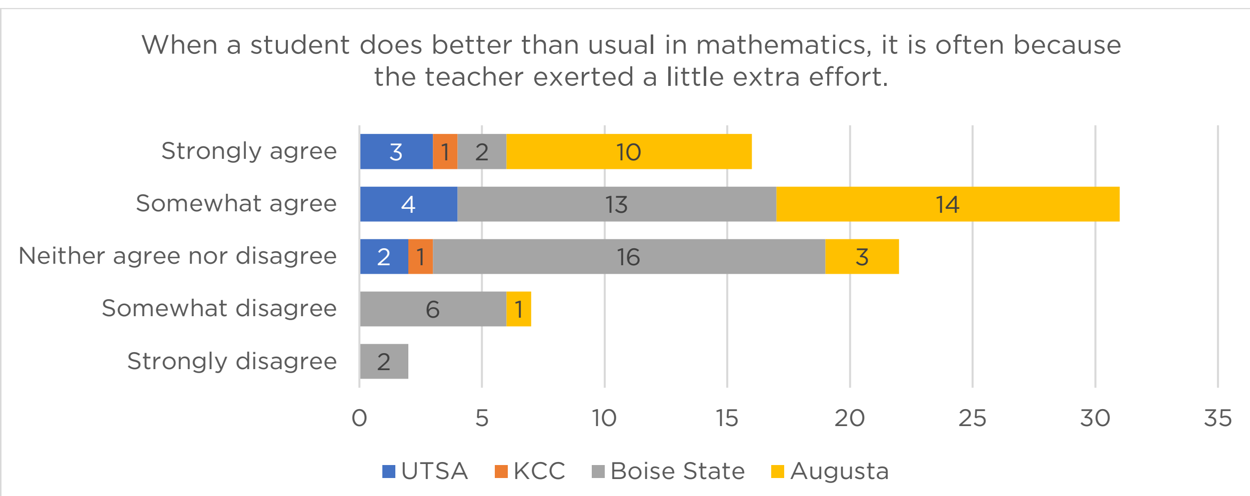


Chart B6: T-STEM Pre-Test – Level of agreement with statements related to teaching STEM

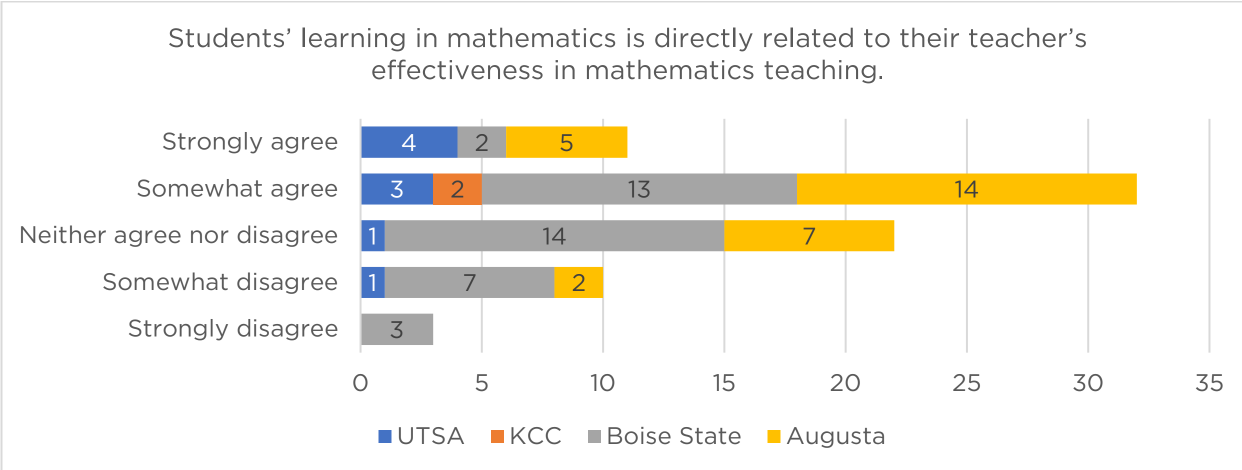


Chart B7: T-STEM Pre-Test – Level of agreement with statements related to teaching STEM

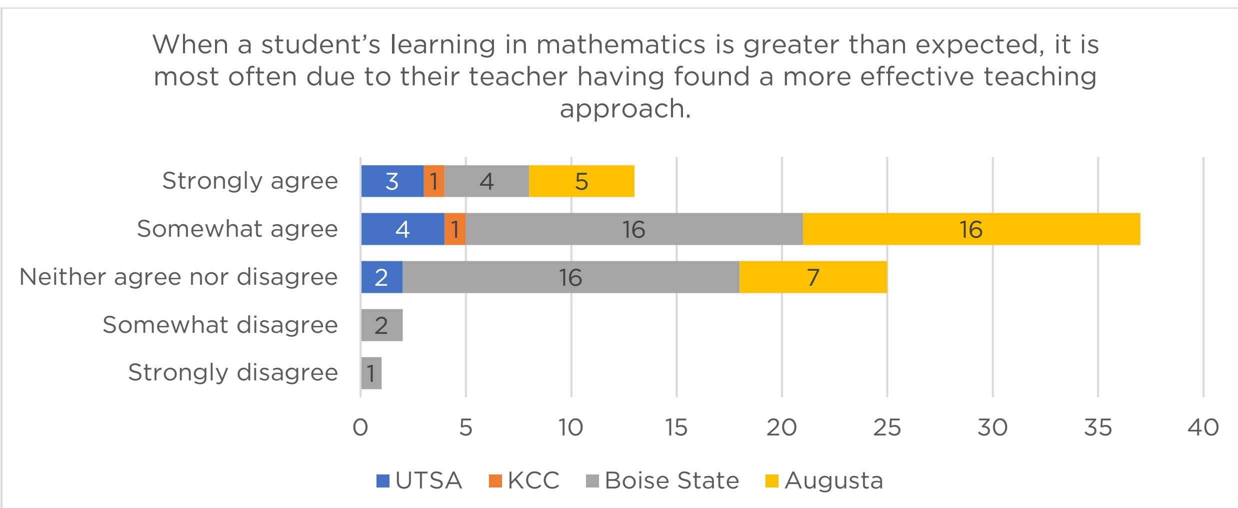


Chart B8: T-STEM Pre-Test – Level of agreement with statements related to teaching STEM

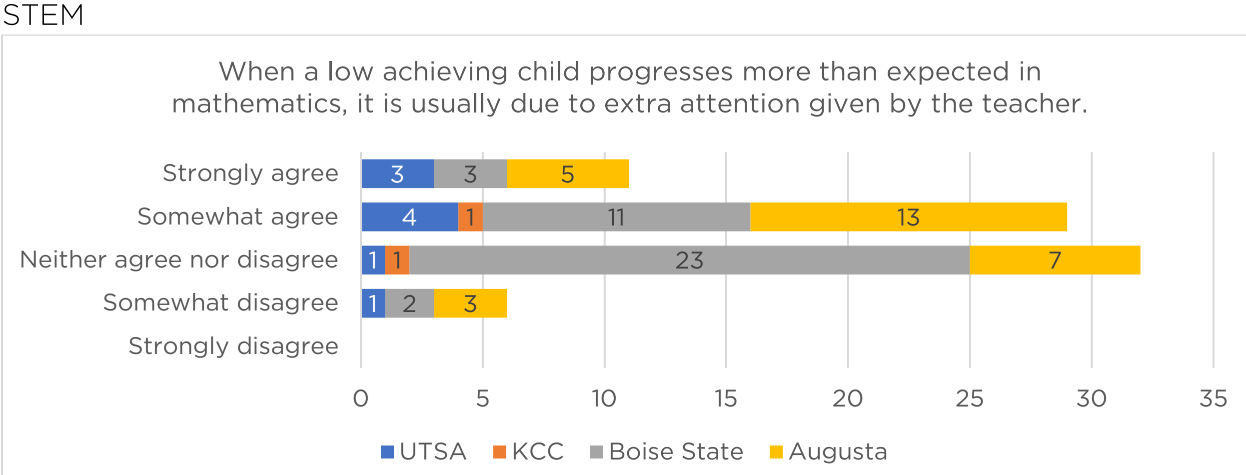


Chart B9: T-STEM Pre-Test – Level of agreement with statements related to teaching STEM

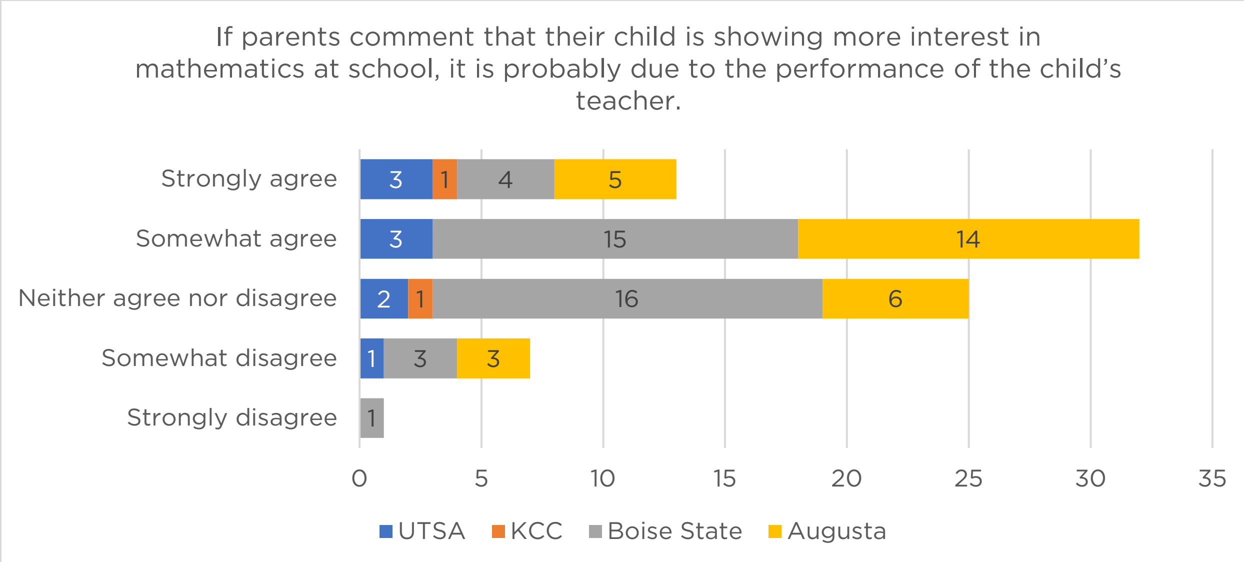


Chart B10: S-STEM Pre- and Post-Test – Level of agreement with statements related to STEM interest

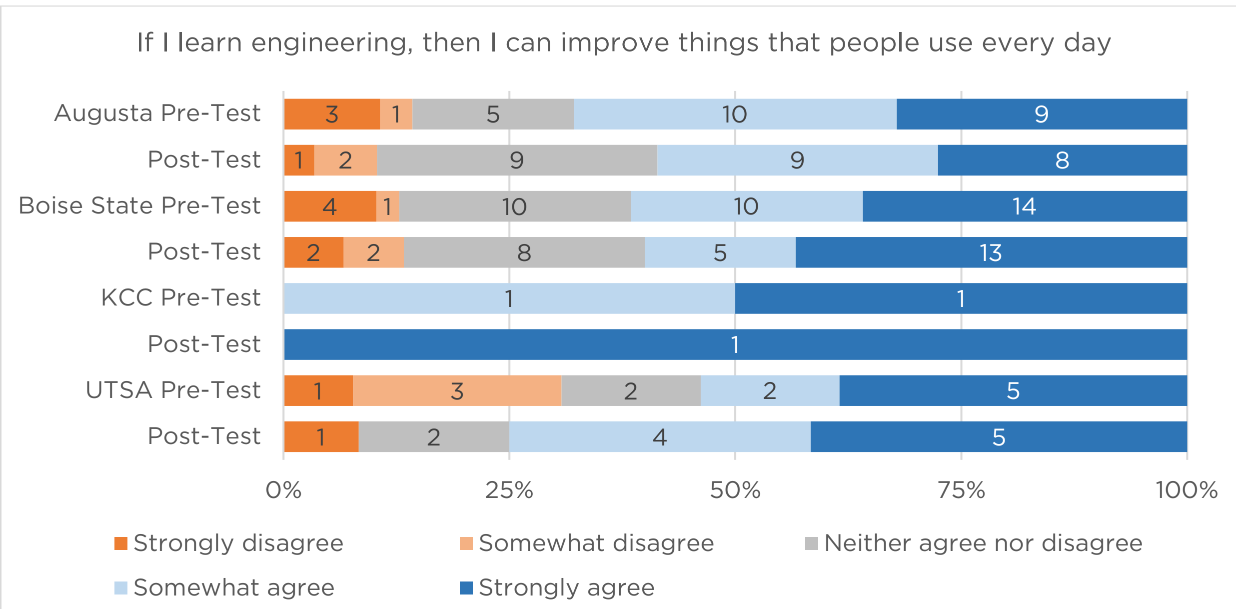


Chart B11: S-STEM Pre- and Post-Test – Level of agreement with statements related to STEM interest

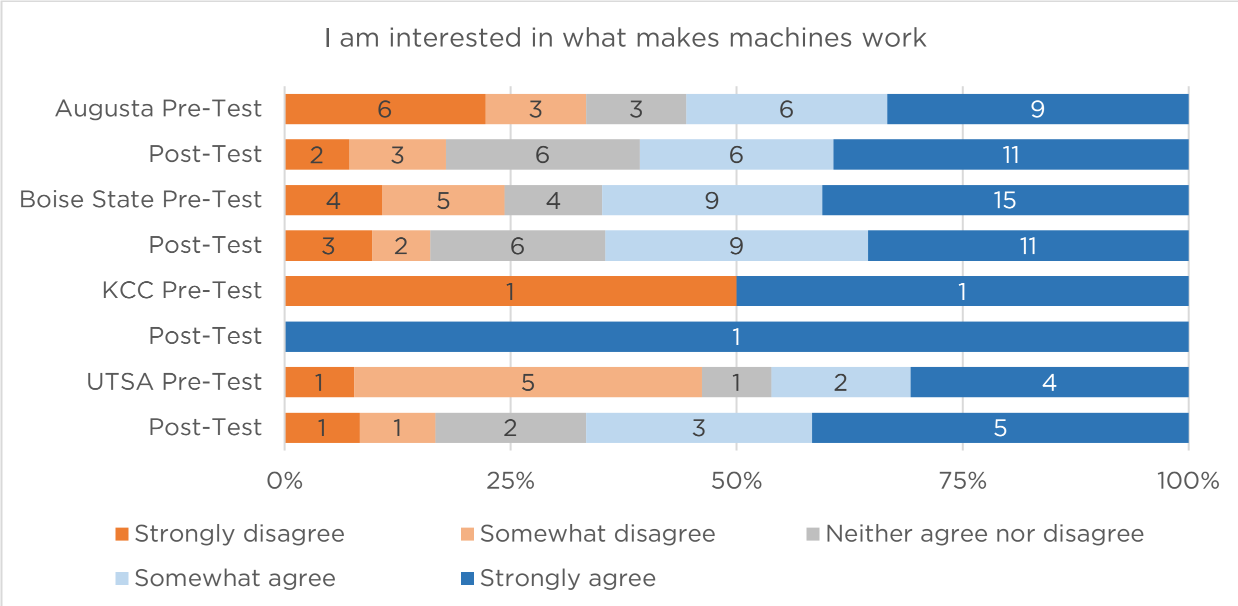


Chart B12: S-STEM Pre- and Post-Test – Level of agreement with statements related to STEM interest

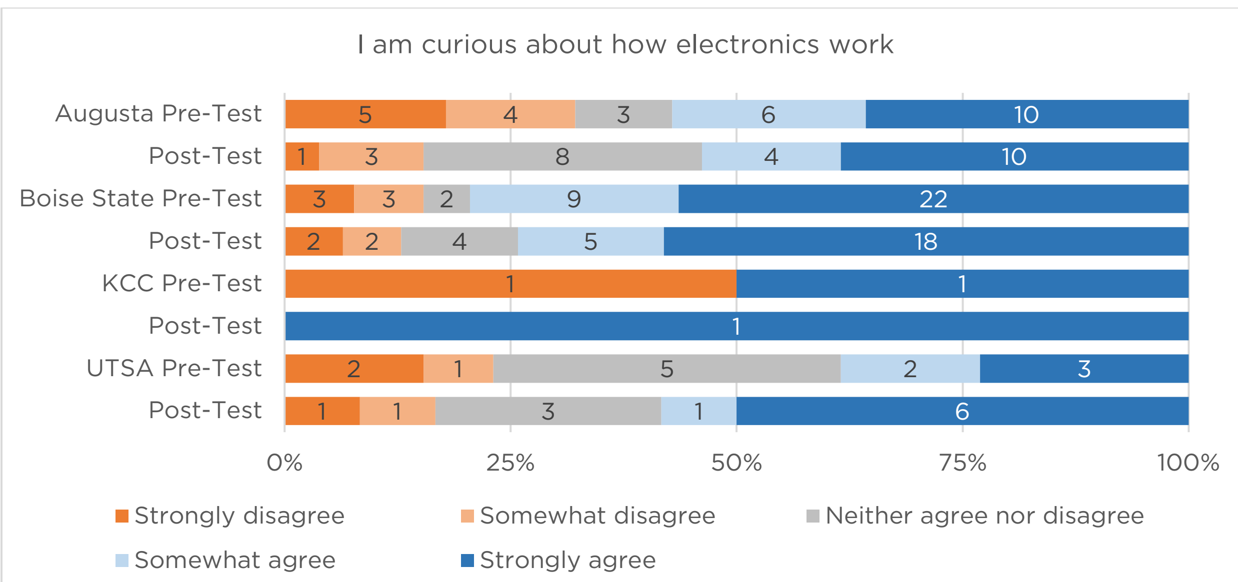


Chart B13: S-STEM Pre- and Post-Test – Level of agreement with statements related to STEM interest