KP Preut

Teaching and Learning Analysis Paper

Introduction

Purpose and Process

The purpose of this paper is to analyze the effectiveness of various learning theories, lesson design, and teaching strategies, which is useful to inform what changes could be made to the lesson to improve student learning. I partnered with two of my classmates, forming a teaching group in order to develop our lesson plan. The topic of our lesson was based around a "big idea" in our content area. We brainstormed a list of big ideas and chose scientific notation as the topic for our lesson. The significance of the big idea will be described further in the Analysis portion of this paper. In order to gauge student understanding of our topic, we created a pretest. The questions on the pretest were meant to address the five mathematical proficiencies as outlined in the Kansas state standards. The five mathematical proficiencies are:

- Conceptual Understanding
- Procedural fluency
- Strategic Competence
- Adaptive Reasoning
- Productive Disposition

Conceptual Understanding is a student's ability to understand the underlying concepts behind a mathematical topic. Procedural Fluency is a student's ability to accurately utilize formulas and compute answers. Strategic Competence refers to a student's ability to use their prior knowledge in new situations, such as solving word problems. Adaptive Reasoning is a student's ability to explain their reasoning for how they solved a problem. Productive Disposition refers to a student believing in their math skills and viewing math as something that is valuable (National Research Council, 2001, pp. 115-155).

The pretest questions and the proficiencies they address are as follows,

Question 1:

"Describe what scientific notation is."

Question 1 addresses conceptual understanding because it assesses whether students can describe scientific notation in detail beyond basic knowledge.

Question 2:

"Describe a scenario where it would be useful to use scientific notation. Why is it useful in that situation?"

Question 2 addresses conceptual understanding because it assesses whether students know how scientific notation is used in context. It addresses adaptive reasoning because it requires students to justify their response. Finally, it addresses productive disposition as it assesses whether students can describe how scientific notation is useful, therefore seeing an application of math as worthwhile.

Question 3:

"Express 87 in scientific notation, show your work."

Question 3 addresses procedural fluency because it assesses if students are able to accurately convert the number into scientific notation using a positive exponent.

Question 4:

"Express 0.0004 in scientific notation, show your work."

Question 4 addresses procedural fluency because it assesses if students are able to accurately convert the number into scientific notation using a negative exponent.

Question 5:

"Express 8.295 x 10^7 as a real number, show your work."

Question 5 addresses procedural fluency because it assesses if students are able to accurately convert the number from scientific notation into a real number.

Question 6:

“The table shown below gives the approximate number of pieces of mail handled by the United States Postal Service (USPS) for different years.

Year	Approximate number of pieces of mail handled
1950	4.5 x 10^10
1965	7.2 x 10^10
1980	1.0 x 10^11
1995	1.8 x 10^11
2010	1.7 x 10^11

How many more pieces of mail were handled by the USPS in 1995 than in 1965?

Express your answer in scientific notation, show your work.

Express your answer as a real number, show your work.

How would you help a classmate solve this problem if they were struggling to understand?

On a scale of 1-10, how confident would you feel helping them, why?"

Question 6 addresses conceptual understanding because it assesses if students are able to connect what they know about scientific notation to a novel situation. It addresses procedural fluency because students will need to know the procedure for accurately computing the data. It addresses strategic competence because students will need the skills to understand the quantities in the problem and their relationships to one another. Finally it addresses productive disposition because it assesses their confidence in solving the problem.

The next step in the process was to give the pretest to the students in our class. Based on the results, my teaching partners and I each chose a classmate to interview. I chose my interviewee because he scored a 10/10 on the pre-test. This indicated he understood the topic well and I wanted to investigate his understanding to see exactly how he understood the topic and if there were any gaps in his understanding. The interviewee is a Sophomore in the STEMTeach program and is majoring in math.

Interview questions were written to address the pretest questions and by extension, the proficiencies. They were also written to assess the learning preferences of the interviewee. The results of the pretest and the interviews were used to design our lesson. In our case, the class scored well on the pretest, with all of the students scoring an 80% or higher. Therefore we decided to make the content of the lesson and the post test more challenging. My interviewee in particular stated that he did not know how to compute data when it was in scientific notation. Rather, he had to convert the notation into real numbers, compute them, and then convert it back into scientific notation. This was the basis for much of our lesson as we wanted to ensure the class learned how to compute with scientific notation. Our lesson was formed using the 5Es model. The 5Es are as follows:

- Engage: To begin the lesson, students are given an activity that grabs their attention and introduces them to the topic
- Explore: This section allows students to dive deeper into the topic and discover concepts on their own. This could include giving students a problem that requires them to arrive at a formula on their own, rather than giving it to them at the beginning of the lesson.
- Explain: Students are then asked to explain what they found out from the explore section. This also gives the teacher an opportunity to gauge the current understanding.
- Elaborate: This section allows students to continue practicing the concepts or do extension activities.
- Evaluate: Students will be given some type of assessment to evaluate what they have learned (Bybee, 2009, p. 12).

We chose to inform our lesson with the sociocultural theory developed by psychologist Lev Vygotsky. This theory will be further explained in the Analysis section. A copy of the lesson plan is included in the appendix.

After we created our lesson, we taught it to our classmates on a Thursday and gave them the posttest the following Tuesday. The posttest contained similar questions to the pretest, but we included more word problems and required our classmates to compute the data while it was in scientific notation.

Analysis

Analysis of Teaching

The topic for our lesson was based around a "big idea" in math. A big idea is useful for, "connecting and organizing many facts, skills, and experiences; serving as the linchpin of understanding" (Wiggins, 2005, p. 69). Big ideas, although not simple in and of themselves, can be presented in a way that is accessible to those beginning to learn the topic. They can also be expanded upon over time so that a student's knowledge of the topic gains both breadth and depth. Scientific notation is an example of a big idea because it encompasses multiple components in math including decimals, place value, and exponents. Problems with scientific notation can include data analysis as a component, which lends it utility in subjects outside of math, like chemistry.

The 5Es model is based upon student centered, inquiry based learning. Student centered means that students are doing a majority of the classwork, as opposed to the teacher. Inquiry instruction is described as, "involving students in a form of active learning that emphasizes questioning, data analysis, and critical thinking" (Bell, 2005, p. 31). Reports on the effectiveness of the 5E model state, "students whose teachers taught with medium or high levels of fidelity to the BSCS 5E Instructional Model experienced learning gains that were nearly double that of students whose teachers did not use the model or used it with low levels of fidelity" (Bybee, 2009, p. 12). The 5E model, when used correctly, allows students to be active participants in the learning process. Psychologist Jean Piaget, who made significant contributions to the study of cognitive development, also believed that activity was key to learning. "[...] as we act on the environment - as we explore, test, observe, and eventually organize information - we are likely to alter our thinking processes at the same time" (Woolfolk, 2007, p.28).

Learning theories attempt to explain the ways in which students process and store information, essentially describing the way people learn. This explanation informs best practices for teaching and by extension, lesson planning. Our lesson was based upon the work of psychologist Lev Vygotsky. Like Piaget, he asserted that students are active participants in the learning process (Bodrova, 2007, p. 27). However, Vygotsky distinguishes himself from other Constructivist theories with his idea of the sociocultural theory of cognitive development. For Vygotsky, interactions with other people are key to learning. Knowledge is first co-constructed, meaning that two or more people interact and create a shared understanding of a subject. Once this understanding is established, the student can then internalize and further make sense of the information (Woolfolk, 2007, p. 39-40). They were put into groups for most of the lesson, but also shared their solving methods to the entire class. In the Elaborate section, they were given a partner different from anyone in their group.

Within our lesson, we incorporated two instructional strategies; concept maps and think-pair-share. Instructional strategies are techniques that can be used to facilitate learning. Concept maps involve connecting mathematical ideas through writing. Terms are written and circled. Lines are then drawn between them with a verb that shows the connections between the ideas (Baroody, 2000, p. 605). Concept maps are helpful because they provide students an opportunity to address their own understanding of a topic. If they struggle to make connections, this could indicate that their understanding is not as strong as they may have believed (Baroody, 2000, p. 607). Concept maps can be built upon slowly over the course of a unit or semester, allowing the teacher and the student to see gaps in understanding and address any misconceptions accordingly. Coming back to them as more lessons are taught can be helpful to show student progress (Baroody, 2000, p. 608). For our lesson, students were instructed to use the terms “scientific notation”, “decimals”, and “data”. They were then told to add three more terms to their maps. This was done at the beginning of the lesson, before any instruction took place. The concept maps were used again for the think-pair-share. At the end of the lesson, students were to refer back to the concept maps they made earlier and think about any changes they would make to their map and why, as well as adding an additional term. They were then to share these ideas with a partner, who would share with the whole class. The efficacy of think-pair-share is supported by sociocultural theory because students are working together to understand a topic, in this case, scientific notation.

Analysis of Learning and Assessment

Learning of Interviewee:

The pretest, interviews, and posttest are able to shed light on the learning process of the interviewee. Analyzing these reveals that instruction helped him reach all five mathematical proficiencies. The interviewee achieved conceptual understanding because he understands all of the components that make up scientific notation such as place value, decimals, and exponents. He was also able to understand instances when scientific notation is necessary (Interviewee Concept Map). Procedural fluency was achieved because all of the data was computed accurately. He showed strategic competence in solving the word problems as he was able to make sense of the data and what computations needed to be done to find the answer. This is especially apparent in his second interview when he was able to explain that between two numbers in scientific notation, the negative exponent with higher magnitude is the smaller number (2nd Interview, Lines 95-99). Adaptive reasoning is shown because he was able to explain how he would help another student solve this problem; he is therefore having to explain his reasoning behind solving the problem. Finally, he showed productive disposition in two areas. One pattern between the first and second interview was that he said he struggled to explain himself, but felt confident in his understanding (1st Interview, Lines 162-178; 2nd Interview, Lines 134-135). Despite these reservations about his ability to explain, he reported he felt sure about his new understanding of computing numbers in scientific notation (2nd Interview, Lines 146-154); this is an increase in confidence in his abilities compared to what he described during his first interview. Further, in the interview he stated that while he did not personally like doing concept maps, they were helpful for testing his understanding (2nd Interview, Lines 178-185). This shows that he views math as a worthwhile activity and has a desire to learn.

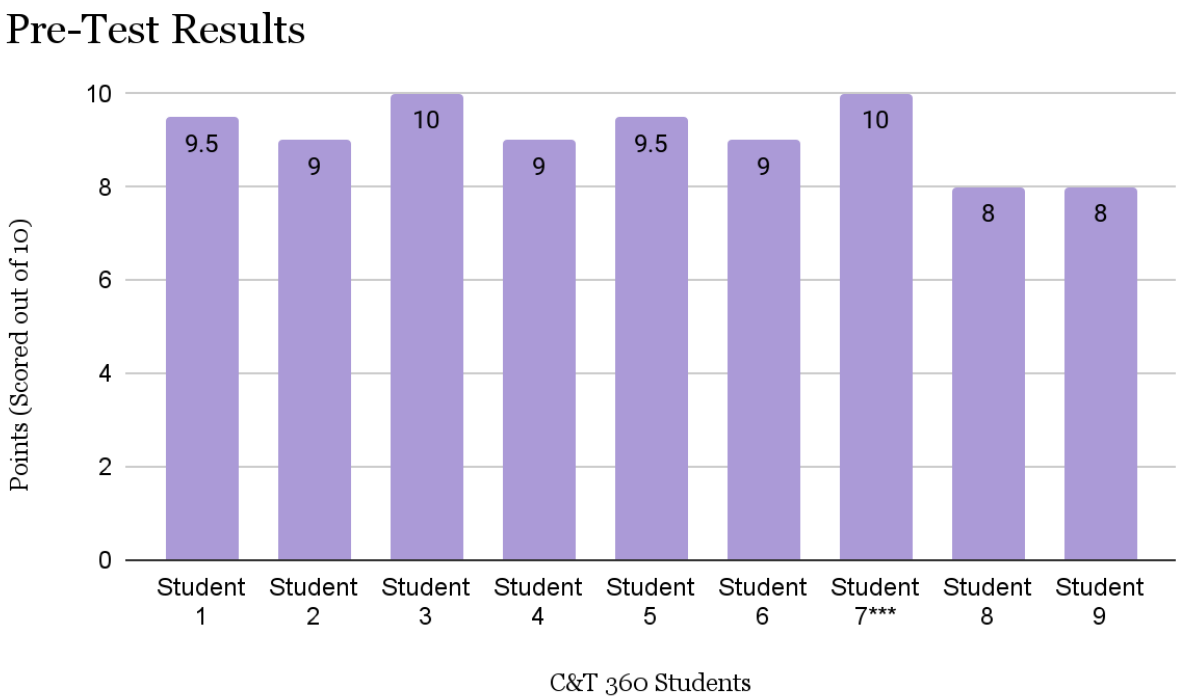
The interviewee met the objective of the lesson and learned how to compute data that was expressed in scientific notation. The evidence for this can be seen in his work on the worksheet, his posttest, and his interview. This learning can be explained with Vygotsky’s theory about the zone of proximal development (ZPD). The ZPD is the area between a student’s current understanding and what they are capable of learning. This area is where instruction should be directed to move a student towards an understanding they are capable of reaching. The interview allowed me to determine what he did and did not know and tailor the lessons to address his gap in understanding. The social aspect of the lesson also helped the interviewee learn. He stated that he enjoyed working in groups and that this complemented his learning style (2nd Interview, Lines 187-189). This aligns with the learning theory behind the lesson, Vygotsky's theory of co-construction (Woolfolk, 2007, pp. 39-40).

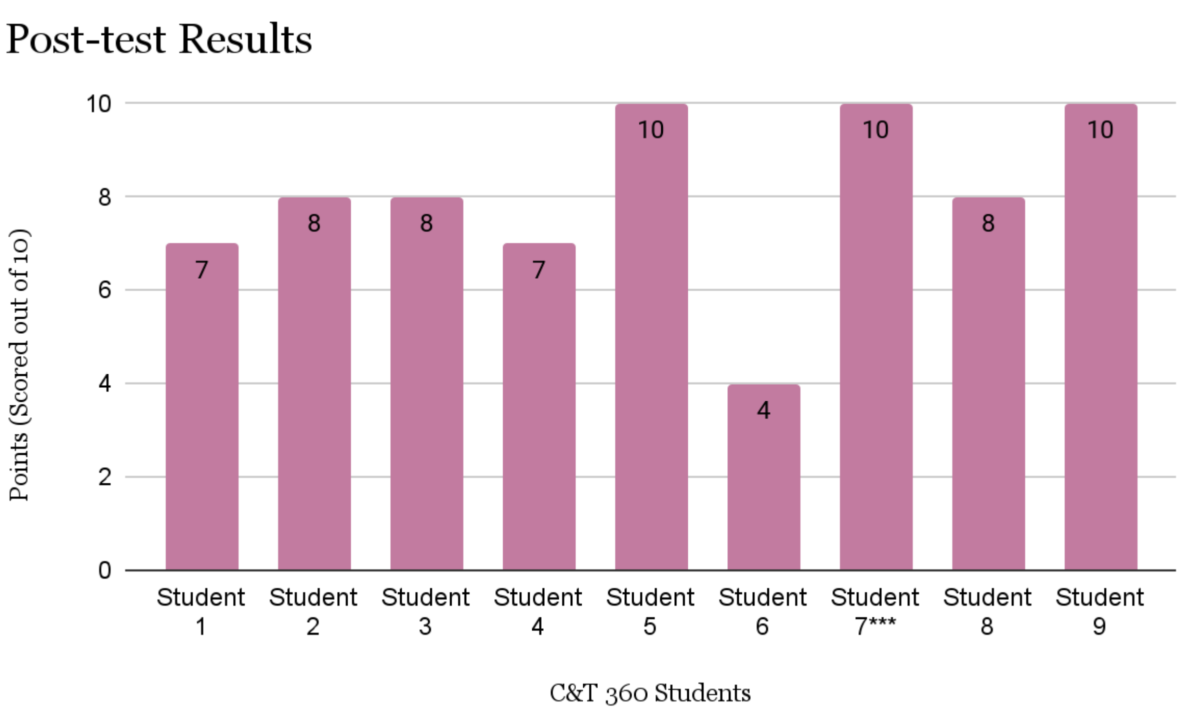
Learning of the Class:

While the social aspect of learning was the basis for the entire lesson, it did not come naturally. Students were assigned to random groups and were not allowed to choose who they wanted to work with. At the beginning of the lesson, my teaching partners and I had to prompt groups repeatedly to discuss the concept maps together and not work on them individually. As the lesson progressed, the students worked with each other without needing to be prompted and were able to effectively work together to accurately solve the word problems. This shows that while Vygotsky's socio-cultural theory can explain how students effectively learn together, it is not always the default that students will work together. The teacher often has to work as a facilitator for students if they are not used to working together.

The concept maps proved to be an interesting point of contention during the lesson. When students were directed to make a concept map, many students expressed out loud that they disliked the activity and did not want to do it. This could be explained using mathematical proficiencies as a guide. One reason for the pushback could be that students did not have the necessary conceptual understanding to meaningfully connect the terms. This lack of understanding led to frustration and disinterest in completing the activity. Another explanation could be a lack of productive disposition. They did not view the activity as worthwhile and therefore did not want to complete it. The interviewee also expressed a dislike for the concept map during the lesson, going as far as writing “BOO” on it. He did not want to add another term and was booing the fact that he had to do it.

Analyzing the data collected from the pretest and the posttest also shed light on the learning that took place. The results from the tests are included below. “Student 7” is the interviewee.


Pre-Test Results
Points (Scored out of 10)
10
8
6
4
2
0
9.5
9
10
9
9.5
9
10
8
8
Student 1
Student 2
Student 3
Student 4
Student 5
Student 6
Student 7***
Student 8
Student 9
C&T 360 Students


Post-test Results
Points (Scored out of 10)
10
8
6
4
2
0
7
8
8
7
10
4
10
8
10
Student 1
Student 2
Student 3
Student 4
Student 5
Student 6
Student 7***
Student 8
Student 9
C&T 360 Students

The class average for the pretest was 82% while the class average for the posttest was 72%, with the majority of students either scoring lower or not improving their score. There cannot be a 1:1 comparison between the tests as they were different and the second one was designed to be harder. However, analyzing the data closer provides a clearer picture of student understanding. One important point to address first is that Student 6 was not present the day of the lesson and therefore did not receive instruction on how to compute data in scientific notation. The larger issue at play was that many students had a misconception regarding proper scientific notation format. When looking at the work shown on the posttest, many students accurately converted both data points to the same power to subtract or add. However, sometimes this led to answers that were not in proper scientific notation, for example expressing an answer as "251.3×10^{19}" instead of "2.513×10^{21}". Students did not know that they needed to adjust their answers to be in the correct format. During the lesson, I saw the interviewee leave an answer in the incorrect form. When I asked "Is that the correct form the answer should be in?" he quickly corrected his answer. However, this was not then addressed with the entire class. This was a failure in instruction because I only addressed one student's mistake rather than making sure it was something everyone understood. The summative assessment was very effective in showing what students did and did not know. For example, it is clear that many of them did grasp the concept of the changing powers to compute data. The assessment highlighted the gap in their understanding of proper formatting and revealed a flaw in instruction.

Conclusion

Changes to Lesson and Assessment

Based on my analysis of the student's learning, two major changes need to be made to the lesson plan. The first change would be to increase the number of questions and sample student answers in order to address student understanding. Predicting how students may respond prepares the teacher to address these misconceptions. The second change would be to specifically outline that any misconceptions discovered through a one on one interaction also need to be addressed with the whole class. It is likely that students share misconceptions about a topic, so addressing them to the class is a direct way to make sure every student receives proper instruction. One change I would make to the assessment is to specify in the instructions that students need to put their answers in proper scientific notation format. I do not believe the test should indicate what the proper format is as that should be part of the assessment, but the reminder will act as a guide to students that they need to recall what the proper notation is.

Applications

One major takeaway I have from this process is how little teachers are aware of their students' understanding without extensive investigation. My interviewee is a perfect example. Had I not interviewed him, I could have assumed his perfect score on the pretest indicated a very strong understanding of scientific notation. It is true that he had a solid understanding, but the interview revealed a large gap in his ability to work with numbers in scientific notation. Similarly, few students made notation errors during the lesson, so I assumed they knew what proper notation was and did not address it with the whole class. The assessment then revealed that many of them in fact did not know proper notation, highlighting the need for several forms of assessing student understanding such as pretests, formative assessments, discussions about the topics, and summative assessments.

This experience also highlighted the importance of instructionally beneficial data that is derived from instructionally useful tests. The Association for Supervision and Curriculum Development published a report to define instructionally useful tests. The first characteristic is "describability" which refers to concrete explanations as to what the test is assessing. The second characteristic is "teachability" meaning that teachers are able to relate the material to all students, regardless of background and experiences. The third characteristic is "reportability" and addresses that test data should not make broad generalizations, rather specific data that goes back to teachers and can be used to affect the day to day operations of the class. The fourth is "non-intrusiveness" which refers to testing not taking up too much time. The final characteristic is "significance" which means tests address big ideas in content, rather than focusing on very specific and ultimately insignificant facts (Popham, 2003, pp. 48-51). I would argue that my assessment produced instructionally beneficial data because the results were clear and highlighted a specific gap in student understanding. This data was used to identify potential changes to the lesson plan to improve student learning.

[Interview transcripts, lesson plan, pre/post-test keys, and pre/post-tests of the interviewee are included on the following pages.]

Pretest Interview Transcript

For the duration of the transcript, the interviewer will be referred to as 'K' and the interviewee will be referred to as "I".

K: Okay, so the first question is what did you think...So again, our test was on scientific notation and I like have a copy of it if you want to refer to it. Um, what did you think when you saw the test and did you feel confident?

I: Like scientific notation? I don't really remember doing this as a math. I thought it was a science person's, like science group's test. So that was my thought process. And I, I wasn't worried about it.

K: Why weren't you worried about it?

I: I've been doing scientific notation for probably three years now.

K: For three years?

I: Yeah.

K: Do you remember like, the first time that you learned it?

I: Junior year of high school.

K: Okay.

I: Or actually... really got into depth with it was Junior year.

K: What class did you go into depth?

I: Chemistry.

K: Oh, chemistry. Okay. Um, so how do you think you did on the quiz then?

I: Pretty good. I feel fairly confident about it.

K: Okay. So what was the hardest question for you? And what was the easiest?

I: [Referring to blank pre-test.] Can I see that?

K: Yeah, yeah.

I: Probably describing what scientific notation is was the hardest because I didn't really know how to describe it.

K: Mhm.

I: But...

K: Why didn't you not, like, know how to describe it? Like what was difficult?

I: I just, I’ve always known how to do it. Not like, it's that I know how to do it, but I can't explain it kind of thing. And then the easiest ones was actually doing the scientific notation.

K: Like which question specifically?

I: Probably four.

K: Four?

I: Yeah. Or three because it's just the two digit number.

K: Yeah. Okay. Um, oh I already asked this. So, “when did you first learn scientific notation?”. You said three years ago. Um, and so I'm just going to go through and like... So for number one. We kind of talked about that already. So describe what scientific notation is, like how, like walk me through like how you solve that problem.

I: So I, once again, I really don't know how to describe it. I just know how to do it. I think I said that scientific notation is making numbers easier to work with. Which is, that's essentially what it is.

K: Like for questions one and two, like kind of...

I: Um, and then a scenario is if, say you have a really big or really small number, but so many decimal places that it's hard to read. Scientific Notation makes it easier to read that number. Say it's like, point like seven zeros three, five. So you move the decimal place to the three behind the three and then multiply it by 10 to the negative whatever. It just makes it easier to read and work with for some people.

K: Okay, and then how did you solve number three?

I: Um, I moved. So it's 87. So I just moved the decimal place one to the left to get 8.7 times 10 to the first.

K: So where's the decimal place in 87 To start with?

I: So that's one place, and 87 that's behind the seven, even though it's not put there. It's just a given. Because if, it'd be written as 87.0. Because it’s a whole number.

K: Gotcha. And so you moved it to the...

I: The left.

K: The left one, okay. And then what else did you do with the? So you moved the decimal place over? Did you do anything else?

I: And then you've got to say times 10 to the whatever power. In this case, it'd be to the first power.

K: Okay. And then how did you solve number four?

I: I moved, so it's.. is that 3? 4? 3 zeros, yeah. I moved the decimal place over four to the right because you have to get it behind the four. And then, so then you have four times 10 to the negative fourth.

K: How do you know that you have to get it behind it the four?

I: Because that is the first whole number.

K: Okay. And then how did you do five?

I: Um, you have to ex-. So this is expanding. So you have to move the decimal place to the right seven times because it says 10 times 10 to the seventh. So if it would have said 10 to the negative seven, you would have to remember that seven to the left.

K: Mhm. And then what do you do with like, so after you move it, you go beyond the numbers that are in like, this original...

I: You add zeros.

K: Okay. Why do you do that?

I: Because anything, so when you're multiplying by 10. So say you have seven times 10. It's 70. You just add a zero behind the last digit.

K: Mhm, okay. And then so first, six, this was like, the kind of like the word problem. So, how did you solve six? Like, like, kind of like, what did you think when you first saw it? Like since it's a word problem so it's a little bit different. And then how did you approach this one? Similarly? Or differently than the other problems?

I: So what I did is I expanded the, the numbers and then subtracted them in a calculator.

K: Okay, so you took these that were in scientific notation and expanded them first and then...

I: And then subtracted them.

K: Okay.

I: Because I can't really do subtraction with, uh, scientific notation.

K: Why can't you do subtraction with scientific notation? Like, do you mean, like it's not possible or you just don't...

I: I just personally can’t.

K: Okay. And then so C is like, how would you help a classmate solve this problem if they were struggling? So, I mean, I can show you your answer. [Showed him his answer, but not any information regarding the grading.]

I: Yeah, what did I say on that one? C? Oh, yeah. So I’d show them that, uh, expanding the number. So like, expanding it, and then doing the subtraction. That's how I would show it and then if they want it back into scientific notation, show ‘em how moving the decimal places back, like, gives you that, uh, exponent of 10.

K: Uh huh. And then from, on a scale of 1 to 10, you said it was a seven. And you said, “I'm hard to understand sometimes” for like, helping them. Why did you answer in that way?

I: Because when I'm trying to explain something, sometimes I don't know what, like, the right word to say.

K: Mhm.

I: So sometimes I get confusing. And it's hard for me, under, sometimes for me to understand myself what I'm trying to say.

K: Do you think that it's less that like, you don't feel confident in your own understanding, so you struggle to explain? Or that you know *you* understand it, but it's like, you have trouble, like, expressing it?

I: I, I know I understand that.

K: Okay

I: I have trouble expressing.

K: Gotcha. And then I think that's like the last question on like, the content. So we have a couple more. Um, do you wish that you could change any of your answers?

I: No.

K: Okay, why?

I: [Laughing] Uh, I feel pretty confident about scientific notation.

K: Okay. Um, what were some uses for scientific notation that you saw in school? Like what were, like, kind of like, word problems or examples that you used it for in school?

I: Mostly in chemistry, like, the really small numbers.

K: For what, in chemistry?

I: So like, reaction problems. Or, uh, like moles.

K: Yeah. Um, would you use scientific notation if you were not instructed to to solve a problem?

I: Probably not.

K: Why not?

I: Like I said, I can't do like, addition, subtraction with just the scientific notation part. I have to expand it. Or else I won't be able to understand the, the connection there.

K: Okay. Um, how confident would you feel solving more complicated problems using scientific notation? So kind of similar to like the word problems that we did?

I: I'd say nine.

K: A nine? And then what is your preferred learning style?

I: I prefer to get hands on, so I would say tactile.

K: Tactile?

I: Yeah.

K: And then do you think you knew more or less about scientific notation after the pretest?

I: I....hold on. Can..say that again?

K: Yeah. Do you think you knew more or less about scientific notation after the pretest? So basically, did taking the pretest affect how you felt about your understanding of scientific notation?

I: No.

K: Okay. Um, do you think you could have done better on this topic with a review session or a lesson?

I: Probably not, because, I mean, to me, scientific notation is fairly simple.

K: Okay.

I: It's just moving a decimal place.

K: Okay, that's it!

I: Okay, thank you!

K: Thank you!

Post-test Interview Transcript

For the duration of the transcript, the interviewer will be referred to as 'K' and the interviewee will be referred to as "I".

K: Okay, so about the post test. So what did you think when you saw the test? Did you feel confident?

I: I mean, yeah. Just, yeah.

K: Why?

I: Because you guys, you guys did a pretty good job, like explaining the moving the decimal for adding and subtracting. That was really the only part where I didn't know how to do.

K: Like before?

I: Yeah.

K: Okay. Um, so how do you think you did on the test?

I: I think I did great.

K: Okay. Do you, um...Kind of going into that more. Do you wish you could change any of your answers?

I: I don't believe so, no.

K: Why not?

I: What's done is done.

K: Yeah. Um, so I'm going to show you the questions. So walk me through your thought process on the post test questions and kind of how you approached solving them. So for number one, it's like asking if you can subtract those numbers.

I: Yeah, so I did. And I said yes. And then I showed, like moving the decimal over on 6.979 times 10 to the eighth over to the right to, so it'd be 679 times 10 to the six. So that you could subtract, subtract that from that and just and move the decimal back. Move the decimal back as needed for final answer.

K: Okay, so why did you move the decimal in the first place? Like why can you not subtract these as is?

I: Because when you're subtracting with, including exponents, the exponent has to be the same, if you're gonna subtract.

K: Why?

I: That's just how I learned it. This is like, say you have an x, x plus x squared. You can't add those because the power is different.

K: Okay. Um, and then you mentioned that after you got like the answer when you subtracted, that you moved the decimal back over as needed. What do you mean “as needed”? Why do you need to move the decimal point over?

I: Because scientific notation the decimal point has to be behind the first nonzero term.

K: Why?

I: [Laughing] Um....But, once again, that's just how I learned scientific notation. I've always been told it's the decimal goes after the first nonzero number. And depending on if the number is before or after the original, say it’s 0.1. It'd be one times 10 to the negative first.

K: Okay. Um, so number two, I'm not gonna say these numbers out loud. Um, how did you approach doing this one?

I: So I moved. So there's an invisible decimal point behind the last zero on each number. So I just moved that to be behind the first nonzero, no the...Oh sorry.

K: You’re good.

I: The, so between the two and the five and the one and the three.

K: Mhm. And then what did you do after that?

I: I counted how many times I moved the decimal to get, I think this one was 21 and this one was like 19. And then I moved, I changed the exponent on this one to match the exponent on this one so I could add them.

K: Okay. So number three, this is the one with like the pieces of mail. Um, so how did you approach answering this one?

I: I moved the decimal point of 1.7 times 10 to the 13th to the right, three times, so that it would have the same exponent as 10 to the 10th.

K: Okay.

I: And then I subtracted 4.5 times 10 to tenth from 1700 times 10 to the tenth.

K: Okay. And then for four, the one about like the ants. How did you approach doing that one?

I: So this one's actually a trick question. Because technically, even though the number is bigger, the exponent, the number is still sm-. The exponent is a smaller number because it's in the negatives. So negative two is bigger than negative five. So I had to move the decimal on 4.56 times 10 to the negative second, over to the right three to match the exponent of 10 to the negative fifth.

K: So I feel like on the other questions, you mentioned that you were moving the exponent, or sorry, the decimal to the left. So why did you move the decimal to the right for this problem?

I: You move the decimal right for all of them.

K: Okay, I'm sorry if I misspoke. But do you? Did you move the decimal point in the same direction for all of them? Or did you move it in the different, different direction?

I: You move it in the same direction because you're trying to get the bigger number to have the same exponent as a smaller number.

K: Okay.

I: And then after you do all your addition, subtraction, then you move it back to the, the highest possible exponent.

K: Okay, sorry, I think I misunderstood you, but that makes sense.

I: Yeah.

K: Um, and then question five. So how do you help a classmate solve question four if they were struggling to understand?

I: I would do the visual of the decimal point moving. So in that example it’d be the two point.... No the 4.56 moving to the right three. So that I would also have the times ten to the negative fifth. And how it's going to explain that negative two is bigger than negative five even though it may not seem like it.

K: Okay. Um, so how... Sorry, that’s literally what I just asked. So on a scale of one to 10 how confident would you feel helping them and why? So it looks like you answered as a seven. And...

I: Because I, I... My confidence in trying to get my thoughts on the paper or out my mouth is difficult sometimes.

K: Okay. That seems to, like similar answer to the first interview. Okay. Sorry, let me make sure this is still going. Okay it is. Do you feel like you learned something new from the lesson? Or maybe if you didn't learn something new, do you feel like you did or did not solidify a concept that you kind of already knew?

I: I did learn something new. The moving the decimal for adding and subtracting because I didn't realize that I always just expanded it and added it that way and then put it back into scientific notation.

K: Do you feel comfortable like doing that, like in the future? Like if you had a class for that, you had to do that would you feel comfortable doing that now?

I: Yeah.

K: Okay. Why would you feel comfortable? Like what makes you feel confident in your understanding?

I: I made that connection. The connection has been made. So it's, it's there now.

K: Do you think the lesson complimented your learning style? Why or why not?

I: Sort of, I mean... I did like that I was able to do practice problems and all of that. And it got my mind thinking and it saw that. So yeah, sort of.

K: Sort of? Where do you think it could have been improved?

I: [Thinking]. Uhh, this was a week ago, I’m trying to remember.

K: You’re okay! [Pause] To give you a reminder, we did the concept map and then the question with the whiteboards, then the worksheet.

I: Oh yeah.

K: And then went back to the concept map and then a few days later, you did your post test.

I: Oh, yeah. Okay, so I really, the concept map was a really good idea. I think the problems, well actually the working together with the problems that was also really good. So I don't really know of any improvements I could think of.

K: Why did you like the concept map?

I: Personally, I don't like doing concept maps, but it was a really good idea to show what we understood on scientific notation.

K: Okay, and then why did you enjoy working in the groups?

I: I just, I like working with other people. I'm a social person.

K: So it's like a personal preference, like learning kind of style thing?

I: Yeah.

K: Okay. I think those are all the questions that I have. Thank you!

I: Yeah.

Lesson Plan

<table>
<tr><td colspan="2">Author (s):
Team Members:
KP Preut, Skyler Shaw, and Sydney Pilger</td><td>Title of Lesson: Application of Scientific Notation

Lesson Source: Scientific Notation Lesson Plan | Study.com word problems scientific notation key.notebook (commackschools.org)</td></tr>
<tr><td colspan="2">Lesson #: 1
Date lesson will be taught:
April 20th, 2023</td><td>Subject/Grade level:
9th Grade Math</td></tr>
<tr><td colspan="3">Concepts/Main Idea – explain the concept(s) that will be the focus of this lesson in detail.
- We will explain the definition of scientific notation and its purposes in the mathematical world.
  - Scientific notation is a way of expressing numbers that are very large or very small
  - This is done by placing one digit from 1 to 9 before the decimal place followed by relevant digits after the decimal place. This decimal is then multiplied by 10 to a power that accurately represents the number.
    - For example, 5,000,000,000,000 would be expressed as 5×10^{12}</td></tr>
<tr><td colspan="3">Common alternative conceptions – Explain the major alternative conceptions or partial understanding that students tend to have about this topic.
- misconception(s):
  - Students will likely be able to compute real numbers then convert to scientific notation. However, some may struggle computing numbers already expressed in scientific notation.</td></tr>
<tr><td colspan="3">Instructional model and strategies – The model (e.g., learning cycle, PEOE, ADI, etc.) and the strategies (e.g., concept-mapping, writing -to-learn, etc.) that will be used during the lesson

Model: 5Es

Strategies: Concept mapping, Think-Pair-Share</td></tr>
<tr><td>Objective/s- Write objectives in SWBAT form…
The Students Will Be Able To:</td><td colspan="2">Evaluation Based on your objectives, draft the content of the questions you will ask on your pre- and post-tests; at least 1 question for each objective. Questions do not have to be multiple choice. Your actual pre- and post-tests will be included in the interview paper.</td></tr>
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Students will be able to express real numbers in scientific notation.
Students will be able to convert numbers in scientific notation to real numbers.
Students will be able to solve word problems using the scientific notation format.

</td>
<td>

Diagnostic assessment – This should line up with the learning targets and provide the teachers with the information needed to make instructional decisions before the lesson begins. Be sure the assessment will make the students' thinking visible.

Students have taken a Pretest on the subject before Lesson.
Students performed very well and helped form the lesson on more word and word based problems.

</td>
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Formative assessment(s) – This should line up with the learning targets and provide teachers with the information needed to make instructional decisions during the lesson. Be sure to describe the format of the assessment and what it is designed to assess.

Concept map comparison
Teacher will observe how concept maps develop and change over the course of the lesson
Fist to five after completing the Explain section
Check for student confidence on the topic before moving on the the elaborate section

</td>
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Summative assessment - This should line up with the learning targets and provide teachers with the information needed to be confident that students understand the content. Be sure to describe the format of the assessment and what it is designed to assess.

Post test will be given the next class after the class
Post Test will include word problems as well as addition and subtraction with scientific notation

</td>
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</table>

Kansas Science and Math Standards- Include standard, benchmark and indicator where applicable

Math Lessons must include:

1. one Common Core Math Practice Standard (Number and Title of standard)
    - Attend to precision
2. A minimum of one Common Core Math Content Standard (domain, cluster, standard)
    - 8.EE.A4 Expressions and Equations (Work with radicals and integer exponents)
3. one science practice from NGSS
    - S4. Analyze and interpret data

Describe the big ideas found in the standards that you are addressing.

The big ideas in the math standard addressing scientific notation is how to read and write scientific notation. Students will be able to work out problems in decimal and scientific notation, through interviews we found that some students had a harder time when the problem was already in scientific notation. Our lesson will also look at the two different ways they would see scientific notation

Write the essential question that will be used to focus this lesson.

How can scientific notation be used to simplify computing data?

<table>
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Materials list (BE SPECIFIC about quantities)
for Whole Class:

per Group: One whiteboard (3 total) for doing computations in the Explore section.

per Student: One piece of paper for every student to make their concept maps

Advance preparation:

<u>Include handouts</u> at the end of this lesson plan document (blank page provided to paste a copy of your document). List handouts in your materials list.

● 9 copies of Elaborate worksheet
● 9 copies of summative assessment.
</td>
<td>
Accommodations: Include a general statement and any specific student needs. Be sure to include struggling readers.

● Teachers provide verbal and visual directions on the board.
    ○ Teacher will be make themself available to read out the problems
</td>
</tr>
</table>

	Safety: Include a general statement and any specific safety concerns • General classroom safety should be enforced. ○ Students need to be respectful to one another.

Describe what the student and the teacher will do during each stage of the lesson. Be sure to describe the learning experiences and the assessments. You also need to discuss any management considerations (e.g., picking up materials, movement of students, etc.)

Engagement: Estimated Time: ___5_minutes______		
What the teacher does AND how will the teacher direct students: (Directions)	**Probing Questions:** Critical questions that will connect prior knowledge and create a "*Need to know"*	**Expected Student Responses AND Misconceptions -** *think like a student to consider student responses INCLUDING misconceptions:*

● Teacher will put students into pre-assigned groups ○ Three groups of three ● Each student should have a piece of paper. ● Students will work with one another to create their concept maps. ○ Everyone should make their own. Group members can have the same map, or individuals can have differences based on their own understanding. ○ Students will be given the terms "scientific notation, decimals, and data" to be included in their concept maps. They also need to come up with three more terms to add to their maps. These terms need to be connected with associative verbs. ● One student from each group will briefly share what they discussed.	- What additional vocab can you add? - What words are you using to connect the terms? - What does it mean if there is a negative in your equation?	- multiply, squared, divide - reduces, groups - That my number will be negative.

Exploration: Estimated Time: _____6 minutes_____		
What the teacher does AND what the teacher will direct students to do: (Directions)	**Probing Questions: Critical questions that will guide students to a "*Common set of Experiences*"**	**Expected Student Responses *AND* Misconceptions -** think like a student to consider student responses *INCLUDING* misconceptions:

● Students will stay in the groups they were placed in for the Engage section. ● They will be given a large whiteboard to show their work for the practice problem. ● Students will be given a word problem to solve as a group. ○ The word problem will include data that has very large numbers. ○ Students will not be directed to solve the problem using a specific method (including scientific notation). ● Students will need to show their boards for the next step, so they will be told to not erase their work.	- How do you handle numbers this large? - Is scientific notation more beneficial for examples this large or detrimental?	- Maybe split the number into smaller ones so they're easier to solve. - Beneficial

Explanation: Estimated Time: ___4 minutes_______		
What the teacher does AND what the teacher will direct students to do: (Directions)	**Clarifying Questions:** Critical questions that will help students "*clarify their understanding*" and introduce information related to the lesson concepts & vocabulary	**Expected Student Responses *AND* Misconceptions -** think like a student to consider student responses *INCLUDING* misconceptions:
● Groups will go to the front of the class with their boards and explain how they found their answers. ○ Other students will be directed to ask the presenting group questions about their method. ● All methods are acceptable, however the goal is that a group explains how to compute numbers expressed in scientific notation. ○ If none of the groups used this method, the teacher will explain the method. ● Teacher will do a fist to five to check for students' understanding and confidence with the content.	- How do the vocab words that you've chosen help explain the process of scientific notation?	- They help express each step of writing scientific notation

Elaboration: Estimated Time: ____8 minutes______		
What the teacher does AND what the teacher will direct students to do: (Directions)	**Probing Questions:** Critical questions that will help students *"extend or apply"* their newly acquired concepts/skills in *new situations*	**Expected Student Responses *AND* Misconceptions -** think like a student to consider student responses *INCLUDING* misconceptions:

● Students will return to their groups and will be given a worksheet to complete. ○ This worksheet will be word problems that require the use of scientific notation. ■ For this worksheet, students will be required to compute numbers that are expressed in scientific notation. ● The teacher will circulate to make sure groups are using the required method. ● When the groups are finished working on the problem, each group will share their answers. ○ If each group got the same answer, move on to the next activity. ○ If groups got different answers, go over the methods used and clear up any misconceptions. ● Next, students will pair up with a student they have not worked with that day. ○ Students will need the concept maps they created earlier. ○ Students will work together in a Think-Pair-Share to describe any changes they would make to their concept map. ■ They need to add at least one more term and create a justification for any changes or why they kept their map	- What changes in your process of computing equations when using scientific notation? - How would you now go about solving equations with larger numbers?	- You have to keep in mind the exponents and pemdas - The same way maybe

otherwise unchanged. ○ Students will briefly tell the class what changes they made.		

Evaluation: Estimated Time: _____7 minutes_____ **Critical questions that ask students to demonstrate their understanding of the lesson's performance objectives.**
Formative Assessment(s): *In addition to the pre- and post-test, how will you determine students' learning within this lesson: (observations, student responses/elaborations, white boards, student questions, etc.)?* ● Concept map comparison ○ Teacher will observe how concept maps develop and change over the course of the lesson ● Fist to five after completing the Explain section ○ Check for student confidence on the topic before moving on the the elaborate section ● Observing student work throughout the lesson ○ When they are working with whiteboards and on the worksheet, teachers will observe their work and check for mistakes and misconceptions. ● Students reporting their answers to the whole class ○ If there are differences in answers, we can go over them
Summative Assessment: *Provide a copy of the key to the post-test in the interview paper.*

Pre-test Key

Question 1:
- Multiple answers accepted.
- 1 point for answering with clear effort given

Question 2:
- Multiple answers accepted.
- 1 point for giving a scenario
- 1 point for justifying their response

Question 3:
- Answers accepted: 8.7 x 10 or 8.7 × 10^1
- 0.5 points for right answer
- 0.5 points for showing work

Question 4:
- Answers accepted: 4.0 x 10^-4 or 4 x E^-4
- 0.5 points for right answer
- 0.5 points for showing work

Question 5:
- Answers accepted: 82950000
- 0.5 points for right answer
- 0.5 points for showing work

Question 6:
- Answers accepted:
  - a) 1.08 x 10^11 pieces of mail
  - b) 108000000000 pieces of mail
  - c) Multiple answers accepted
  - d) multiple answers accepted
- Points
  - a) 0.5 points for correct answer, 0.5 points for showing work
  - b) 0.5 points for correct answer, 0.5 points for showing work
  - c) 1 point for clear effort shown
  - d) 1 point for clear effort shown

Post-test Key

Question 1:

- Answers accepted:
  - Yes, you have to convert them to the same power.
  - No, you cannot in the current form, you have to convert first
- 1 point for correct answer
- 1 point for explanation

Question 2:

- Answer accepted: 2.513×10^{21}
- 1 point for correct answer
- 1 point for doing the computation in scientific notation

Question 3:

- Answer accepted: 1.6955×10^{13}
- 1 point for correct answer
- 1 point for doing the computation in scientific notation

Question 4:

- Answer accepted: 4.557×10^{-2}
- 1 point for correct answer
- 1 point for doing the computation in scientific notation

Question 5:

- Multiple answers accepted for both questions
- 1 point for answering the first question with an explanation
- 1 point for answering the second question with an explanation

Interviewee Pretest

[redacted]

10/10

1. Describe what scientific notation is.

1.73×10^4 ← that

2. Describe a scenario where it would be useful to use scientific notation. Why is it useful in that situation?

When dealing with very large or small numbers. It makes it easier to read & apply.

3. Express 87 in scientific notation, show your work.

8.7×10^1 8.7

4. Express 0.0004 in scientific notation, show your work.

4×10^{-4}

5. Express 8.295 x 10^7 as a real number, show your work.

82,950,000

The table shown below gives the approximate number of pieces of mail handled by the United States Postal Service (USPS) for different years.

Year	Approximate number of pieces of mail handled
1950	4.5 x 10^10
1965	7.2 x 10^10
1980	1.0 x 10^11
1995	1.8 x 10^11
2010	1.7 x 10^11

6. How many more pieces of mail were handled by the USPS in 1995 than in 1965?

a) Express your answer in scientific notation, show your work.

180000000000 − 72000000000

1.08×10^{11} or 108,000,000,000

b) Express your answer as a real number, show your work.

c) How would you help a classmate solve this problem if they were struggling to understand?

I would show them how moving the decimal Place relates to the Power relation

d) On a scale of 1-10, how confident would you feel helping them, why?

7 I'm hard to understand sometimes

Interviewee Post-test

10/10

Name: [redacted]

Scientific Notation Post Test

*****For each problem, compute with the data expressed in scientific notation.*****

1. Can you subtract 1.494×10^6 from 6.79×10^8? If so, explain the process. If not, explain why it is not possible.

2/2

Yes move the decimal place on 6.79×10^8 two to the right to be 679×10^6 then subtract

679×10^6
$- \; 1.494 \times 10^6$
677.506×10^6 $\quad 6.77506 \times 10^8$

2/2

2. What is 2500000000000000000000 plus 13000000000000000000?

2.5×10^{21} $\quad 1.3 \times 10^{19}$

250×10^{19}
$+ \; 1.3 \times 10^{19}$

251.3×10^{19}
2.513×10^{21}

3. The table shown below gives the approximate number of pieces of mail handled by the United States Postal Service (USPS) for different years.

Year	Approximate number of pieces of mail handled
1950	4.5×10^{10}
1965	7.2×10^{11}
1980	1.0×10^{11}
1995	1.8×10^{12}
2010	1.7×10^{13}

a. How many more pieces of mail were handled by the USPS in 2010 than in 1950?

2/2

1700 x10^10
- 4.5x10^10
1695.5 x10^10

1.6955 x10^13 more pieces of mail

4. A weak ant carries a spec of food that is 2.34 x 10^{-5} inches long. A stronger ant carries a spec of food that is 4.56 x 10^{-2} inches long. How much longer is the stronger ant's spec of food?

2/2

4560 x10^-5
- 2.34 x10^-5
4557.66

4.55766 x10^-2

5. How would you help a classmate solve question 4 if they were struggling to understand?

2/2

Move the decimal of 4.56x10^3 to the right because it is the bigger number

On a scale of 1-10, how confident would you feel helping them, why?

7, Sometimes I struggle to express my thoughts.

Interviewee Concept Map

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