Spring 2017

Evaluating the Degree of STEM Curriculum Incorporation in the Elementary Classroom

Mary Grismer
University of Iowa

EVALUATING THE DEGREE OF STEM CURRICULUM INCORPORATION IN THE ELEMENTARY CLASSROOM

by

Mary Grismer

A thesis submitted in partial fulfillment of the requirements for graduation with Honors in the Education

Mark McDermott
Thesis Mentor

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INTRODUCTION

Science has always been a controversial topic in education that cannot seem to be figured out for the masses. It is evident that science is important for students to learn about, starting from when they begin school all the way through high school and potentially college. The big question around science curriculum seems to be: What is the best way to teach it? There are so many different theories and opinions about science curriculum and how it should be incorporated into the classroom, that in some cases the potential, or point of the lesson, can become lost or a burden to teach. Science has always been something that I have had a passion for growing up in school. Sometimes it seemed too ‘by the book’ or there was not enough experimentation within the given time that we had as students. I enjoyed the challenge as well as the feeling of being ‘stumped’ by an inquiry based lesson or project, which seemed to only happen occasionally through my experiences.

Being a pre-service teacher and going through the University of Iowa’s College of Education science courses, my idea of what science curriculum is, has changed the way I have always thought about science and really opened my eyes to the potential that it has in an elementary classroom. Through these courses, inquiry based learning was the key component that showed the application that we, as future teachers, could utilize in our classrooms as we experienced this type of learning ourselves. I was lucky enough to have had the opportunity to be in a classroom through my student teaching experience where every single one of the students enjoyed science. Although I was able to try out a few inquiry-based lessons, the science curriculum that was provided did not allow for much variance in the way it was to be taught. I was placed at a high-risk school where math and reading needed to be the biggest areas of curriculum, and science was somewhat shoved at the end of the day with an “if we get to it, we will do it" mindset. I saw how excited the students were when we *could* do science, and just thought that with a different sort of curriculum that could incorporate those other areas of learning, that it could make a big difference in the students' learning and approach to other subjects as well.

I have been involved with this research project alongside Mark McDermott's research team as they have implemented a professional development training program for teachers that is supported by a Title IIA Teacher Quality grant at the University of Iowa. This training program is an instructional approach based on a STEM theoretical perspective of integration between the four disciplines of science; Science, Technology, Engineering, Mathematics. His current research has been the implementation of this new instructional approach into real-life classrooms and learning through these experiences what does and does not make an effective STEM learning environment for both the teachers and the students. My role in this research was to evaluate the assessment tools to understand the degree of STEM integration that was already produced through the ASSIST (Argument-based Strategies for STEM Infused Science Teaching) STEM project, and to create a new tool to show the degree of integration with the units and lesson plans these teachers are using in their classrooms. This process resulted in a mixture of a qualitative and quantitative data as my portion of the project was to create a new 'tool' that would be available to use as a comparison method towards the different units and lesson plans for the degree of STEM integration as their research continues.

Working towards this goal, I needed to have a basic understanding of what STEM integration was, what the teacher's roles would be in this new integrated curriculum, as well as how it could be evaluated for the concepts taught. These three main components of research funneled into my main research question of: "How can one evaluate and compare the degree of STEM integration in lessons as a part of an ASSIST learning environment?"

LITERATURE REVIEW

STEM Integration as a Whole

Although STEM (science, technology, engineering, mathematics) integration is known nation-wide and is widely discussed within school systems, there seems to be a big question mark on if it really works, or what the best way to go about the implementation is.

> *The natural connections between science, technology, engineering, and mathematics have caused them to be lumped together in local, state, and national conversations, but despite their proximity in discussions of policy and practice, they still remain largely isolated within the silo-structure of most schools (Glancy & Moore, 2013, pg. 4).*

Throughout my initial research, I have found many studies all showing different key components to STEM and the different qualifications the curriculum needs to have to be deemed a "STEM curriculum." One way that STEM has been clearly represented and explained was through the STEM translation model (see figure 1). As Glancy & Moore (2013) state, "… lessons and activities are at their best when they encourage students to make translations between the ideas of multiple disciplines" (pg. 19). In this way, instead of a teacher doing an explicit science lesson, they promote an inquiry-based learning strategy to allow students to work across these

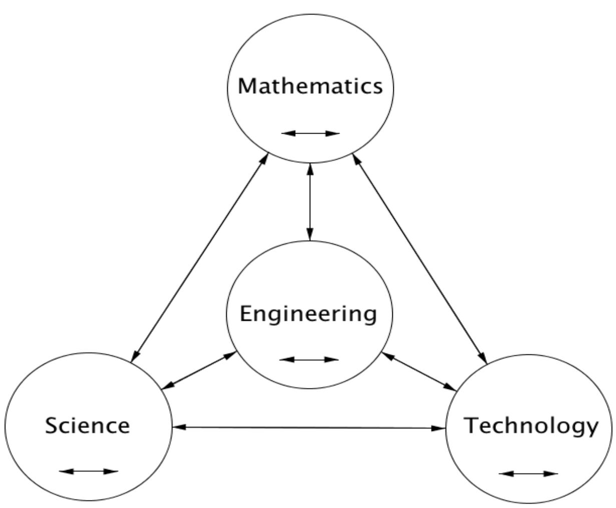

Figure 1. STEM translation model reproduced from Glancy & Moore (2013) Theoretical Foundations for Effective STEM Learning Environments.

subjects and broaden their understanding for the curricular concept that is meant to be taught, but then 'translated' through the four disciplines. This would make the science concept more abundantly clear and allow the students to have a larger opportunity for their own exploration and problem-solving strategies, which can reap benefits through many other curriculum areas as well.

The Teacher's Roles

New data and research is released daily claiming the "next best thing" in curriculum across all subjects. In some ways, many people may feel this way about STEM integration as it could be a "too good to be true" curriculum method. This may be the reason for many schools to keep the explicit science curriculum until the STEM programs become more widely used and accepted. Schmidt and Fulton's research (2016) claims that students, as well as teachers, have a hard time with engaging in the inquiry process; "The many requests to teach facts and to provide explicit instructions … provide evidence not only that PSTs [pre-service teachers] struggled with the inquiry approach, but also give some indication of their epistemological beliefs." (pg. 309-310).

STEM integration is all about melding the four subject domains into an active learning process. "However, moving towards integrated STEM education is not easy; providing opportunities for teachers to learn about the nature and practices of STEM disciplines with which they have limited background is critical" (Guzey & Moore, 2016, pg. 23). Because most pre-service teachers do not get this STEM education, it is important that proper training and support be given for educators to succeed. Part of this training would need to include not only the information on the curriculum, but also techniques for the inquiry based teaching and learning for their classroom. “The organization of a STEM unit is critical,” Guzey and Moore state, “…the learning goals and objectives of the unit are all tied meaningfully to the standards” (2016, pg. 21). Most teachers are used to explicit curriculums, or step by step instructions on the lesson progression, as it is easier to mediate in the large quantities that are needed between classrooms, schools, and districts. Unfortunately, having an inquiry based lesson using a STEM approach does not make the most reliable curricula as the lesson can go in many different directions based on how much or how little the students know and are understanding. Teachers using this approach have a higher responsibility of understanding the overall topic as they work with the students to compose and answer these exploration-based questions.

Evaluation of STEM Incorporation

The best way to create a sense of what fundamental skills are the most beneficial, or what key characteristics are needed for there to be a successful unit or lesson in the STEM disciplines, is through evaluation. “Good evaluation [of the teachers] provides meaningful information that helps guide the content, form, and structure” of any lesson or unit of teaching (Avery, 2010, pg. 17). When teachers are using a STEM pedagogy in the classroom, evaluation is a component that allows for reliability of STEM learning environments and instructional practices across grade levels and schools. In this way, evaluation is utilized as a way for teachers to reflect and gain knowledge to better their content and teaching procedures instead of using standard evaluation tools based on curriculum that the teachers are following step by step.

Schmidt and Fulton conducted research focusing on pre-service teachers as well as inquiry-based approaches as they try to develop an integrated STEM learning environment. It was seen that “… their lack of familiarity with the pedagogical approach, they had little basis from which to evaluate their learning progress or to draw experiences that they could generalize to their own teaching" (2016, pg. 310). Without this education and training for teachers, there will likely be less potential of learning that could commence within the classroom. Teachers are going to need guidance on how to engage students with concepts and subjects within an integrated STEM learning environment. If not, they may not have the "fundamental skills," and in turn, "short circuit" the implementations, or do so insignificantly (Avery, 2010, pg.14). In turn, without the training and knowledge required for the different sorts of curricula, the evaluations will fall short of the possibility that they could have on the science education. Through Avery's research; "… it was concluded that the more teachers understand how students learn, the more valuable the knowledge is, and the better teachers become at refining and improving their own practices" (Avery, 2010, pg. 18). Creating, explaining, and utilizing different evaluation approaches for the students as well as the teachers will only allow for STEM curriculum to blossom.

METHODOLOGY

The STEM teaching approach that has been used throughout this research project has been developed by Mark McDermott and his research team supported through a Title IIA Teacher Quality grant. They have created training and tools to help teachers utilize the Argument-based Strategies for STEM Infused Science Teaching (ASSIST) approach. This approach has been built on background information from three main research-based areas: research exploring characteristics of effective STEM learning environments; research exploring Argument-Based Inquiry (ABI); and research supporting utilization of multimodal communication and how to improve the understanding of science concepts as a way to model how scientists communicate in the real world. As a new approach, the one goal of this research team is determining the best way to help teachers understand what this integrated STEM is, and the beneficial ways that it can be implemented into their daily science classrooms (McDermott, 2017).

The teachers who are currently involved teach in five different school districts. For these participating classrooms, the ASSIST approach emphasizes the different characteristics that are important to have an effective STEM learning environment. These characteristics include things such as; focus on cognitively demanding the targeted concepts in the curriculum instead of having a focus on retention of specific content facts, real-world and authentic problems and issues instead of isolated scientific facts, and involving new and emergent technology into the instructional activity and all facets of the students' work (McDermott, 2017). Through these characteristics, McDermott's team of researchers has determined that utilizing this ASSIST approach to infuse STEM integration can promote greater student science literacy.

As figure 2 shows, through the ASSIST approach towards a STEM integrated lesson, the science conceptual big idea can be transformed, supplemental material can be provided, and the three main areas are utilized. These three main areas include; science practices, argument-based practices, and multimodal communication. Engaging students in these areas,

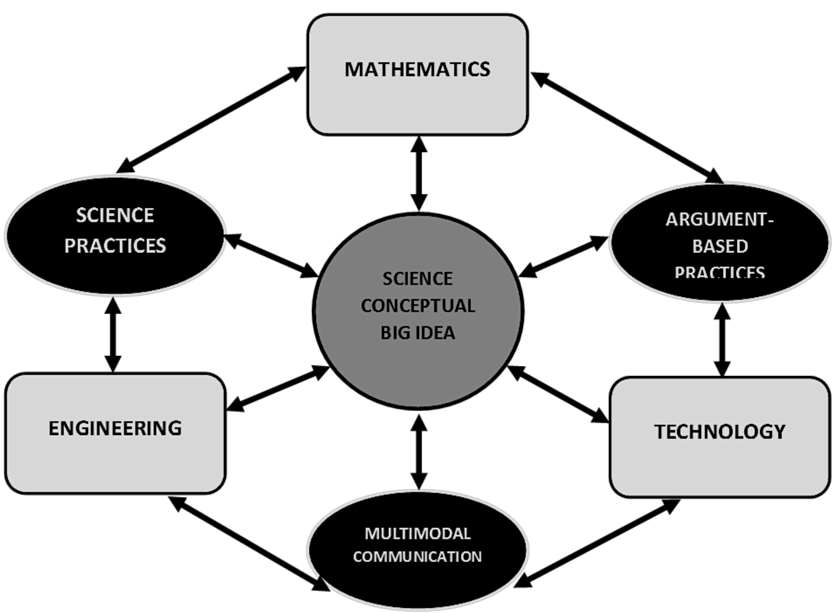

Figure 2. Translation opportunities reproduced from McDermott's (2016) ASSISTing with STEM Education Promoting Argument-Based Strategies for STEM-Infused Science Teaching.

encourages negotiation and communication as they make sense of the science conceptual big idea. Through the ASSIST approach, and the translation opportunities model (see figure 1) teachers will have the "...opportunity to move between activities in the different STEM disciplinary realms, as well as activity that is centered on argument and negotiation, the science practices, and multimodal communication" (McDermott (2017), pg. 7).

Through the development of the ASSIST approach, the research team is also developing evaluation tools to be used to assess the implementation by the teachers in this study. The focus of this study was on this evaluation aspect of the STEM integrated units and lesson plans that teachers had already participated in as part of the professional development associated with the project. These assessments are a way for the research team to document the degree of fidelity with which the teachers implement the ASSIST approach, as well as give feedback to the teachers and help build a theoretical framework for the approach. Building off the tools and experiences of the research team, a new tool, or rubric, was created for this study to gain a quantitative representation that explains the degree of the ASSIST STEM integration through the lessons and units. Because these original assessment tools are subjective with written feedback for the teachers on their units and specific lessons, it is harder for these to provide a concrete comparable method to determine which lessons and units were more integrated, and more successful while using the ASSIST approach.

Initial consultation with the ASSIST research team led to identification of an overarching theme for a tool of assessing the "degree" of implementation within both the units and the individual lessons. A higher score would be indicative of greater implementation with a stronger STEM unit or lesson, and a lower score indicating a weaker implementation for that specific unit or lesson with less integration. Using a starting point of questioning what *ideal* results would look like and translated the most effectively towards large audiences, a visual representation seemed to be the best way to communicate numerical and comparable data. The sample results that were created are based on extreme representations of the degree scores of implementation that could be measured using this new evaluation tool. These sample graph results are showing a comparison between the unit plan score and the individual lesson plan scores. The graphs are a way to have a visually comparable method to show the score for the unit that was developed before the implementation of the lesson plans compared to the actual individual scores after the lessons were taught.

Shown below are two example bar charts (figures 3 and 4) with the unit plan being the first bar, and the lesson plans represented after. The y-axis shows the degree number score (in a percentage) that the unit and lesson plans received based on my evaluation rubric, and the x-axis labels the different classes with their unit and lesson plans. Because the overall score that can be achieved for the unit and lesson plans are different, a percentage is used to represent the score to compare the two fairly. The intention of creating these two bar charts was to show how contrastive the unit plans and lesson plans can potentially be when stacked next to each other. The bar graphs show the impact of planning a unit with the intentions of using the ASSIST approach to achieve STEM integration, and then compared to how it was carried out through the individual lessons. The overall point being, that a teacher could have a unit that may look like it will have a high STEM integration, but in reality the individual lessons have a low degree of STEM integration when carried out, and vice versa.

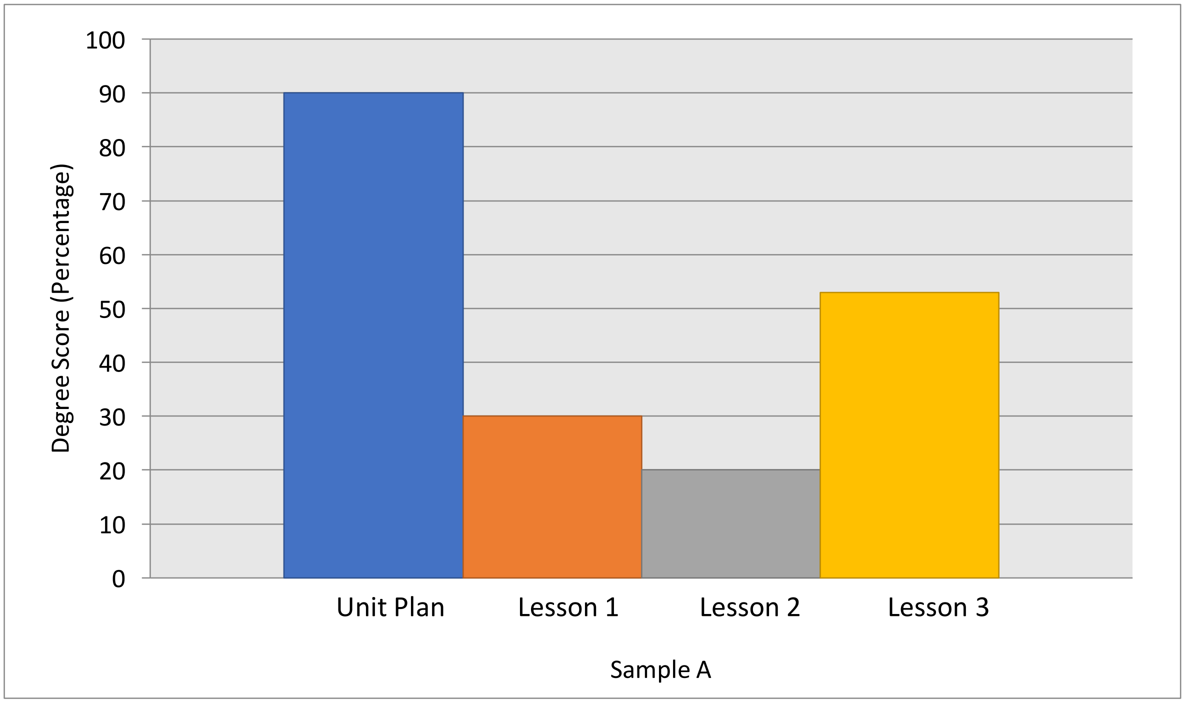

Figure 3. Example bar chart for comparison showing the unit plan with a high degree score, and the lesson plans with lower degree scores.

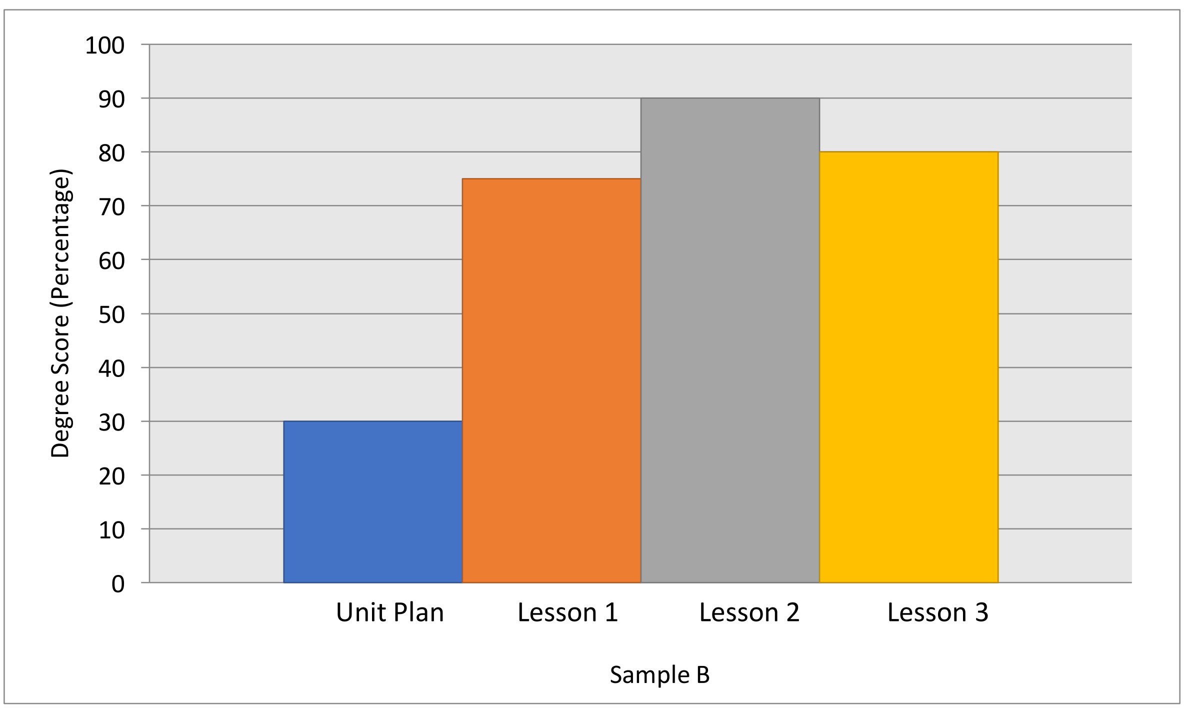

Figure 4. Example bar chart for comparison showing the unit plan with a lower degree score, and the lesson plans with high degree scores.

After creating visual sample ending results, it was then a matter of turning an imaginary chart into a quantifiable rubric while working with the assessment tools that are already put in place through the ASSIST handbook. Starting with the unit plan assessment tool from the ASSIST handbook, the key aspects that could influence a numerical score were then translated into a new developed tool as it pertains to the degree of STEM integration. It was evident that for each area there needed to be a range of scores; ie. high, medium, low, instead of a complete versus incomplete. This is due to the subjective feedback that teachers will receive based on the evaluation rubric, and to gain a better understanding for the integration based on a numerical score. To incorporate this necessity, the revised tool took the subjective data that is given during the evaluation and transfers it into quantifiable data. This same procedure was applied to the development of a revised lesson planning tool. At the end of both new evaluation tools, there is a key indicating whether the lesson scored a high degree of STEM integration, an average degree of STEM integration, or a low degree of STEM integration. The broadest range of scores is in the "average degree of STEM integration" as that would be the goal to have the teachers aiming to achieve the average degree, but with opportunity to achieve either a high or low degree of STEM integration through implementation of the ASSIST approach.

The main purpose to create this tool is for a way of comparing data while using the ASSIST approach. This tool can be used for teachers to reflect on their planning as they see the results of their degree scores compared to their units and individual lessons. It can be used across a grade level where teachers of the same grade are all teaching the same scientific concept, but because of the inquiry-based approach no two classrooms are going to be going through the same actions as it is all based on the questions and the solutions that the students and teachers create. In this way, one classroom could really go into depth and achieve a high degree of the STEM integration because they took extra steps of exploration allowing for there to be a healthy variance across different classrooms. This evaluation tool can also be used as a look at the school and how the teachers are doing as they reflect upon previous lessons and units that have been planned and taught. The possibilities and potential for this tool are numerous with the main goal of comparing and reflecting upon the use of the ASSIST STEM approach when looking at the degree of implementation. The immediate use for this tool will be to help the ASSIST research team as they compare and analyze the teachers' units and lessons as they continue to develop this approach.

As a method of testing out the new evaluation tool, a pre-service teacher course at the University of Iowa College of Education was videotaped and the unit plan for the unit was provided. The overall unit was on evolution with several separate lesson plans. I used my tool with his unit plan that was written, and then wrote notes on his lesson plans using the original ASSIST evaluation tool while watching the videos. Only the sections that were directly correspondent towards the new evaluation tool were filled out, and they were not written in the format of feedback or for reflection but for the main purpose of gaining a score. These lessons were in the format of a lecture, and two lab classes.

DISCUSSION

Results

The results for this test show that the original written unit plan scored a degree score of 81%, which is a high degree of ASSIST STEM integration. It showed great promise for integrating the ASSIST STEM approach. The first lesson video that was viewed was of a lab learning environment, it scored an average degree of ASSIST STEM integration with a degree percentage of 74%. This lesson had a lot of inquiry-based questions and problem solving along with a hands-on activity that allowed for individual exploration. The second lesson was in a lecture setting with the teacher giving information to the students with an inquiry based approach, but without any hands-on activities, as it scored a low degree of ASSIST STEM integration with a degree percentage score of 27%. The last lesson that was evaluated was in a lab learning environment and again had inquiry-based questions, and multimodal communication, and earned an average degree of ASSIST STEM integration with a degree percentage score of 53%. These percentage scores are shown in the graph below comparing the written unit plan to the videoed lesson plans.

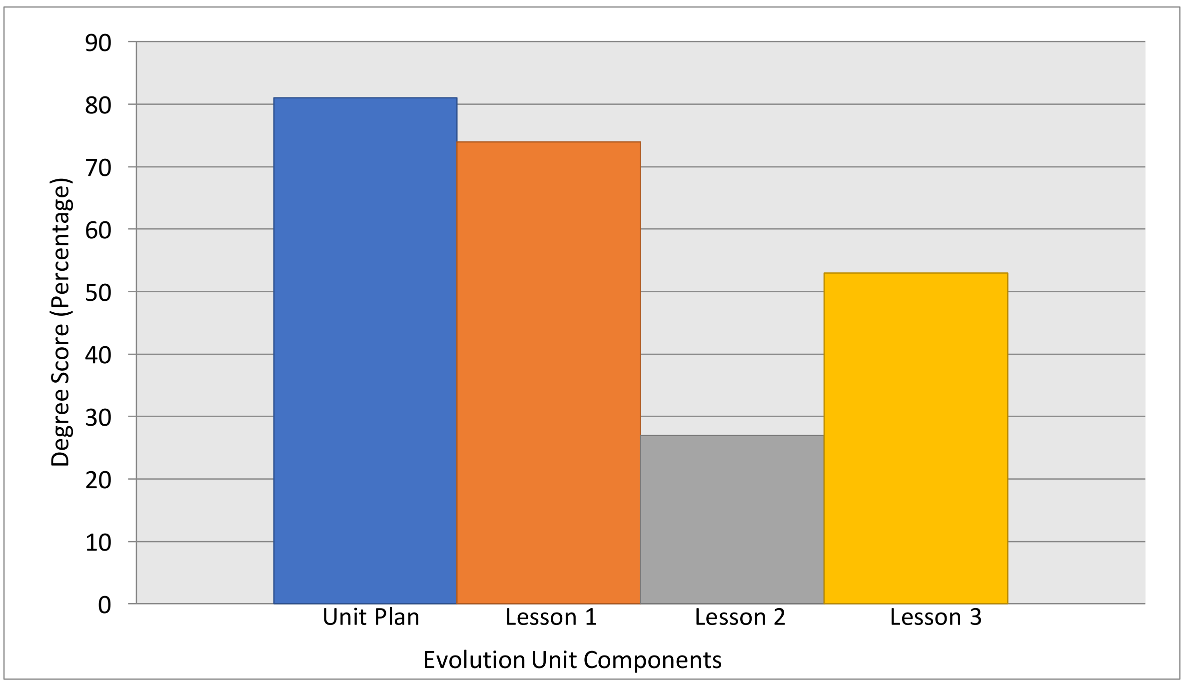

Figure 5. Results from the pre-service teaching course using the new developed evaluation tool with a written unit plan and videotaped lessons.

Discussion of Results

The original evaluation tool that has been developed for the ASSIST approach was needed for the new degree of integration evaluation tool to be used. This is due to the new evaluation tool being based off the original ASSIST approach tool. It would be difficult to use the new evaluation tool solely by itself, but with new development it could. After having the original assessment tool filled out, the new degree evaluation scoring rubric was rather easy to gain the degree score as the original ASSIST assessment tool did not need to be filled out in its entirety.

Limitations

This new developed evaluation tool does have limitations, just as any tool would. The tool does not have any subjective feedback, which is why it has the range of scores in each category. However, in some categories it is based on how many different strategies are used based on the translations opportunities model (figure 2). So, if there is only one or two of these translations used within an activity or lesson, it is going to gain a lower score. Sometimes a lesson may only need one or two translations for the lesson to be successful and understood by the students. In this case, the lesson would score lower on the new evaluation tool, but it may be more successful compared to a lesson that does have majority of the translations used.

Another limitation that the new evaluation tool possesses is the capability for there to be only student driven inquiry and exploration. This, however, is not realistic to have happen for every activity, and the students may not gain the same inquiry process as if it was a student and teacher combination, which scores lower on the new evaluation tool. A student and teacher combination would have a back and forth motion between the student and teacher, allowing for a higher level of the inquiry based teaching process. In this way, the student would most likely achieve a higher understanding of the science concept, but the evaluation tool would reflect a lower score.

This is true as well with lessons that only have one stem discipline throughout, but if there is a lot of different discussions and inquiry thinking and questioning happening between the students and the teacher, then it could be a stronger lesson as well but it will gain a lower score using my tool. As long as teachers can look beyond the score and reflect on their lesson even if there were not that many integrations of the STEM ASSIST program, then they should be happy with their inquiry lesson.

If there would be any changes made to the new evaluation tool it would be to look at all of the lessons as a whole and average their scores, or to use all of the individual lesson scores on a unit scoring sheet to see what the overarching themes were as the unit progressed. It may be beneficial to compare the lessons using the unit scoring chart to see if each of the areas were utilized like how they were supposed to be while looking at the original unit plan. The goal should be to gain all the components throughout the whole unit instead of through each individual lesson would be something that I would change on my lesson plan tool. This is because there is not a realistic way for every single lesson to have every single discipline within the STEM ASSIST pedagogy, but if the teachers are working towards implementing these different things, then it can be potentially a more successful lesson, and unit.

Implications for Teachers

The new evaluation tool reaps many benefits for both researchers, teachers, principals, etc. who will be using the ASSIST approach. This new evaluation tool is a simplistic version of what the original ASSIST evaluation tools may provide for the teachers as feedback on their lessons. Written feedback is widely beneficial both for documentation of the research, and for the teachers participating as they look and reflect on their own lessons as they start to integrate this new STEM pedagogy into their teaching. The new evaluation tool then comes in to provide a concrete way for there to be comparison between the different lessons and units throughout the study, and eventually for the teachers and principals themselves. A teacher may use this tool and assess themselves on the degree of their integration based on the written feedback that they have received by either the researcher or the principal who may be evaluating their STEM lessons. This tool allows for there to be a way to determine how integrated a lesson was.

Conclusion

Working alongside the ASSIST research team, the implementation for this tool will not only benefit their research towards creating this pedagogy of STEM integration in the classroom, but will also allow teachers, principals, and others to have a better understanding of what STEM can look like in the classroom. Inquiry based learning is a key component in this STEM integration that can be utilized to create more variance in science concepts and teaching practices. As the research continues for the ASSIST team, the utilization of the new evaluation tool will be helpful in allowing for comparable data between teachers, lessons, and units. In this way, the integration of this approach will grow and become more stable and reliable.

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APPENDIX

APPENDIX A

UNIT PLAN INTEGRATION DEGREE SCORING RUBRIC

Overview of Unit Plan

SCORE	EXPLANATION OF SCORING
3	All three aspects; Science and Engineering Practices, Conceptual Big Ideas Framing, Crosscutting Concepts, are filled in their entirety
1	Only some are filled out, or the three aspects are not filled out in their entirety
0	None of the overview aspects of the unit plan are filled out

When Aspects of Unit Plan are Translated

SCORE	ASSIST TRANSLATION CATEGORY DEGREE OF INTEGRATION
	Mathematics Degree of Integration
3	Consistent: 4 or more times mathematics is implemented within unit lesson plans OR implemented into each lesson if there are less than 4 lessons within the unit
2	Multiple: 2-3 times mathematics is implemented within unit lesson plans
1	One Time: 1 lesson has mathematics implemented within it
	Engineering Degree of Integration
3	Consistent: 4 or more times engineering is implemented within unit lesson plans OR implemented into each lesson if there are less than 4 lessons within the unit
2	Multiple: 2-3 times engineering is implemented within unit lesson plans
1	One Time: 1 lesson has engineering implemented within it
	Technology Degree of Integration
3	Consistent: 4 or more times technology is implemented within unit lesson plans OR implemented into each lesson if there are less than 4 lessons within the unit
2	Multiple: 2-3 times technology is implemented within unit lesson plans
1	One Time: 1 lesson has technology implemented within it
	Argument-Based Strategies Degree of integration
3	Consistent: 4 or more times argument-based strategies is implemented within unit lesson plans OR implemented into each lesson if there are less than 4 lessons within the unit
2	Multiple: 2-3 times argument-based strategies is implemented within unit lesson plans

1	<u>One Time</u>: 1 lesson has argument-based strategies implemented within it
	Multimodal Communication Degree of integration
3	<u>Consistent</u>: 4 or more times multimodal communication is implemented within unit lesson plans OR implemented into each lesson if there are less than 4 lessons within the unit
2	<u>Multiple</u>: 2-3 times multimodal communication s is implemented within unit lesson plans
1	<u>One Time</u>: 1 lesson has multimodal communication implemented within it
	Science Practices Degree of integration
3	<u>Consistent</u>: 4 or more times science practices is implemented within unit lesson plans OR implemented into each lesson if there are less than 4 lessons within the unit
2	<u>Multiple</u>: 2-3 times science practices is implemented within unit lesson plans
1	<u>One Time</u>: 1 lesson has science practices implemented within it

<u>Alignment with Standards</u>

SCORE	EXPLANATION OF SCORING
3	Complete
1	Partial
0	None

<u>Translation Category Integration</u>

SCORE	INTRA-UNIT/INTRA-ACTIVITY DEGREE OF INTEGRATION
3	5-6 Translation categories integrated within the unit
2	3-4 Translation categories integrated within the unit
1	1-2 Translation categories integrated within the unit

OVERALL UNIT SCORE: _______

<u>KEY:</u>

OVERALL SCORE	SCORE DESCRIPTION
27-22	High Degree of ASSIST STEM Integration within a Unit
13-21	Average Degree of ASSIST STEM Integration within a Unit
12-7	Low Degree of ASSIST STEM Integration within a Unit

APPENDIX B

LESSON PLAN INTEGRATION DEGREE SCORING RUBRIC

<u>Classroom Activity Progression</u>

SCORE	EACH ACTIVITY'S DEGREE OF INTEGRATION
	Activity
3	Only student action during an activity
2	A teacher action and a student action during an activity
1	Just a teacher action during an activity
3	5-6 key aspects implemented into activity
2	3-4 key aspects implemented into activity
1	1-2 key aspects implemented into activity
	Activity 2 (if needed)
3	Only student action during an activity
2	A teacher action and a student action during an activity
1	Just a teacher action during an activity
3	5-6 key aspects implemented into activity
2	3-4 key aspects implemented into activity
1	1-2 key aspects implemented into activity
	Activity 3 (if needed)
3	Only student action during an activity
2	A teacher action and a student action during an activity
1	Just a teacher action during an activity
3	5-6 key aspects implemented into activity
2	3-4 key aspects implemented into activity
1	1-2 key aspects implemented into activity

Multiple Aspects

SCORE	EXPLANATION OF SCORING
3	Primary aspect and secondary aspects including significant evidence of implementation
2	Having either only a primary aspect with significant evidence, OR having a primary and secondary aspect, but without significant evidence shown
1	Only having a primary aspect with little to no evidence of implementation

Transitions between Aspects

SCORE	DEGREE OF INTEGRATION DURING TRANSITION
3	Seamless transition/integrated aspects; transitioning back and forth
2	Clear transition of switching aspects
1	Small transition touching upon another aspect

OVERALL LESSON SCORE: _______

KEY:

OVERALL SCORE	SCORE DESCRIPTION
30-23	High Degree of ASSIST STEM Integration within the Lesson
12-22	Average Degree of ASSIST STEM Integration within the Lesson
11-4	Low Degree of ASSIST STEM Integration within the Lesson