UNDERSTANDING CURRENT PRACTICES OF INTEGRATED STEM EDUCATION IN K-12 SCIENCE CLASSROOMS

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[Abstract] This study examined current practices in integrated STEM education using a new classroom observation protocol designed specifically for K-12 science and engineering classrooms. Our work examined protocol scores from over 2,000 video-recorded classroom observations to better understand how integrated STEM is being implemented in various classroom settings, including different science domain focus and grade levels. Findings revealed that integrated STEM lessons with a focus on physical science content included more integrated STEM instructional practices at higher levels compared to earth and life science lessons. Further, scores from elementary classroom observations indicate that more integrated STEM practices are used at higher levels compared to middle and high school classroom observations.

[Key words] STEM education, observation protocol, quantitative research, classroom practice

Ⅰ. Problem

The integration of science, technology, engineering, and mathematics (STEM) subjects in K-12 education has been theorized as an educational approach to improve student learning (Jong et al., 2020) and better prepare students to address 21st century, interdisciplinary problems (e.g., Moore et al., 2020, NAE and NRC, 2014). Although school districts and teachers have begun to adopt integrated STEM approaches into their teaching, this has been challenging due to disagreement on models and effective approaches. The literature points out inconsistencies related to which and how many of the STEM disciplines must be included, putting into question the nature of integration among disciplines (Moore et al., 2020). This confusion of definitions is reflected in the lack of an observation protocol sensitive to the unique nature of integrated STEM education However, our team has recently developed such an instrument for this specific use in science and engineering classrooms engaging in integrated STEM teaching and learning.

Ⅱ. Research Method

The work presented here shares how we used the STEM Observation Protocol (STEM-OP) (Dare et al., 2021) to measure the degree of integrated STEM within K-12 teaching, drawing upon a large dataset of video-recorded classroom observations, collected from a previous project in which teachers co-created integrated STEM curriculum units for use in a science classroom. This work attempts to address questions that educators have about integrated STEM in science classrooms concerning science content areas and grade-levels. The work presented here addresses the following research questions: 1) *To what extent is integrated STEM education being implemented in K-12 science classrooms as evidence by our integrated STEM protocol?*, 2) *What differences in practice as measured by protocol scores, if any, exist across different science domains?*, and 3) *What differences in practice as measured by protocol scores, if any, exist between protocol scores across grade levels?*

1. Context

Our project team had access to over 2000 video-recorded classroom observations of integrated STEM teaching in K-12 science classrooms that were collected as part of a prior, federally funded 5-year project. This prior project included professional development for the observed teachers that used a design-based framework for integrated STEM education drawing from frameworks described by Moore, Glancy et al. (2014) and Moore, Stohlmann et al. (2014) to develop and implement integrated STEM curriculum. These frameworks additionally guided the development of teacher team-created integrated STEM curriculum units. Participating teachers individually implemented their co-created curriculum unit in their classrooms during which the observations were video-recorded each day of implementation. The data set includes observations from 106 unique teachers' classrooms from five school districts that include urban, inner-ring suburban, and outer-ring suburban K-12 settings in the Midwestern United States. Most of the observations focus on grades 4-8, although early elementary (K-3) and high school (grade 9 in particular) are represented to a lesser extent. The science content covered in these units spans several topics in Physical Science (e.g., force and motion), Life Science (e.g., ecosystems), and Earth Science (e.g., plate tectonics).

2. Data Collection and Analysis

To answer our research questions, we used a new observation protocol for K-12 integrated STEM education (Dare et al., 2021) that we developed based on our conceptual framework for integrated STEM (Roehrig et al., 2021) that focuses on seven key characteristics: 1) a focus on real-world problems, 2) the centrality of engineering, 3) context integration, 4) content integration, 5) engagement in STEM practices, 6) 21st century skills, and 7) informing students about STEM careers. our framework centralizes engineering design in which students are presented with an authentic problem to solve. The STEM Observation Protocol (STEM-OP), strategically aligned to this conceptual framework, includes 10 items with four descriptive levels for each item (scored 0-3): 1) Relating content to students' lives, 2) Contextualizing student learning, 3) Developing multiple solutions, 4) Cognitive engagement in STEM, 5) Integrating STEM content, 6) Student agency, 7) Student collaboration, 8) Evidence-based reasoning, 9) Technology practices in STEM, and 10) STEM career awareness.

The project team used the STEM-OP to score the previously collected video observations. Throughout this process, some video observations were removed for various logistical reasons, including video and/or audio issues or incomplete observations that were significantly shorter than a class period; this accounted for a small percentage of total video observations available (less than 10%). Each video recorded observation served as our unit of analysis, representing one class period of instruction (approximately 50 minutes). At the end of this process, we were left with a total of 2,030 scored video observations. These included 999 Physical Science, 434 Earth Science, and 597 Life Science observations. These videos also represented 885 elementary (K-5), 1071 middle school (6-8), and 74 high school (9-12) classrooms.

To determine the extent to which integrated STEM education occurred in our observed K-12 classrooms, we first examined the mean, median, and overall distribution of item scores across the entire data set. We then used two complementary methods to determine the extent to which integrated STEM instruction varied across grade level and science content type. We initially used a crosstab analysis to compare the absence or presence of each item given our context focus (either comparing science domain or grade level). We used this analysis simply to compare the absence or presence of each item in a binary fashion; this allowed us to first understand in what contexts items were statistically more present, disregarding the extent or rigor to which it was included (i.e., the level scored on each item).

Due to the non-normal distribution of most of our item scores, we then used a Kruskal-Wallis test (Siegel & Castellan, 1988) to analyze the means of our original item scores (scaled 0-3) across science content area and grade-level to determine the extent to which these different classroom types differed in terms of the degree (or level of rigor) to which a given item was implemented. As with the crosstab analysis, this was done to compare across science content area and grade-level.

Ⅲ. Findings

The means and medians of our item scores were relatively low across all ten items observed in our 2,030 classroom videos. This suggests that current classroom practices related to integrated STEM education are not necessarily aligned with the aspirations of the instrument and the theory supporting it. This is most notable for Items 1, 9, and 10, which were also underrepresented in the data set, but also for Items 3 and 8, which focus more on engineering. When comparing across science domains, we observed that Items 1, 2, 3, 5, 6, and 9 were more present and scored at higher levels in physical science classrooms compared to life science with differences also found between physical science and earth science for Items 5, 6 and 9. Differences between earth science and life science occurs only for Item 2 and 6 with earth science outperforming life science. No difference in presence or score was detected for Items 4, 7, or 10. When comparing grade levels, our findings reveal that Items 2, 3, 7, 8, and 10 were more present in elementary observations compared to both middle and high school observations; Item 6 was more present in elementary compared to middle school, but not high school. Similarly, Items 2, 3, 4, 6, 7, and 10 were scored higher in elementary observations compared to middle school observations. Additional differences were observed between elementary and high school observations (Items 2 and 10) and between middle school and high school observations (Item 2). Curiously, Item 2 decreased in both presence and mean score as grade-level increased. Items 1, 5, and 9 showed no differences with respect to presence or rigor (i.e., item score) when comparing grade levels.

Ⅳ. Discussion

This work suggests that in general classrooms are not yet at the ambitious level of integrated STEM education as the literature (and our conceptual framework) suggests; this indicates that more work is needed to educate teachers about integrated STEM practices. Further, we find two conditions under which integrated STEM is happening more and at higher levels – when physical science is the focal science content and in elementary classrooms. Life science observations tend to not only include fewer practices, but when the practices are present, they are not as rigorous. This suggests that more work is needed to improve integrated STEM practices within the context of life science.; learning why physical science tends to lead to higher scores is imperative for this task. What is interesting to note is that when comparing science content areas, there were no differences with items 4, 7, and 10, which are most strongly related to 21st century skills and STEM career awareness. When comparing across grade levels, Item 5 does not depend on grade level, suggesting that all grade levels have equal opportunities to engage in integrating STEM content. What is concerning is that Item 2, which relates to contextualizing student learning, appears to decrease as grade level increases. Further work is needed to better understand what elementary teachers are doing with respect to integrated STEM education so that middle and high school teachers may learn from these practices.

It should be noted that this work has several limitations. Although our dataset is large, it is primarily focused on grades 4-8. It is possible that more data collected from early elementary and high school classrooms would results in different results. The data is also limited by the placement of the camera in the classroom, which could impact how the implemented lessons were scored on the STEM-OP. Further, the professional development that contextualized the curriculum written and observed for this work shared one vision of integrated STEM education that slightly varies from the one portrayed in the STEM-OP. In particular, the originally professional development did not emphasis practices related to Items 1, 9, and 10, which likely explains the low representation of these items within the STEM-OP score data set.

Ⅴ. Conclusions

In total, this work indicates that more professional learning opportunities are needed for teachers to learn about integrated STEM. Because the science and STEM education communities' understanding of integrated STEM education has not yet been well-defined when it comes to implementation and practice, this work helps us and others better understand the current landscape of integrated STEM education in practice. Of note, it appears that teachers may benefit from targeted support in relating content to students' lives (Item 1), technology practices in STEM (Item 9), and STEM career awareness (Item 10). Further, the low presence and lower mean item scores of Items 3 (Developing multiple solutions) and 8 (Evidence-based reasoning) suggest that science teachers may benefit from learning more about engineering and engineering education. Teacher educators should also rethink teacher professional learning; the inclusion of this within pre-service spaces is also necessary. While the instrument was designed in part for research purposes, it is clear that the tool can be used in formative ways, such as for coaching, curriculum writing, and professional development (including pre- and in-service environments). Our work indicates that there is more to be done to reach the ambitious demands of the integrated STEM literature.

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