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# 49 Stories That Make an Ultimate STEM Lesson Plan

SWATI MEHTA, ROHIT MEHTA, INESE BERZINA-PITCHER,
CHRISTOPHER SEALS, AND PUNYA MISHRA
*Michigan State University, USA*
mehtaswa@msu.edu
mehtaro3@msu.edu
berzina1@msu.edu
sealschr@msu.edu
punya@msu.edu

In this paper we reviewed what 49 large urban public school district STEM teachers enrolled in a year-long graduate certificate and fellowship program at a large Midwestern university considered as their amazing teaching moments. They were asked to share their amazing teaching moments that would make an Ultimate Lesson Plan in STEM. In smaller groups of five, then they were asked to find connections between their amazing teaching moments and to look for the essential components that make these moments amazing. This activity led the teachers to discover 51 key components that made an ultimate lesson plan. We analyzed these 51 key components to find common and overarching themes that were grouped together into a final list of seven key components for an ultimate STEM lesson plan. These key components that make an ultimate STEM lesson plan give us an insight into what working teachers consider to be important for student engagement and learning in STEM content in classrooms, and whether it is in tandem with what research or policy has suggested in past.

## INTRODUCTION

With increased emphasis on integrating STEM in curricula, an important question that comes up is what goes into creating an excellent STEM lesson plan? This study seeks to answer this question through a close analysis of 49 lesson plans that have been identified as being transformative and powerful by a select group of STEM teachers. Our analysis of these excellent and powerful learning opportunities allows us to identify themes and broad principles that cut across these diverse lessons and thus provides teachers and researchers with guidelines as they seek to integrate STEM in the K12 classroom context.

STEM (science, technology, engineering, and mathematics) education in the United States has become an important topic of discussion among policy-makers, researchers, and teachers (Kuenzi, 2008). President Obama has also stressed on the value of STEM education and its role in making the US a problem solver (The White House, 2013). One of the reasons behind this attention is that students are gradually moving away from STEM-related topics as they face multiple challenges in understanding the subject-matter and relating to them (National Academy of Sciences, 2012). Looking at this trend in K-12 education, the National Academy of Sciences designed a framework (Next Generation Science Standards) that defines the vital dimensions of science and engineering. According to the NAS:

> K-12 science and engineering education should focus on a limited number of disciplinary core ideas and crosscutting concepts, be designed so that students continually build on and revise their knowledge and abilities over multiple years, and support the integration of such knowledge and abilities with the practices needed to engage in scientific inquiry and engineering design. (NAS, 2012, p. 2)

To enable learning that focuses on these aspects, NAS also suggested that teachers should encourage students to ask questions and solve problems; analyze, evaluate, and interpret data; carefully examine and "carry out investigations" (NAS, 2012, p. 17); and be part of intellectual arguments with their peers and teachers. They also stressed that for these efforts to have the intended effects, these three dimensions should be included into standards, curriculum, instruction, and assessment (NAS, 2012).

Although a lot of emphasis is given to research and how it shapes policy when it comes to STEM education, we often forget to weigh in what teachers have to say from their experiences in teaching these topic areas. Teachers' voices on the matters of policy, especially when it affects them directly, or involves something as critical as STEM education, must be assessed before its implementation (Darling-Hammond & Sykes, 1999).

In this article, we discuss our attempt at understanding some of the perspectives of teachers located in an urban school district. We analyzed stories of 49 STEM teachers from a large urban school district in the Midwest. These stories were written by these teachers as a part of a graduate-level certificate course they were all enrolled for with a large Midwestern university. These teachers shared their best teaching moments, and, in groups of five, compiled a list of five key ingredients that make an ultimate STEM lesson plan. We used these ingredients to look for themes, and grouped those in a list of key components that teachers find important to STEM education. Before we discuss these themes and our method in detail, let us take a quick look at the program which made this possible.

### Urban STEM Fellowship

A large public Midwestern university, in collaboration with a large urban public school district, and a private international IT company, designed a year-long graduate certificate and fellowship program. This program, known as the Urban STEM, concentrates on empowering STEM teachers in K-12 settings to create transformative, innovative, and multimodal instructional experiences for their students. The second cohort of this program comprises of 49 STEM teachers. One of the many projects that these fellows do during the span of a year involves them to work together in groups of four to five and share their experiences, also known as their 'amazing teaching moments.' We then asked the fellows to find common threads between their amazing teaching moments to compile a list of five key components per group that makes an amazing lesson plan in STEM. We then compiled all the 49 amazing teaching moments and their 51 key components for an ultimate lesson plan in STEM into a book called "Ultimate STEM."

## METHOD

In this section, we take a closer look at the 51 key components that the fellows considered to be critical to make a STEM lesson plan great. Here, we will discuss how we took these 51 components and coded them to compile a list of recurring themes. To begin the coding process, first, we compiled each of 51 quotes that defined a single key component into a separate word document. We then printed these on sheets of paper to cut them down into individual strips. Four of the authors of this paper then discusses each of these quotes one-by-one and posted a sticky note with a theme each time they agreed on it. Each quote went through a grueling discussion between the authors and was not considered as *complete* unless all four of the coders agreed on a theme. After going over each of these quotes, we ended up with multiple themes for each of the components. Seventeen such themes evolved from our first round of coding.

Second, we entered all the coded data into a Google spreadsheet. Rows contained the 51 key components and the broad themes that came out of our first round of coding were entered into columns. Next to each of the key components, we marked a '1' under the column for a theme. We repeated this step for each component and all themes. This step was done to systematically arrange the codes along with quotes and count off the recurring themes. For example, for the following component: "**Creativity:** Creativity allows for multiple intelligences, with open interpretations that exceed teacher expectations, and plays on students' strengths," we marked '1' for *student-centered pedagogy, teacher affect and interest,* and *pedagogy to support creativity*.

After entering this data into the spreadsheet, we looked for patterns that emerged across the themes to find common thread between them. This gave us an insight into the overarching themes and allowed us to group the key components that these educators considered as critical to student learning, cognition, motivation, collaboration, etc. In the next section, we will discuss these recurring themes in detail.

## THE SEVEN KEY COMPONENTS

Out of the seventeen themes that were coded in the first round, we found similarities and noticed some patterns between them, which allowed us to group these codes together into seven overarching themes. Based on the final round of combining these themes, our study indicates that teachers emphasize creativity and collaboration, which helps students to take ownership of their learning, to gain conceptual clarity, and link concepts across and within disciplines. Seven themes that recurred the most, in sequence of the times they recurred, were (a) ownership of learning process, (b) student-centered pedagogy, (c) structure and culture of classroom, (d) student collaboration, (e) fostering student creativity, (f) teacher as facilitator, and (g) experiential learning. These themes appeared between six to sixteen times. To better understand these themes, let us look at each of these in detail.

### Ownership of Learning Process

Previously, O'Neill (2005) has defined ownership as, "a complex, multifaceted process that captures the relationships that students build between themselves, as youth and as learners, with science as the subject they aspire to participate in and with the context in which that participation takes place." In the amazing teaching moments that the Urban STEM fellows shared, students taking ownership of their learning process stood as the most recurring theme. Fellows stressed that they believe it is important for their students to actively participate in classroom activities and find "confidence to explore and expand their learning" themselves (as referenced throughout the paper from the ingredients the fellows mentioned.). Looking at their key components for an ultimate STEM lesson plan, we found that the fellows believe that for teaching practices to be effective it is extremely important that the students take ownership of their learning. In the following example, we can see that fellows connected the sense of ownership with a sense of discovery and wonder as well: "Empowering students to take ownership of their learning: Students learn best when they have confidence to explore or expand upon their learning. As teachers, this is when we see the most 'wow' moments."

### Structure and Culture of Classroom

Structure of classroom concentrates on the type of activities that the students partake in, how they approach these activities, and how the information within these activities helps them analyze their ability and approaches to perform these activities (Ames, 1992). The Urban STEM fellows in their amazing teaching moments shared that the range and diversity of the activities ensures that the "students have choice in obtaining the goal." They also observed that the "conditions" created in the classroom should support "student engagement and understanding" and their "confidence in exploring ideas."

A classroom culture, on the other hand, is indicative of an environment of trust and acceptance that forms the foundation for empowering students and creates a comfortable environment that enables them to learn from their mistakes. Such culture should enhance student achievement and empower them to reach their maximum potential. The fellows suggested similar outcomes for their students. They reflected that the classroom culture for students creates a "comfortable space to explore the range of their abilities" and that lessons should balance classroom structure and provide students the freedom to explore different options. In the following example, a group of fellows speak of such safe and encouraging classroom culture: "Safe classroom culture: Each lesson is dependent on students feeling confident that they can explore their ideas, make them public, and be supported in their efforts."

### Student-Centered Pedagogy

Moving away from the traditional lecture-based method of teaching, student-centered pedagogy places the focus of an activity on the student (Prince and Felder, 2006). These approaches involve students to solve problems, discuss different scenarios, brainstorm possible solutions, role-play different perspectives, and collaborate in teams to resolve these problems. The fellows highlighted that students should be able to gain conceptual understanding of the "subject-matter," and identify different levels of learning, which encourages active participation. Teachers, here, help "bridge the gap between textbook and student learning." Being a recurring theme in the amazing teaching moments, most of the fellows envisioned their lesson plans with their students in the driving seat. In defining what makes a lesson plan ultimate, few fellows said that "student-centered learning is driven by the students. The teacher becomes a facilitator as students "run" the learning environment." Others, while envisioning their students at the center of learning, also made connections with other themes like ownership and collaboration: "Student self-directed learning: The learning environment encourages student collaboration and higher order thinking to make sense of the world. Students reflect and communicate their findings taking ownership of their learning."

### Student Collaboration

Another theme that works with the concepts of ownership and student-centered pedagogy, but still is discussed enough to stand by itself is the theme of student collaboration. Students interact and work together on a problem, project, or activity, to gain an in-depth conceptual understanding. The fellows, when speaking of an ultimate lesson plan, deduced similar findings as they said, “Each lesson allows students to deepen their understanding while participating in constructing their own knowledge through collaborative hands-on activities.” Working in groups, the fellows also observed that students were able to “pool their collective mental resources to better address problems,” by giving feedbacks to each other students were able to augment their learning, which also helped them to take ownership of their learning, and hence “meaningfully contribute to their group’s success.” Some of the fellows concluded that the success of a group depends on how effectively the group members communicate with each other.

### Fostering Student Creativity

Teaching for creativity has been defined as using “forms of teaching that are intended to develop young people’s own creative thinking or behavior” (Jefferey and Craft, 2004, p. 77). Teaching to foster creativity focuses primarily on inspiring students to be innovative and promote student empowerment. Csikszentmihalyi (1997), when speaking of systemic model of creativity, has highlighted the role of gatekeepers in recognizing and fostering individual creativity. In a classroom setting, the teachers can be considered as the gatekeepers for student creativity. Through their innovative pedagogical approaches, the fellows gathered that “Creativity allows for multiple intelligences, with open interpretations that exceed teacher expectations and plays on students’ strengths.” They also recognized that when teachers support and encourage student creativity, they are freely able to express their ideas in public, which in turn results in multiple “creative responses” from the students.

### Teacher as Facilitator

As seen above, the fellows put their students in the driving seat and stressed on the importance of a student-centered pedagogy. In addition to this, they also emphasized on a critical role of themselves -- the teachers. Bolstering students’ learning processes helps students choose and achieve their goals. This can be done by providing them with resources, challenging tasks, guidance in developing their cognitive skills, and providing support in learning, etc. This encapsulates the process of scaffolding, which in turn helps students to draw from their prior knowledge as well. Fellows underscored that this support aids students to "apply and transfer their understanding to novel situations," and enables "them to use their individual strengths and prior knowledge to develop understanding." These STEM teachers found themselves in the role of a facilitator, following a system that can look like: "I do, we do, you do together, you do alone." *[sic].* This gentle removal of scaffolding was considered an important part of an ultimate STEM lesson.

In addition, the fellows connected the importance of facilitation back to some of the other themes. They said that when teachers play the role of a facilitator, students are better able to take ownership of their learning and are also able to collaborate in each other's learning process, which increases their knowledge and skills. Fellows also concluded that teachers should actively "repurpose goals" for students to comprehend with a concept in new ways and engage creatively in classroom activities. They emphasized that teachers should help bridge the gap between "textbook and student learning (hands-on activities, discussions, etc.) to provide opportunities for student-driven learning and open-ended thinking."

### Experiential Learning

Drawing from Dewey's philosophy of experience-based learning, students reflect on their prior experiences and apply them to their present experiences (Dewey, 1938). They do this by drawing conclusions from prior experiences and using them to conceptualize present ones. Experience-based learning aids students to also make connections between their experiences and the concepts being studied in school. The fellows observed the significance of experiential learning in their classroom settings as well, and highlighted how students should be able to "connect with their environment to abstract ideas in the content" and use "real world situations and tools... to connect to their own world." Through hands-on learning students can research and "develop their own evidence which leads to relational understanding."

Apart from these seven major themes, we also found themes that were not as dominant and recurred only between one to five times. These themes were (a) interdisciplinary approach, (b) elaborate cognitive skills, (c) practicality and expected utility, (d) teacher affect and interest, (e) inclusive pedagogy, (f) technological pedagogical and content knowledge (TPACK), (g) student diversity, (h) student motivation, and (i) teacher/colleague collaboration. Although these themes were not as prominent as the seven themes that we discussed, one cannot undermine their importance in classroom setting as well. That said, it is important to identify the seven key themes that stand out as most recurring themes essential to make an ultimate lesson in STEM.

## CONCLUSION

The emphasis of new student-centered pedagogies and its possible positive effects on student engagement is noteworthy. The seven key components for an ultimate lesson plan, according to 49 STEM teachers from a Midwestern urban school district give us a sense of what teachers as practitioners find important when designing and teaching STEM lessons in their classrooms. These seven themes are: (a) ownership of learning process, (b) student-centered pedagogy, (c) structure and culture of classroom, (d) student collaboration, (e) fostering student creativity, (f) teacher as facilitator, and (g) experiential learning.

The manner in which these teachers design their activities results in student collaborating with each other, student empowerment, helps them gain ownership of their learning, and encouraging student creativity. In addition, it also helps us to view teaching as an active process for students, where teachers facilitate a culture that helps students gain a conceptual understanding of the subject-matter. We observed that the teachers did this by creating an environment that encouraged students to explore their maximum potential, provided them with choices to engage in different activities, and supporting innovation, which, in their experiences, resulted in students freely expressing their ideas and views.

In addition to these key components, we found that few teachers integrated technology in their pedagogies to support their experiments with their lessons. Technology, which is considered integral to support pedagogy and content knowledge was put on the back burner by the fellows. This could be because it was either felt too natural or normal a part of the teaching environments to be counted or because it was not considered important to their lessons. We believe that the former is more likely to be the case because the Urban STEM program is essentially driven by the TPACK (Technological Pedagogical Content Knowledge) (Mishra & Koelher, 2006) framework and Dewey's philosophy of experience-based learning, which is why the fellows are exposed to technology and its integration throughout the program. This somewhat reiterates what Bax (2003) said about normalization of technology, where it becomes invisible to its users: "Our aim should be to attain a state of '*normalization*' in which the technology is invisible and truly integrated."

In conclusion, in comparison to the Next Generation Science Standards, it appears that the fellows in this study acknowledged the importance of the NGSS strategies, but also underscored the importance of flexibility and creativity, in addition to these standards. Generally, practice (of the fellows) seems to be sailing in tandem with the policymakers and researchers. Although there still are some difference of opinions and several points open for discussion, it appears that all the three ships (practice, policy, and research) are sailing in the same direction.

Once again, we would like to highlight that our analysis of these excellent and powerful learning opportunities, which allowed us to identify what teachers consider to be important components for engaging and amazing plans, provides teachers, researchers, and policymakers with guidelines as we seek to integrate STEM in the K12 classroom context. We need to keep in mind where our teachers are and what pedagogies work for the content that they teach. Only then we can think of using technology effectively to support their pedagogical content knowledge, and help them develop professionally.

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