Facilitating Teaching and Learning Across STEM Fields

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Abstract

The reformation of the instruction of subjects across STEM fields has changed the role of STEM educators from being "dictators" in the classroom/laboratory to being facilitators of students' activities. This new paradigm shift means STEM educators are no longer limited to delivering instruction intuitively, but rather with effective facilitation of students' activities. Thus, the STEM educator is now to assume the role of the creator of effective educational environments for learning while teaching. This is enhanced by instructional strategies and delivery that synergize diverse students, strategies, technologies, societies, and subjects. This article addresses a paradigm shift for STEM educators as facilitators, their roles as students' activities enablers, and factors influencing effective facilitation in STEM programs.

Introduction

Many schools have implemented a new Science, Technology, Engineering, and Math (STEM) education program that will introduce students to a number of STEM concepts in the school curriculum. Institutions of learning through educators' active participation must strive to create programs that will encourage students to get excited about STEM disciplines through various activities, including hands-on activities (Aleman, 1992; Darling-Hammond, 1994). The practical applications of the concepts students learn in the classroom and laboratory will help enhance the quality of STEM education (Darling-Hammond, 1994; Fajemidagba, Salman & Olawoye, 2010). More important is partnership between schools and professionals in the industry to help prepare lectures, as well as the participation of schools in hands-on activities in the classroom that introduce the students to careers across STEM fields and fundamental skills. STEM educators, with a new paradigm shift as "facilitators" and laboratories well-equipped with modules where students will spend most of their time learning, will help students to take what they learn in the classroom and laboratory and apply it to future jobs in the real world.

Employers are looking for employees who possess the skills that are taught in STEM programs, including creative problem solving, product building, collaborative team work, design, and critical thinking (Aleman, 1992; Darling-Hammond, 1994). It is mandatory for these STEM programs to build those skill sets. There are so many ways to build these skill sets. One approach is to offer courses in career paths, as evidenced by the case of the ASK Academy. In an effort to boost the number of graduates who pursue careers in STEM, the school offers courses in two career paths: engineering and design, and biomedical sciences. In this curriculum, there is a focus on science, technology, engineering and mathematics and electives that will help students get a job in those fields. This approach is implemented by creating partnerships with the business community and finding mentors for students.

Another feasible approach is to provide hands-on training for the young engineers needed by the industries of tomorrow. This is an opportunity for engineering students to take practical action for the future, as demonstrated in the case of the UK's JCB academy. At the JCB academy, students are taught practical subjects such as engineering, product design, and health sciences, which require specialized equipment, as well as English, mathematics, science, humanities, foreign languages, and IT. More importantly, each problem has a business element to it and the rest of the curriculum is built through engineering.

In the two examples stated, students are going to understand what STEM area careers are by employing the machines used in the laboratories that are similar to the ones they would use on the job. More importantly, students will use technology in the way one might when working in a STEM profession. This reformation has made learning student centered and has changed the role of STEM educators "from providing information to providing structure, support, and connections to the resources" (Glasgow, 1997, p. 123) needed by both educators and students.

What is facilitation?

Facilitation has been given many definitions by many authors. The dictionary definitions of facilitation are "to make easy or easier" (Webster) and to "expedite, smooth, assist, aid, help, further" (Oxford). Bentley (1994) opined that facilitation is a process that also includes nonaction, silence, and even the facilitator's absence. It is however required that the facilitator work with students (individually or as a group) when they are gathering and using information (brainstorming, designing, or solving problems) to make a difference towards the achievement of learning goals.

What is a facilitator?

The STEM educator as a facilitator is to guide and manage students when they are engaged in any form of learning activities in the classroom or laboratory facility (Darling-Hammond, 1994; Kuskie and Kuskie, 1994; Fajemidagba et al., 2010). The STEM educator as a guide is required to be fully prepared before any classroom activities, so that students' time will be wisely spent and learning will take place. Otherwise, when students are not fully engaged in the work of learning, the educators become mere managers (Glasgow, 1997, p. 21). More importantly, STEM educators are to facilitate the activities of students with reduced input to solutions needed to problem solve or to do hands-on activities. Aleman (1992) described this further:

> "It is no longer acceptable for the teacher to be the one with the knowledge. Teachers must become comfortable with students as their own teachers working in cooperative groups to solve problems in a culturally, technologically, and socially evolving environment. We need to rediscover the natural curiosity of students that will lead them to bodies of knowledge and means of discovery that…teachers can encourage." (p. 97)

In addition, it is also the responsibility of the STEM educator to be accountable for students' learning based upon some learner outcomes (Kuskie et al., 1994). This is necessary in an effort to produce citizens who are productive and could make a difference. Glasgow (1997) noted that "continued learning and problem solving are requirements of life. Classroom [and laboratory] activities should reflect a greater connection to the conditions found outside the classroom" (p. xviii). This confirms the relevance of interdisciplinary activities in STEM programs in the school curriculum.

Enabling student's learning in STEM education

Integrated instruction is any program in which there is an explicit assimilation of concepts from more than one discipline (Satchwell & Loepp, 2002). According to Laboy-Rush (2011):

> "Integrated STEM education programs apply equal attention to the standards and objectives of two or more of the STEM fields …. When teachers expose students early to opportunities to learn math and science in interactive environments that develop communication and collaboration skills, students are more confident and competent in these subjects. This does not only make higher education more attainable for students, but also contributes to a well-prepared society."

According to Darling-Hammond (1994) it is necessary to engage the service of educators who know how to connect with individual learners in a wide variety of ways. This is necessary "to allow more time for in-depth and cross-disciplinary learning, for more challenging forms of hands-on work, and for greater opportunities for team teaching and team planning" (Darling-Hammond, 1994, p. 6). Therefore, this new paradigm shift gives no room for professionals who see teaching as a dumping ground. Teaching in this environment requires competency in pedagogy that ensures active participation in classroom activities by learners. More importantly, educator's efforts should be geared towards meaningful teaching and learning through practical illustrations and applications (Fajemidagba et al., 2010).

Enabling students' learning involves motivation. This will help create genuine interest in choosing the tasks to be engaged with and will make learning student-centered. This experience will give students the opportunity to demonstrate the achievement of desired learning outcomes such as thinking skills, character development, civic responsibility, interpersonal skills, valuing diversity, oral presentation, organization, and research (Cawelti, 1993). Obanya (2003) noted that there could be no meaningful development without the right type and appropriate quality of education. Thus, there is a need for investing in the preparation of the potential STEM educator so he or she will be well-equipped with the skills necessary to navigate successfully in this new mindset.

In addition to STEM educators being well educated, educators' attitudes toward teaching and self-efficacy are crucial to promoting an enabling learning environment for learners. It is believed that the potential effects of attitude are vital for the nature of commitment and resilience an individual may have (Adeyemo, Onongha & Agokei, 2010). Thus it is crucial to understand and examine the attitude of the STEM educator in order to ascertain how they will adapt to the challenges a STEM program initiative may bring. This awareness is necessary because positive STEM educator attitudes will influence classroom strategies used to teach and contribute to the formation of positive learner attitudes (Relich, Way, & Martin, 1994; Carpenter & Lubinski, 1990).

Tschannen-Moran & Woolfolk-Hoy (2001) defined educator efficacy as an educator's judgment of his/her capabilities to bring about desired outcomes of student engagement and learning, even among those students who may be difficult or unmotivated. Educator efficacy has been observed as a predictor of achievement (Moore & Esseiman, 1992) and student motivation (Midgley, Feldlaufer, & Eccles, 1989). Research had also shown that educators with a high sense of efficacy exhibit greater enthusiasms for teaching (Allinder, 1994), have greater commitment to teaching, and are more likely to stay in teaching (Burley, Hall, Villeme, & Brockmeier, 1991). Brown (1998) noted that when individuals have low self-efficacy expectations regarding their behavior, they limit the extent to which they participate in the endeavor and are more apt to give up at the first sign of difficulty. As such, a potential STEM educator needs to be organized, enthusiastic, and productive (Adeyemo et. al., 2010).

Content preparation

Instructional materials provide learners with the actual contents of instruction—precisely the information they need to achieve the performance objectives (Rothwell & Kazanaz, 1992). Thus, instructional material will be effective if it contains the content required for instruction.Instructional goals and objectives are vital to the success of any teaching and learning endeavors. According to Olivia (2009),

> "an instructional goal is a statement of performance expected of each student in a class, phrased in general terms without criteria of achievement. While an instructional objective is a statement of performance to be demonstrated by each student in the class, derived from an instructional goal and phrased in measurable and observable terms." (p. 310)

If the United States is to remain competitive in a global economy, the participation of American students in STEM fields must increase. One way to do this is to implement initiative programs. For example, to increase students' interest in STEM and improve student learning at the institution where I teach, the department of technology has proposed a nano-design and fabrication integrated learning laboratory to enable the study of nano-design and fabrication so that students will gain a deeper understanding of engineering and science. Nanotechnology appeals to a broad range of interests and allows multiple points of access to science, mathematics, and engineering for many types of learners, as well as teamwork and management skills (Clark & Ernst, 2008). Upon funding, this project will provide students with a diverse and newly developed nanotechnology set of courses and introduce them to conducting research activities at the earliest time possible.

Preparation of course contents

"Preparing instructional materials is the process by which a sketchy working outline is transformed into finished learner directions or guide-sheets, instructional materials, tests, and instructor directions or guide-sheets" (Rothwell et al., 1992, p. 207). In order to attract and retain a new generation of learners, engineering and technology curricula need to be renovated to optimize the skills that are relevant today. The development and revision of courses will be based on information that deals with nanotechnology-related knowledge and skills needed by practicing engineers and technologists. To collect this information, the project cluster members will compile an initial course outline based on their own experiences and trends in the literature. This outline will be reviewed by a panel of educators and practicing engineers for relevance to industrial settings. This revised document will help formulate the course content and course outcomes, as well as strategies for teaching the content and achieving the course outcomes. The courses will be field tested in the first semester of instruction while instructional strategy revisions will continue in the following semester so that the redesigned course will be implemented at that time.

Students will be required to submit weekly journal entries to promote reflections on the course content. This is a way to solicit student input during the design and implementation of the project. In addition, students will be asked to comment on and interpret experiences, discuss any frustrations/problems that require addressing, demonstrate accomplishments or milestones reached, and evaluate the leaning experiences. More important, students will also be able to submit their personal observations and reflections about topics and/or issues related to nanotechnology and the progress of the course. Student input will also be obtained from semi-structured interviews at the end of the semester.

All new teaching materials will provide clear guidelines for all anticipated workload and classroom activities. Instructors and students will benefit from explicit outcomes for courses, assignments, and projects. When specific and clear outcomes are identified, not only can the instructors focus their instruction on specific knowledge, but they can also link their knowledge assessment directly to the outcomes.

Facilitating studentss activities in STEM programs

Facilitation of students' activities has been with us since time immemorial. It becomes part of the teacher when it is learned (Wittmer & Myrick, 1980). This makes learners more active during the learning process through active participation (Pullias, 1994; Glasgow, 1997). Since facilitative teaching is not an art innate in teachers (Wittmer et al., 1980), STEM educators must learn this skill. Learning is fostered when there is active facilitation of students' activities and their interactions between with peer learners. According to Kuskie et al., (1994), the purposes of "facilitative responses is to hear and validate the student and to encourage continued self-exploration of the problem or issue being discussed" (p. 10). As a result, questions are asked and students are called upon to answer in an orderly manner. The responses given or suggested by the students are documented or written on the chalkboard for a feedback at the late part of the learning process. On the other hand, students are asked to document the ideas that are relevant or related to questions asked. In the latter case, the educator serves as the facilitator and the recorder. In the former, the educator serves as the facilitator while the students keep the record of ideas generated.

The transformation that has taken place in learners' educational needs has brought with it the need to facilitate students' activities effectively. Learning is now "learner centered" as opposed to teacher centered. A student centered approach to teaching and learning will provide an environment for both the student and the STEM educator to succeed (Kuskie et al., 1994, p. 10). This reflects a change in the role of the STEM educator to that of a facilitator and in the role of the student to that of an "active learner." The educator facilitates the activities of the students "and creates a classroom climate of acceptance so that students will reach higher levels of learning" (Kuskie et al., 1994, p. 10), while the students generate the "input" needed to problem solve or to execute hands-on activities. According to Pullias (1994), "It is commonly accepted that student learning is greatly enhanced through hands-on experiences as opposed to merely sitting, listening, taking notes and answering a series of questions that usually do not require higher-level thinking" (p. 5). Therefore, knowledge of the learner's entry behavior is a key factor determining how facilitation is applied as a teaching or learning tool in STEM education.

Learners' achievement of their potential in STEM classroom activities requires allowing students to actively participate in the learning process (Darling-Hammond, 1994; Kuskie et al., 1994; Glasgow, 1997). To be active learners, students should be:

- prepared to take responsibility for their own learning;
- faced with broadening choices and recurrent decisions about learning;
- entitled to a range of guidance and learner support services;
- willing to work cooperatively with STEM educators and, where appropriate, their peers in achieving their own learning goals;
- willing to offer regular feedback on the quality of their educational experience and the guidance and support services available to them.

Facilitation in STEM program facilities

Facilitation of students' activities cannot take place without adequate facilities. This does not mean that the facility should be expensive, but that it should be conducive to the learning needs of the students. The facility must be equipped with tools, materials, and equipment that will make the STEM educators' activities more meaningful and realistic. Ofoefuna (1999) referred to the laboratory as a wonderful setting for providing learners opportunities to think about, discuss, and solve real problems. Omosewo (2001) defines the laboratory method as an activity carried out by an individual or a group for the purpose of making personal observations of processes, products, or events. This is aimed at instilling in learners confidence, critical thinking, perseverance, aspiration towards scientific studies, and the development of manipulative skills. Equally important is the need to engage learners with instructional procedures in which "cause and effect" is determined by individual or collective experience. Anderson (1995) noted that hands-on and other relevant activities by students in a facility that is well-equipped will make education more meaningful, challenging, and exciting to students, as well as helping to develop skills for problem solving.

Factors influencing effective facilitation

There are many factors that can influence effective facilitation of student's activities in the STEM classroom or laboratory. Some of them are as follows:

1. How STEM educators teach matters

STEM educators will be effective in the classroom if they understand their subject matter deeply enough that they can explain concepts and procedures from multiple perspectives. Even more important is the need to be able to turn questions into teachable moments that will help ignite student interest in STEM. The National Research Council (2010) noted that in STEM learning, the ability to command teaching strategies needed to illuminate STEM for learners is as important as teachers knowing the variety of ways in which learners develop STEM knowledge and skills. This will help in preparing learners with the tools necessary to cope with STEM programs.

It is important that learning activities are open-ended, giving students the freedom to explore and experiment within their own interests and learning styles, rather than just encouraging recipes to right answers. The emphasis from the outset of student learning should be based on problem solving. The correct answer shouldn't matter as much as how students arrive at it. This will enable learners to see that many problems have more than one solution (Wang, Thompson, & Shuler, 1998).

2. Classroom/laboratory activities should be connected to reality

Bridges & Hallinger (1995) assert that "knowledge is learned most effectively when it is organized around the disciplines." According to Clark et al. (2008), the integration of science, technology, engineering, and mathematics in the curriculum will harness higher-order thinking skills and will promote the integration of academic areas and a broader focus on economic growth. Most importantly, these real-world problems are designed and developed to challenge students; they should be implemented in a safe and supportive environment or facility to utilize the range of technology and laboratory equipment available. This suggests that for effective facilitation of educational activities, there is need for a classroom or laboratory with enough space to accommodate learners and educators.

3. Implementation of effective teaching strategies

STEM educators should be prepared, creative, open to good ideas from others, and able to think on their feet or intuitively as unexpected problems come up. For example, teachers should introduce various strategies for effectively utilizing learning resources, implementing positive feedback strategies, engendering group interaction skills, fostering cooperation, and downplaying competition during the learning process.

Mastery of pedagogy is necessary for enhancing STEM educators' abilities to manage their classroom efficiently. To be successful at this, STEM educators must be able to call on a repertoire of strategies and methods for illuminating STEM topics—guiding students in scientific inquiry, the design of experiments, and making sense of data. STEM educators need to hone and adapt the skills needed for effective classroom management. These tactics can be taught in teacher preparation, induction, and professional development. More important is the need to develop good questioning skills.

4. Encouraging students' participation in learning activities

The knowledge of who your students are will help in making paths and goals that are reasonable, individualized, and attainable. Therefore, it is imperative that the curricular activities should be designed in ways that allow students to personally identify with them, or that they enhance students' personal investment and engagement in a more self-directed and self-motivated way (Glasgow, 1997). Since STEM teachers are no longer lecturers or information distributors, this new role will enable students to be responsible for their own learning. For example, when a cooperative learning approach is engaged as a teaching strategy , everyone in a small group is held accountable for the successful learning of his or her group members. According to Wang et al. (1998):

> "When learning needs are identified in a learning case, each member will take a small portion of the learning tasks and become "master" of those tasks. They will then come back to help their teammates understand where, what, and how they learned their information. This is a way to develop their communication skills because they must communicate what they learn to their teammates on a continuing basis."

Conclusion

Facilitating students' activities successfully depends on how well STEM educators have prepared for the challenges they will face when engaged in classroom or laboratory instruction. The STEM educator should make sure that students are engaged actively in motivational activities that integrate the curriculum to promote "hands-on" and other related experiences that would be needed to help solve problems as they relate to their environments.

Districts that provide structured, sustained induction training and support for their teachers achieve what every school district seeks to achieve: improved student learning through improved professional learning. No nation can afford to ruin her future through poor education. The importance and the need for STEM programs in school curricula should be taken seriously. At the same time, this responsibility belongs to everyone and should involve the parents, students, educators, administrators, business leaders, and legislators from the students' communities.

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