Education Strategies for STEM Teachers: A Brief Synthesis

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Very few people in the United States dispute that science, technology, engineering, and mathematics education in its current state does a disservice to many students. The main problem rests in early STEM education, which is taught as a string of memorization tricks, rather than a comprehensive understanding of human's current knowledge of the world. "Show Me What You Know: Exploring Student Representations across STEM Disciplines", which explores students' understanding of common STEM topics; "Outcome-Based Science, Technology, Engineering, and Mathematics Education", which discusses practices for a STEM classroom based on psychological theories; "Science, Technology, Engineering, Mathematics (STEM) as Mathematics Learning Approach in 21st Century"; and "A Comparison of Students' Quantitative Reasoning Skills in STEM and Non-STEM Math Pathways" all illuminate and discuss strategies for improving students' learning of STEM topics. The most relevant of the theories include cognitive and educational insights for rebuilding curriculum, methods for successful evaluation and assessment of students, goals for a cohesive STEM class, and ideas regarding the importance of interdisciplinary STEM learning.

Rebuilding Curriculum, Structuring Assignments and Projects

The following are cognitive theories that form a basis for rebuilding STEM curriculum. Behavioral theory relies on positive or negative reinforcement and immediate feedback; cognitive theory pays attention to how knowledge is arranged, readiness to learn, intuition, and motivation/positive outlooks on learning; constructivist theory has different schools of thought like learning is a function of social interpretations, or the real world is understood differently for individuals; and situated learning theory states that context significantly affects learning [4]. Curriculum design should draw on knowing (acquisition of information and ability to apply that information), acting (playing a role and being fully engaged), and being (possess high levels of self-awareness) [4]. Individually, these theories are just that- beliefs that do not have real-world application. However, when considered together, these form a consideration for structuring curriculum. Another theory is outcome-based education, which embodies clarity of focus (toward the outcome), expanded opportunity (to demonstrate learning in a variety of ways), high expectations, and design down (curriculum itself is designed with outcome in mind) [4]. Something to keep in mind when implementing this theory, however, is being wary of "high expectations". Students are overwhelmed and if they view themselves as underperforming, they may suffer from excess amounts of stress and anxiety. Other consequences of overworking students are discussed in the Methods for Assessment and Evaluation section.

When implementing outcome-based curriculum, one must first identify desired outcome and build content from there: spending extra time on topics that students will find difficult, fostering natural curiosity by allowing students to choose topics when possible, and explicitly defining "unwritten rules" that could aid in their thinking approach (brain tricks). Apply variation, which is a technique to help students stay engaged, to solving approaches, learning spaces, repetition, focal awareness, diachronic simultaneity, synchronic simultaneity, representation, and object of learning [4]. Another notable reminder when implementing any new curriculum is that observation, participation, and description are not separable [1] – students must be able to observe and interact with something if they are to understand how it works or recreate it. Finally, educators should adopt strategies that have historical success, but should not simply transplant them. This is an imperative strategy because every situation is different and adopting a curriculum blindly could lead to disastrous effects. One example is an environmental factor that contradicts or clashes with a feature of the curriculum; if the curriculum is blindly followed despite this, it could cause dissent and adverse effects on the students and/or faculty.

Methods for Assessment and Evaluation

The foremost strategy for improving STEM assessment methods is to shift evaluation method from conventional assessments to authentic assessments, where evaluations encourage students to solve complex problems and think high-level [3]. This way, the teacher more clearly sees a student's train of thought. Instead of students answering single questions of varying difficulty, they should demonstrate their understanding of a whole concept and the logic behind it. The results of these assessments should not fit a normal distribution [4]- most students should be understanding more than half of the material- and indicate failure on behalf of the curriculum if they do.

A more complicated matter is assessing practical intelligence- the ability to combine concepts to achieve results, hands on experiments. Typically, this skill is not tested at all because success is a function of the specific job that one is hired to do, so a school assessment of the skills would be inaccurate (since each job would require different skills) [4]. Evaluating the ability to integrate concepts and produce a coherent solution in this context is difficult, but typical methods is not the only way to assess a student's ability. Students can be introduced to the skills that they will need for a job generically, without having to cater to a specific job title for a specific company. For example, software developers need to be able to read previous code and add to it, a skill that can be taught and assessed in a project or lab environment. It is important to note that an overloading of work results in students' desire to learn morphing into a desire to earn a passing grade, especially when an evaluation method is structured to result in most students failing the course or bringing down their GPA. Students have more intellectual curiosity if they have room to wonder. If constant busywork and stress from assessments is being forced onto students, they have no time or energy to pursue curiosities of their own on the subject, which is where the best learning opportunities come from.

General and Specific Goals of STEM Curriculum

Since the faults of STEM education begin at a young age, so must the goals for improving STEM education. Early emphasis should be placed on the geometric real line model for real numbers [1]; the number line is a physical object with its own properties, as well as a way display of other mathematical objects, allowing communication about general mathematical ideas. This can be achieved by beginning to focus emphasis early on from individual points on a line to intervals on a line.

For all STEM education, not just that which applies to young learners, teachers should be facilitators and guides, not informants, addressing the progression and growth of students' reasoning in relation to their previous activity [4]. Additionally, the learning mode of such education should be learner-centered instead of teacher-centered [3], which means encouraging collaborative learning and emphasizing application, creativity, and problem solving. STEM courses should highlight the following characteristics in its students: communication, critical thinking, teamwork, information management, entrepreneurship, proactiveness, ethics, and integrity [4].

These general goals, along with teachers acting as facilitators and shifting the class' focal awareness to the students, should form a basis for an educator's behavior.

Along with an understanding of line intervals and developing positive personality traits, students should be able to logistically demonstrate STEM skills. Students should be able to build models and relate them to educational concepts, not simply select pre-formulated models for a phenomenon [1]. This ensures that students understand how to build and use models, not simply "plug-and-chug", which is key to understanding geometry and calculus concepts. Volume formulas are much easier to memorize if students realize they are areas stacking in the third dimension. Understanding that concept helps understand integrals as well (which students have a much harder time with if they do not understand the concepts behind the formulas). Students should also be able to plan activities, produce a preliminary idea generation, and select materials for a given project [1]. Finally, students should understand that characteristics and design of a discipline (in this case, STEM disciplines) are initiated by humans as a form of knowledge and investigation [3]. Understanding this allows students to accept that each concept they are learning was created by a past scholar, meaning it is disputable and based on a predetermined set of axioms (or assumptions). It is vital for students to realize that their thinking is not necessarily wrong, it just contradicts the agreed-upon rules in some way.

Approaches to Interdisciplinary Learning

A key aspect of incorporating interdisciplinary learning into the STEM learners is by recognizing and addressing the ways STEM concepts can apply to those who will not continue studying science, technology, engineering, or mathematics. For example, non-STEM career paths still need quantitative reasoning skills, so greater emphasis should be put on applying mathematic and logic skills to other disciplines within the STEM classroom [2]. One way to implement this is by emphasizing that the mathematical graphs students learn in math class can be used to represent, communicate, and consider diverse information in many different contexts (history, psychology, etc.) [1]. Curriculum should incorporate fast detection of inconsistencies and errors in graphs and teach students how to relate those graphs to other data or theoretical knowledge (considering thoughts like "the trend SHOULD be… based on theory"). Students completing a STEM class (whether they are pursuing a STEM pathway or not) should be taught how all aspects of a graph fit together: type of graph (bar graphs are easier to comprehend), content, visual contrast, color, direction, and size [1]. Besides drawing attention to non-STEM disciplines within a STEM classroom, educators can also embark on interdisciplinary learning by incorporating STEM into other disciplines [3]. This may look like acknowledging a problem in nature (science), finding information for solutions (technology), designing a solution (engineering) and estimating the effectiveness (math).

Interdisciplinary education can also be considered the successful application of STEM disciplines in the real world. Principles across all disciplines are learning, interdisciplinary learning, and teamwork. Engineers (and every professional, STEM or not) should provide services that meet the needs of humanity and society, possess fundamental understanding of the knowledge and skills within the discipline, engage in a domain of professional practice, have the capacity to make judgement under conditions of uncertainty, and learn from experience [4]. Students of STEM should desire to become involved in issues as constructive, concerned, and reflective citizens [3]. This should be explicitly stated to students. They should understand that their education is primarily to aid in their ability to be constructive citizens. They should also obtain knowledge, attitudes, and skills to identify questions and problems in real-life situations, explain natural phenomena, and draw conclusions based on evidence [3]. These goals, when considered together, can become a resource for encouragement between teacher and student- allowing the student to understand why they are learning concepts that incorrectly seem unrelated to their career path.

Works Cited

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