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STEM Education Research: Enhancing Problem Solving Skills in Science, Technology, Engineering and Mathematics Study

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Abstract: STEM subjects comprise of Science, Technology, Engineering and Mathematics. It has been found that manystudents leave the STEM subjects or do not want to join these courses as they face problems in understanding. This problem is particularly found among girl student and in most of the institutions the number of girl students is much lessthan the number of boys, As the science and engineering problems becomes more and more complex it becomes increasingly important to employ a systematic approach. Interactive Video tutorials are being designed keeping these issues in mind so that they can help students learn problem solving and reasoning skills using suitable examples in an interactive environment. The tutorials are designed in such a way so that students are forced to analyse the problem qualitatively and spend time deciding which principles of science are appropriate. Consistent use of qualitative analysis and planning tasks can help students develop reasoning skills. Also, students can reflect upon the problem-solving process at the end of every problem and thus it will force them to think about what they learnt by solving the problem. It helps them to restructure, extend and organize their knowledge and developing their cognitive skills. The nature of the research-guided video tutorials along with rewinding and stopping ability makes them suited for all students in introductory courses. The video tutorials are based on the interactive teaching/learning process in classroom environment. The teachergives the students a real-life problem and divides the class into several groups. The students will discuss among themselves and the discussion will be recorded. This live discussion will help the teacher to understand the difficulty in their concept. This information will be incorporated in the tutorials. The video tutorial will assign students a problem with different answers. If the student chose the wrong answer the tutorial will tell why the answer is wrong. So the student can correct his/her misconception. The interactive tutorials will help students in doing their homework. It will also help students having learning disability.

Keywords*:* Interactive Video tutorial; teaching/learning method, STEM subjects, Interactive learning, Flipped classroom

I. INTRODUCTION

Students enter college STEM courses with school-level knowledge of the subject which may facilitate their learning. However, students can also have some preconception regarding how a science course should be taught, based on their prior experience. The science courses consist of lectures, laboratory, homework, quizzes and exams. Students often sitquietly in lectures and listen to the teacher called “the sage on the stage”. They also do not engage themselves in the learning process. Courses based on discipline-based educational research are generally interactive and students remain engaged with one another and class activities often. The research focuses on developing learning techniques by researchers through years of hard work.

In STEM problem solving students are given a situation and he/she performs a sequence of steps to achieve a goal. To solve problems effectively one must analyse the problem, followed by planning, implementation, assessment and reflection. Different levels of cognitive achievements as given in Bloom’s Taxonomy are Knowledge, Comprehension, Application, Analysis, Synthesis and Evaluation. Active participation of students in classroom is important because teaching by telling does not work. Most of what is told by the teacher is lost in time and the rest may stay in the notebook.Different steps in Interactive learning are i) Clarify goals and objectives of lesson at the beginning ii) Share with studentsa list what they should be able to do after instruction. iii) Success of instruction depends on alignment of student’s priorknowledge. So, a pre-test has to be conducted to identify weak students iv) Design (course materials, assignment etc.) v)Assessment of what they have learnt. Students in interactive learning are given an opportunity to reconstruct, extend and organize their knowledge. Discipline-based education researchers have developed many instructional strategies to improve conceptual understanding and problem-solving skills through active engagement by the students (Fig 1). In laboratories students are directed to discover important ideas through guided inquiry. They are expected to be physicallyand/or intellectually active during class.

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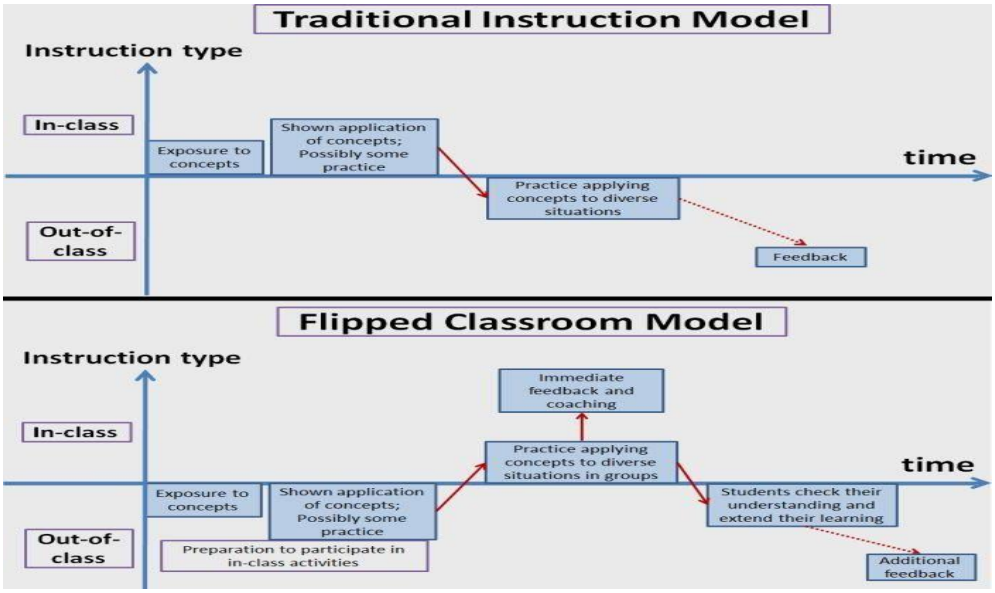

Fig. 1 Traditional Instruction Model and Flipped Classroom Model

II. EXAMPLE OF INTERACTIVE TEACHING

During class, the teacher briefly lectures (5-10 minutes) about a particular concept or idea. Then, he poses several conceptual questions regarding that concept in the form of multiple-choice question. For each question, students first answer it individually (via a classroom response system (an electronic clicker) A, B, C, D or E to denote their choice forthe multiple-choice question), then they discuss their answer with a peer, after which they answer it again.

A. Problem on Newton's third law of motion

A big car moving with a velocity 100km/hour collides with a small carmoving with 50 km/hour coming from opposite direction. Which car will exert more force on the other? These are 4 answers given a) The big car will exert more force on the small car b) The small car will exert more force on the big car
c) The force exerted by the truck is equal to the force that small car exerts on the big car d) None of the above. The students are divided into a few groups and given 2 minutes time to discuss over it. Each group gives different answers. The instructor will ask each group to explain their answer and counter question if their logic is not right. In most of the cases students will choose answer a). Because they think that the big car will exert greater force on the small car. The correct answer is c). The force exerted by the big car will be exactly equal to the force exerted by the small car on the bigcar. The reason is: Newton's third law of motion. Then the instructor will ask: if the forces are equal then what else willbe different? The answer is: acceleration because Force=mass x acceleration because Force=mass x acceleration (Newton's second law of motion Thus the students should experience different diverse /contradictory situations to solveeach time stretching their knowledge a bit above the existing level .
Example: Problem on acceleration: A car is moving along north at 60 km /hour then changes its velocity to 30 km/hour along west in 7 seconds. Find out the average acceleration during this period. The teacher should explain the concept ofacceleration in Newton's second law of motion first and give students some real life situations to solve.

B. Learn by analogy

Here is an example how analogy between different parameters can help students to correlate different physical phenomena.

TABLE 1: RELATION BETWEEN DIFFERENT QUANTITIES IN LINEAR AND ROTATIONAL MOTION

Linear Motion	**Rotational Motion**
linear distance	angular distance
linear velocity	angular velocity
linear acceleration	angular acceleration
force = mass x acceleration, linear momentum = mass x linear velocity	Torque, angular momentum/ moment of momentum
mass	moment of inertia

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Now the teacher will ask questions: Write the expression of angular momentum or torque. Help of audio visual is also advised in some cases.

C. Student interactions can be of different types

i. Student-teacher interactions, (teacher's role in class)
ii. Student-content interaction, (e.g., reflection activities, connecting concepts with real life)
iii. These can also be interactions between students and equipment
iv. Student-student interactions, which define how students interact with one another (e.g., collaborative problemsolving, classroom discussions in small groups followed by full class discussion, small group work, students actively criticizing each other's' ideas, etc.) .

III. INTERACTIVE VIDEO TUTORIALS

These tutorials involve problem solving techniques in an interactive environment. Research-based real life problems are given to students so that 80% can answer correctly they are kept actively engaged in discussion because when theytalk to each other they become cautious. This think aloud discussion should be recorded to incorporate in video tutorials.Interactive video tutorials perform the following steps:

- Students will be given research based multiple choice questions to show their level of understanding at everystage of problem solving
- If they click the wrong answer the tutorial will tell them why it is wrong
- This step shows the difficulty students have with related concepts
- Tutorials are web based, self-paced
- Address diverse variety of students (learning disability)
- Help students doing homework and self-study
- Helpful for teachers to prepare assignments for students

Future Impact of using Interactive Video Tutorials

- Comparison of performance between two groups of students. One group is using them while the other group isnot using them
- Distance education tools
- Underprepared students (remedial classes)
- Design curriculum and research project for students
- Learning problem solving technique for competitive examinations like GATE, UPSC, AIEEE, NEET, JEEetc.

IV. CONCLUSION

STEM education merging science, technology, engineering, and mathematics helps us to solve the challenges of our day-to-day life and in turn development of our society. It gives people skills that make them more employable. Science helps students to think logically and excel at research. Technology and engineering helps them to apply science in transforming society with sustainable solutions. Mathematics enables people to analyse information, eliminate errors, and make logical decisions while designing solutions. STEM education combines these disciplines into a integrated system. This requires a special mode of learning known as interaction-based assignments which can be done through interactive video tutorials. In this paper an attempt has been made to explore the application of interactive video tutorialsin STEM education to enhance problem solving skill of the students.

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