Stories of Active Learning in STEM: Lessons for STEM Education

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Introduction

• Active vs. passive learning

• Active learning:
  – student-centered learning
  – “Students do things and think about what they are doing” (Bonwell and Eison, 1991)
  – Examples
    • Class discussion, question-and-answer
    • Role playing, peer teaching, flipped lessons

from www.case.edu
Introduction

• Challenges of teaching in STEM education
  – Breadth vs. depth
  – Stimulate student engagement
  – Can students develop responsibility as learners?
  – Can they participate in the construction of knowledge?
  – Can they challenge mainstream thinking?
Introduction

• The need for a new approach to learning in the sciences has been emphasized in the last decades.
  – Students seek new knowledge, re-organize it, explain it to others (Huba and Freed, 2000)

• Does active learning help in STEM disciplines?
  – Active learning in STEM was shown to:
    • Increase student performance
    • Improve students’ attitudes

• Active Learning empowers students
  – Students develop responsibility and learn to challenge taken-for-granted knowledge
The aim of this paper is to
- Identify effective teaching strategies that promote active learning in STEM.
- Provide a guide for future studies on active learning in STEM.
Methodology

- Five undergraduate courses in STEM disciplines were selected.
  - three in science, one in math, one in information technology
- Instructor feedback was provided through an open-ended questionnaire; five narratives were produced ("stories")
- Analysis, discussion and conclusions followed.
# How the Five Instructors Define Active Learning

<table>
<thead>
<tr>
<th>Course</th>
<th>Definition of Active Learning</th>
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</thead>
<tbody>
<tr>
<td>Case A (Environmental Science)</td>
<td><strong>Learner-centered</strong>: learning by experience and by “doing”; various in-class activities</td>
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<tr>
<td>Case B (Biology)</td>
<td>More focus on developing student understanding and other skills; <strong>problem-based</strong>, interactive, <strong>collaborative</strong> and <strong>cooperative</strong> learning</td>
</tr>
<tr>
<td>Case C (Greening the Campus)</td>
<td><strong>Learner-centered</strong>: students are involved in the learning process; instructor acts as mentor and facilitator; experiential and <strong>action-based</strong> learning</td>
</tr>
<tr>
<td>Case D (Mathematics for Business, Economics and Sciences)</td>
<td><strong>Learner-centered</strong>: instructor acts as facilitator to actively engage students throughout the learning process</td>
</tr>
<tr>
<td>Case E (IS for Decision Making)</td>
<td>Engage students in the exploration of knowledge; <strong>critical problem solving</strong>; personal and <strong>team skills development</strong></td>
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# Stories of Active Learning: Environmental Science (Case A)

<table>
<thead>
<tr>
<th>Case A</th>
<th>Environmental Science</th>
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<tbody>
<tr>
<td><strong>Specific Goals for the course</strong></td>
<td>• Transmission of knowledge (achieve scientific literacy); <strong>critical evaluation</strong>, <strong>analysis</strong>, application to everyday life; • Develop <strong>practical and transferable skills</strong> (including teamwork and scientific writing)</td>
</tr>
<tr>
<td><strong>Active Learning Methods used</strong></td>
<td>• Question and answer • Brainstorming and class discussion • In-class debate • Lab and field activities involving team work • Lab reports • Group discussion based on video screening • Pause and in-class summaries • Online technologies (Use of Blackboard for course information and material, instructor feedback, discussion boards, interaction with instructor and class mates, feedback on assignments)</td>
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## Stories of Active Learning: Biology (Case B)

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<th>Case B</th>
<th>Biology</th>
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<tr>
<td><strong>Specific Goals for the course</strong></td>
<td>• Transmission of <strong>knowledge</strong> (biology from human perspective); <strong>critical evaluation, analysis, applications</strong> (connections with life and society)</td>
</tr>
<tr>
<td></td>
<td>• Develop <strong>practical and transferable skills</strong></td>
</tr>
<tr>
<td></td>
<td>• Stimulate interest using <strong>digital and modern pedagogical approaches</strong></td>
</tr>
<tr>
<td><strong>Active Learning Methods used</strong></td>
<td>• Question and answer</td>
</tr>
<tr>
<td></td>
<td>• Class discussion</td>
</tr>
<tr>
<td></td>
<td>• Lab activities involving team work</td>
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<td></td>
<td>• Student companion site of the textbook</td>
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<td></td>
<td>• Online technologies (Use of Blackboard and of the online resources of the textbook for information, material, online quizzes and questions, animations, audio and visual material, virtual labs)</td>
</tr>
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Stories of Active Learning:
Lab Activities

Lab Activities: Environmental Science, Biology
Stories of Active Learning: Field Activities and Visits
# Stories of Active Learning: “Greening the Campus” (Case C)

<table>
<thead>
<tr>
<th>Case C</th>
<th>Greening the Campus</th>
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</table>
| **Specific Goals for the course** | • Help students develop **ownership of basic knowledge**; develop **critical thinking** about generally accepted knowledge in a subject matter  
• Provide opportunity for **collaboration of faculty with students on campus issues; experiential learning; action research** |
| **Active Learning Methods used** | • Field activities, lab activities and visits  
• Group project involving field and lab work, data collection, analysis and final report  
• Collaborative learning through group work in field projects, creative projects and interviews; game  
• Portfolio with essays and journal entries  
• Creative project  
• Online technologies (Use of Blackboard for course information and material, instructor feedback, discussion boards including group discussion boards, interaction with instructor and classmates) |
Stories of Active Learning: Experiential Learning and Action Research

Activities from Greening the Campus
Stories of Active Learning

Activities from Greening the Campus
# Stories of Active Learning: Mathematics (Case D)

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<tr>
<th>Case D</th>
<th>Mathematics</th>
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</table>
| **Specific Goals for the course** | • Understanding of quantitative information; application in and outside their discipline; application to real-life word problems  
• opportunities for authentic learning using different active learning methods |
| **Active Learning Methods used** | • Flipped classroom (students watch videos w. lecture and exercises at home)  
• Question and answer  
• Class discussion  
• Mini-lecture with pause  
• Problem solving with think-pair-share  
• Collaborative learning through in-class team work (think-pair-share)  
• Instructor feedback on assignments  
• Online technologies (Blackboard with access to course information and material; survey tool of Blackboard was used for a survey) |
### Stories of Active Learning: Information Technology (Case E)

<table>
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<th>Case E</th>
<th>Information Systems</th>
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<tbody>
<tr>
<td><strong>Specific Goals for the course</strong></td>
<td>• Transmission of <strong>knowledge</strong>, ability for <strong>communication</strong>, <strong>critical thinking</strong></td>
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<tr>
<td></td>
<td>• Development of <strong>research skills</strong> (knowledge management and decision making).</td>
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<td></td>
<td>• <strong>Connection with real life and real world problems</strong></td>
</tr>
<tr>
<td><strong>Active Learning Methods used</strong></td>
<td>• Case studies requiring a multidimensional analysis</td>
</tr>
<tr>
<td></td>
<td>• Class discussion</td>
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<tr>
<td></td>
<td>• Collaborative learning (sharing of resources and ideas; collaborative development</td>
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<td>of students’ research model on Knowledge Management; feedback from instructor at</td>
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<td></td>
<td>various stages of the project)</td>
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<td></td>
<td>• Online technologies (Use of online platforms for collaborative work; use of knowledge mapping tools)</td>
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Instructors’ Perception of Active Learning

• Instructors’ definition of active learning shows similarities and differences (table 1)
  - learner-centered
  - problem-based
  - action based; experiential
  - collaborative
  - focusing on the development of skills other than knowledge
Teaching Goals and Teaching Strategies

• Comparison of teaching goals
  – All aimed at knowledge, understanding, but also at developing skills for critical evaluation, analysis, application and connection with real world cases.
  – Three courses aimed directly at the development of teamwork skills
  – One course aimed at the development of research skills

• All teaching strategies were connected with the learning outcomes and the teaching goals for the course.

• Assessments were also designed to test learning outcomes and meet teaching goals.
Student Learning:
Effective Teaching Strategies (1)

• Level of engagement and autonomy of students plays a role.
  – **Group field project** (Case C) and **flipped classroom** (Case D) promoted more student autonomy.
  – In science courses (Cases A, B and C), **lab activities and lab reports** also involve high level of student engagement and help students gain practical and transferable skills (teamwork, scientific writing)
  – Prior exposure to similar material seems to increase the level of engagement and autonomy (Cases A and B)
A combination of different active learning methods can prove effective.

- In the math class (Case D), the combination of methods used (flipped lessons with follow-up in-class activities) affected positively both students’ perception of the course and student learning, as assessed by a survey.

- In the Information Systems class (Case E), class discussions, case study analysis and student project presentations produced learning and enhanced student research skills.
Student Learning: Effective Teaching Strategies (3)

Other observations made

- In-class debate and group discussion after video screenings helped resolve misconceptions on environmental issues.
- Journal entries encouraged freedom of expression and stimulated emotions.
- Group discussion boards became an effective communication tool among groups.
- Online tools (quizzes, animations, discussion boards) helped the students who engaged with them.
Challenges – Issues to Consider

- Level of course
- Composition of student population (age, educational and cultural background, major)
- Achieving depth without sacrificing breadth
- Time management
- Classroom management
- Maintaining student motivation and engagement
Conclusion

• Different teaching strategies prove effective for different STEM courses depending on course goals.

• More systematic evaluation of active learning strategies needed
  – student and instructor surveys
  – student performance
  – instructors’ conceptions of effective teaching
References


THANK YOU!

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