Taking a Closer Look at Active Learning

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Engineering educators often experiment with various teaching methods to figure out which methods most effectively improve learning. A common research design uses a pairwise comparison – pitting one pedagogical method against another method and comparing the results. Often the two methods compared are traditional lecture versus active learning. These pairwise comparison studies are commonly framed as investigating the question, Does active learning work? This question has been uppermost in the mind of many in the engineering education community (Streveler & Smith, 2006). In this guest editorial we argue that the broad research question, Does active learning work? has been sufficiently answered for most types of students (Freeman et al., 2014; Prince, 2004; Springer et al., 1999) and contend that it is now appropriate and helpful to take a more nuanced view of active learning.

Drawbacks of the Current Approach

What’s wrong with asking, Does active learning work? We put forward two concerns.

First, we argue that this broad question has been sufficiently answered. A recent meta-analysis by Freeman et al. (2014) found that, on average, students who were active learned more than students who were passive. The shift was significant – learning improved by about 0.5 standard deviations, a result that agrees with an earlier meta-analysis of small-group activities (Springer, Stanne, & Donovan, 1999). Prince (2004) conducted a literature review to compare active and passive learning in engineering education and found a generally positive trend – although he did not quantify the effect. These consistent results allow us to be confident that, on average, engaging students through active strategies enhances learning.

A second concern lies in the fact that the phrase “active learning” encompasses a wide spectrum of learning activities – all contrasted with passively sitting and listening to a lecture. An example offers an illustration of the limitations of this approach. Suppose instead of investigating learning gains, we wanted to investigate health gains, and we asked the question, Is it better to be physically active rather than sedentary? To answer that question, we could group together people who did any kind of exercise and compare them to people who did not exercise at all. Not surprisingly, we would find that on average people who do some exercise are healthier than people who do not exercise at all. However, there are other important questions about the effectiveness of exercise that we could not answer with this approach:

What kind of exercise works best?
What is the relative effectiveness of exercise A compared with exercise B?
How much exercise is optimum?
What kinds of exercise are best for people with certain physical conditions?
We do have a sense that vigorous activity may be extremely beneficial for a healthy 19-year-old but catastrophic for a 75-year-old heart patient. But asking our general question about exercise would not provide us with useful data about this concern. Similar limitations arise if we group all kinds of active learning strategies and compare them with a passive approach.

As we saw with the physical exercise example, many questions are still left unanswered:

- What kind of activities work best in which situations?
- For which disciplines?
- For which learning objectives?
- For what kinds of students?

Asking a generic question about active versus passive learning is not specific enough to enlighten us.

**Two Frameworks**

What do we mean when we recommend a more nuanced view of active learning? How does one classify kinds of active learning activities? We offer two frameworks that may be useful.

**Interactive-constructive-active-passive framework**

One way to categorize types of active learning is to specify behaviors exhibited by students. Chi (2009) developed a framework she called ICAP (interactive-constructive-active-passive) that categorized behaviors and compared the learning outcomes that resulted. When the comparison was made, an intriguing pattern was revealed. Learning gains were lowest when there was no active engagement, for example, when students passively listened to a lecture or watched a slide show or video without taking any notes; learning gains were larger when students were prompted to rehearse and reinforce new knowledge by repeating sentences after hearing them, or underlining or highlighting some sentences while reading (Chi, 2009; Menekse, Stump, Krause, & Chi, 2013).

Even greater learning gains occurred when students exhibited behaviors that helped them to individually construct new knowledge. Examples of constructive activities include drawing a concept map, solving a problem, generating self-explanations, comparing and contrasting different circumstances, interpreting graphs, using analogy to describe certain cases, and describing examples from daily life. Other constructive strategies include asking comprehensive questions, constructing meanings, drawing, justifying claims with evidence, designing a study, posing a research question, monitoring one’s comprehension, giving strategic decisions in a video game, and converting text-based information into symbolic notation.

The greatest learning gains occurred when two or more students worked together to co-construct knowledge (Chi, 2009; Chi & Menekse, 2015; Chi & Wylie, 2014). Chi called these “interactive” activities. They can include activities others have called “collaborative” or “cooperative learning” (Smith, Sheppard, Johnson, & Johnson, 2005). Examples of interactive activities are studying and working in teams; peer teaching; interacting with feedback from a teacher, an expert or a computer agent; responding to scaffolding; and arguing or defending a position with evidence.

Not all “group work” qualifies as an interactive activity, however. Precisely how students interact in pairs or groups affects learning. Menekse and Chi (2014) found that learning improved when group members built on others’ statements. However, learning decreased if group members simply agreed with statements others had made. So we see that true co-construction of
knowledge is important. Simply agreeing with what has already been said can actually retard learning. If one group member dominates the discussion or if one group member does not contribute to the discussion or product, then the group is not fully interacting.

In addition to this kind of interaction, the effectiveness of interactive activities may also depend on the domain or topic being studied, and on student characteristics such as age, prior knowledge, and how the students learn. An instructor needs to be mindful that students process information in different ways and with differing speeds; some need more time to make sense of what they have learned. Gonzales (2016) recounted his struggles as a student with severe dyslexia and referred to his active learning experience as a “nightmare.” Not all students can process and respond quickly: accommodations could be required for second language learners and for students with learning and other disabilities.

Knowledge integration framework

A second exemplary framework used to design learning activities to teach complex concepts – the scaffolded knowledge integration framework – was proposed by Linn (1995). This framework describes knowledge integration as a dynamic process of linking, organizing, and differentiating patterns, ideas, and theories that one can use to rationalize a specific concept. According to this framework, learners construct knowledge by continuously evaluating, refining, and developing ideas they receive from formal training in schools as well as from their everyday lives.

By using this framework, Linn (2000) proposed the knowledge integration environment (KIE) principles and guidelines on how to design learning activities to promote integrated understanding of complex concepts. According to the KIE principles, an effective design of the integrated learning activity should

- **make content accessible** by encouraging students to investigate personally-relevant problems and to connect new and existing knowledge,
- **make thinking visible** by embedding and providing multiple visual representations to model the scientific phenomena,
- **help students learn from each other** by designing multiple social activity structures to promote collaborative interactions, and
- **promote lifelong learning** by establishing a generalizable inquiry process suitable for diverse learning projects.

Chiu and Linn (2011) demonstrated how to connect science and engineering ideas to support inquiry-based learning in high school science classrooms by using the KIE principles. They argued the KIE instructional pattern offers a research-based design guide to create learning activities that aligns with the engineering design process. For example they designed a curricular unit for high school physics classes to guide students in thinking like engineers. In the unit, students conducted experiments to explore how airbag and car designs can keep passengers safe in case of collisions. Students were also provided with videos of crash tests to explore what conditions could lead to injury from deploying airbags. The KIE principles significantly shaped this unit by

- **making content accessible** by setting the fundamental physics concepts within the everyday context of cars, driving, and safety,
- **making thinking visible** by helping students to discover the relation between motion and velocity and position graphs by using a series of dynamic visualizations,
helping students learn from each other by encouraging students to work in dyads of mixed prior knowledge for the targeted concepts, and

promoting lifelong learning by scaffolding students to practice self-monitoring and reflection while working on the embedded challenges in this unit.

Implications

Active learning is not a panacea that is a blanket remedy for all instructional inadequacies. Instead, it is a collective term for a group of instructional strategies that produce different results and require differing degrees of time to design, implement, and assess. We urge the engineering education community to more precisely describe the active learning strategies they are using in their classrooms. Being more specific about our descriptions will allow us to ask more detailed research questions – and allow instructors to more wisely design instruction that meets students’ needs.

If we more carefully describe our strategies, then we can design instruction that matches kinds of activities to the importance and difficulty of outcomes to be achieved. So for example, if the learning objective is to understand complex and important concepts, interactive engagement might be used because it produces the deepest learning, although it often requires the most time and preparation. In contrast, if the learning objective is to recall and recognize certain terms and facts, a less intensive type of activity might be used, such as asking students to repeat what they have learned. Just as a designer of a physical structure will use the strongest (but perhaps most expensive) material where the most weight needs to be supported, so the instructional designer could use the most effective (but perhaps most time-intensive) engagement strategies with the most difficult concepts. And when creating interventions, we can use frameworks like KIE as a guide.

We call on the engineering education community to take a more nuanced approach to active learning. Instead of asking, Does active learning work? one can now ask, What kind of active method produces the highest learning in specific settings, or with specific kinds of students?

References


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