Kinesthetic Learning in the Classroom

"Great ideas originate in the muscles" – Thomas Edison

Introduction

A great deal of information exists regarding the different means by which students learn new concepts. Although visual, auditory and kinesthetic learning are the most commonly listed learning styles, little attention has been given to kinesthetic learning. This is especially true in lecture-based courses at the college level where the format favors verbal and visual learners. Here we make a tentative argument for the value of including kinesthetic learning activities in lecture-based classes as a vehicle for teaching concepts.

To begin, it is important to make clear how our working definition of kinesthetic learning may be different from previous work. First, the term "active learning" already means something to the education community and may include instructor demonstrations, brainstorming, reflections and minute papers. The version of kinesthetic learning considered here is a sub-set of active learning where students will be out of their seats and quite literally active. Second, the term "kinesthetic learning" is in common use in some education circles. Within those circles, the focus is typically on learning a manual skill or refining muscle coordination. Engineers must learn to build physical structures, often using their hands to perform complex tasks. While a great deal of learning takes place in becoming competent at wire wrapping and soldering a circuit board, connecting and sealing tubes in a flow loop or drilling a precise hole in a section of sheet metal, the learning is largely a fine tuning of muscle memory. In most curricula, these skills are practiced and mastered in a lab setting. The version of kinesthetic learning considered here will take place in the classroom with the objective of introducing and strengthening concepts as well as connecting ideas together. Therefore, when the terms, "active" or "activity" appear below, they quite literally mean some type of physical activity that is intended to stimulate deep thinking.

We first review some relevant literature, followed by an outline of a generic activity, an illustrative example, suggestions for generating ideas and designing activities, and finally student and instructor observations.

"Games lubricate the body and the mind" – Benjamin Franklin

What is Known about Kinesthetic Learning

Kinesthetic learning is often listed in surveys of learning styles along side, verbal and visual learning. Despite this recognition as an important learning style, kinesthetic activities have not received much attention at the college level. In fact, the degree to which physical activity is present in the classroom appears to drop to nearly zero as students progress from primary to secondary to post-secondary school. Below we summarize some of the work that has been conducted on the effectiveness of kinesthetic learning.

Primary and Secondary School

Jean Piaget – All of the most basic facts about the world are first discovered through physical means. As the brain matures, facts are abstracted and related to other concepts. Although the ability to abstract a concept and make complex connections between concepts are considered to be signatures of a mature mind, humans learn best by doing something concrete first, and then abstracting to more general concepts.

Dunn and Dunn - "Children enter kindergarten as kinesthetic and tactual learners, moving and touching everything as they learn. By second or third grade, some students have become visual learners. During the late elementary years some students, primarily females, become auditory learners. Yet, many adults, especially males, maintain kinesthetic and tactual strengths throughout their lives."

Feldman and McPhee – "Kinesthetic learners are most successful when totally engaged with a learning activity. They acquire information fastest when participating in a science lab, drama presentation, skit, field trip, dance, or other active activity. Because of the high numbers of kinesthetic learners, education is shifting toward a more hands-on approach; manipulatives and other 'props' are incorporated into almost every school subject, from physical education to language arts. Hands-on teaching techniques are gaining recognition because they address the challenging needs of kinesthetic learners, as well as the diverse needs of auditory and visual learners."

Muneera Spence - Visual learners account for around 30% of the population and auditory learners account for around 25% of the population. Kinesthetic learners may account for as much as 45% of the population.

Benjamin Bloom – In addition to cognitive and affective taxonomies, Bloom (as well as Dave and Harrow) developed a psychomotor taxonomy. The taxonomy ranges from basic proprioception to the ability to improvise new and complex movement.

Howard Gardner – Intelligence is a multifaceted quality that cannot be measured by a single score on a test. Furthermore, some types of intelligence are not even located in the brain. For example, an understanding of space and motion is a distinct kind of intelligence that is useful to the athlete, dancer, martial artist and engineer.

Post-Secondary School

Although many engineers are acknowledged to be kinesthetic learners, there is little data to support this claim. Furthermore, the distinction between an activity as a means of learning a skill (e.g. lab skills) versus learning a concept, has not been addressed in any study. Instruments such as Felder's Index of Learning Styles (ILS) come the closest to assessing the definition of "active" prescribed here. In a survey of thousands of college-age engineering majors, 67% reported that they process information best by being active. The term "active" in the ILS, however, is contrasted with "reflective". When the template for a kinesthetic activity is explained below, it will be clear that both active and reflective elements are involved and tightly integrated.

Despite the lack of data in the engineering education field, some educators, such as those in dance, graphic arts, and communications, use kinesthetic learning daily. In a study on graphic arts education, where one would expect a high percentage of visual learners, it was estimated that 45% of students were categorized as kinesthetic learners. Furthermore, kinesthetic activities have been found to be effective in special adult populations, such as the blind and deaf. It should be noted, however, that these fields place emphasis on refining muscle memory and conditioning responses. Two studies in English and Computer Science, however, did use kinesthetic learning to teach concepts. Virginia Zimmerman guides students in developing dance steps that correspond to the rhythm of a poem. The purpose is to highlighting the use of meter and structure by different authors, and point out how they sometimes violate the structure for effect. A small group of computer science faculty have also been building a repository of kinesthetic learning activities at http://ws.cs.ubc.ca/~kla/index.php that demonstrate a wide range of sorting and networking algorithms.

A Subset of Active Learning

Kinethetic learning is a type of active learning in that students are quite literally participating in their education. As such, it shares many of the benefits of active learning. We summarize below, three of the most often cited benefits .

- The traditional lecture format is teacher-centered, with information flowing almost entirely in one direction. As such, only the most basic levels of intellectual behavior can be reached (Bloom's Knowledge, Understand, Application). Active learning, on the other hand, is student-centered and provides students with the time and space to reach more sophisticated levels (Bloom's Analysis, Synthesis, Evaluation) of abstraction.

- As faculty, we are constantly in motion in the classroom, writing, explaining, erasing, using the computer, and we have many pairs of eyes watching us. It is easy for us to keep our energy level up. Student, however, can lose focus over the course of a lecture. Active learning can help reenergize a classroom.

- By offering a variety of active learning, different learning styles may be targeted.

Identifying Kinesthetic Learners

Marilee Sprenger has compiled a list of characteristics may help identify students who will be most deeply impacted by kinesthetic activities:

- Sit comfortably, slouching or fidgeting. Leans back in chair or taps pencils
- Distracted by comfort variations such as temperature, light or movement
- Accesses memories by recreating the movements associated with those memories
- Says things like, "Can you give me a concrete example?"
- Enjoy taking things apart and putting them back together again, working on projects
- Don't like to read manuals but rather like to "figure it out"
- Act out what they are learning
- Dooodling

"You don't just learn knowledge; you have to create it. Get in the drivers seat, don't just be a passenger. You have to contribute to it or you don't understand it"

– Dr. W. Edwards Deming

Designing an Activity

In this section we will discuss the elements that should be considered in the design of a successful activity.

Identifying the Objective

The objective of the activity should be tied very tightly to the preceding and followup lectures. Students must be able to connect the activity to the wider objectives of the course or they will treat the activity as simply a break from learning.

Rules to Simulate the Activity

It is important to lay down clear rules and parameters for the activity. Depending upon the activity, oral or written instructions may be most effective. A number of parameters are especially important to consider. First, how could students misinterpret the rules? If they do, how will you get them back on track? Second, how many times will the activity be performed? Is there a purpose in repeating the activity? Will repeated the activity result in the same outcome? Lastly, are there variations of the activity that will highlight nuisances of a concept or introduce a more advanced topic?

Logistics

Some activities require either props or a special environment. Any materials or space reservations should be made well in advance to ensure the activity runs smoothly. Efficiently assigning roles in an activity can speed the transition from lecture to an activity. These logistical points may be best addressed if the instructor first rehearses the activity in their mind several times.

Post-processing

The post-processing is where students will reflect on the deeper meaning of the activity. It is therefore the most critical step in designing a kinesthetic learning activity, more important than the actual activity itself. Put another way, students will remember the activity and associate it to the activity. It is therefore imperative that the processing be tightly tied to the learning objective.

Post-processing may take many forms including minute papers, out-of-class assignments or class discussions. If a discussion is to be conducted, it is helpful to have an outline of questions, prepared in advance, to keep the dialog moving forward. One simple question is to ask for modifications to the activity that may have analogies to the concept. An interesting variation is to split the class into groups. Each group develops their own interpretation of the meaning of the activity, which they share and discuss with another group.

Closing
It is very important to have a way to end the activity and return to class. A suggestion is to agree upon a simple signal to indicate the end of an activity. In a small class, returning to the board and becoming silent can be very effective. A final rhetorical question can also serve the purpose well. Finally, a more direct approach may be to simply say, "let's go back to class".

> *"Spoon feeding in the long run teaches us nothing but the shape of the spoon."*
> *– Edward Morgan Forster*

Kinesthetic Learning in Action
Although kinesthetic learning is a part of all courses taught by the author, the ideas were explored in the most detail in a senior level Neural Signals and Systems elective. Below is an example activity.

Background and Objective
Neurons propagate electrical impulses down an axon or dendrite by passing charge from one section of cell membrane to the next. The mathematical theory used to describe this phenomenon is the same used to model electrical transmission of signals in a cable. Although students at the senior level are capable of digesting the mathematical model of cable propagation, it is helpful to offer a concrete analogy. The objective of this particular activity is to introduce the concept of passive electrical propagation that will later be described mathematically.

The Activity
Students form a line, shoulder to shoulder, with the instructor at one end. The instructor places in their hands a large quantity of shredded paper. Everyone counts "1,2,3" and the instructor passes the shreddings to the next person. That person then passes to the next, and so on down the line. The activity is timed and an emphasis is placed on speed. As motivation, the activity is repeated at least two more times to try to "break the class record". Inevitably, much paper is lost by the time the shreddings reach the end of the line, and the last person often has only a few scraps of paper.

Post-processing
In the post-processing, students are asked to make connections between charge and scraps of paper, and current and the passing of paper. Students are also helped to make analogies between 1) the size of their hands and the capacitance of a membrane and 2) the dropping of paper onto the floor and a leaky membrane resistance. When students make these connections, it is a small jump to introduce the concepts of electrical attenuation, as well as time and space constants, without the use of mathematics. One student even pointed out that the decay rate down the line was roughly exponential. I often ask students at the end of any activity to list problems (diseases) they think may occur if something is disrupted.

Followup
The lectures that follow this activity are mathematical but refer back to the activity. When active transmission of neural impulses is discussed, the activity is repeated, but with an addition. Every student already has shreddings in one hand before the passing begins. The result is that the student at the end of the line receives a full handful of shreddings. In comparing this analogy of active propagation to the previous analogy of passive propagation, students literally see how attenuation is present in passive but not active propagation. Later activities can address how myelin speeds up propagation and how the soma sums inputs from the dendrites.

> *"Ideas that enter the mind under fire remain there securely and forever. "*
> – Leon Trotsky

Source of Ideas
Analogies
The example above was an adaptation of a common analogy used in the electrophysiology community. Despite the use of the analogy in textbooks and lectures, it is never acted out, but rather explained using words. Translating an analogy to an activity is often simple. A general rule is that most analogies an instructor may make during lecture could be transformed into an activity.

Primary and Secondary School Activities
Quantitative studies have been conducted to show the effectiveness of kinesthetic learning in primary and secondary school environments, and so there exists a wealth of activities available for free either online or in textbooks. Most of these activities focus on the building of motor skills or muscle memory. The key to a successful activity in a college setting, however, is the post-processing. It is often possible to reinterpret a pre-college activity by simply adding more sophisticated post-processing.

Reuse
Often the same activity could be modified, or sometimes used as is, in more than one course. It is even possible to repeat the same activity within a single a course with slight modifications (e.g. passive and active propagation). Again, it is only the post-processing that needs to be changed.

Student Design Activities
Tasking students with developing their own activity serves two purposes. First, developing an analogy requires deep thinking. In fact, Douglas Hofstadter in his book Metamagical Themes argues that creating analogies is how the mind builds upon previous knowledge and experiences to learn new concepts. Second, some student-designed activities may be of sufficient educational value to be reused in future classes.

> *"Some people talk in their sleep. Lecturers talk while other people sleep."*
> – Albert Camus

Faculty Observations

Most students who have reached a college engineering program are certainly able to learn by visual and verbal means. Based upon our audience, it is therefore not clear if physical activity is an effective means of teaching concepts. Even assuming that the educational process has filtered out natural kinesthetic learners, everyone has some complex and adaptable mix of learning styles. We are therefore not suggesting that a course be dominated by kinesthetic activities, but rather that it supplement more traditional instruction methods. The following are observations and opinions of the author. There is no claim that they are supported by hard data.

Benefits of Kinesthetic Activities

- Kinethetic activities reach two very different types of students. First are the students who are attempting to earn their degree with the minimal possible effort and are bright enough to achieve this feat. These students may simply welcome the break. But on a few occasions, a student in this category has an eye-opening experience which enables them to become more invested in the course. Second are students who are striving to gain a deep understanding of the material. It is often the case these they are not the brightest or highest achieving students. For these students, kinesthetic activities offer a way to enhance their understanding.
- Most students only understand a concept in the context in which it was introduced by the instructor. Furthermore, in a lecture setting only a few connections may be made by the instructor between the current topic and other course topics. Kinesthetic activities are a time when students can develop their own personal interpretation of a concept and make connections to other ideas and concepts.
- The statements and actions of students during and activity can very quickly allow the instructor to assess the level of understanding. This valuable information allows the instructor to then better address the source of any misconceptions or gaps in understanding.
- In a traditional lecture, the natural diversity of student abilities can hamper efforts to meet every student on their level. Kinesthetic activities strip down concepts to their barest essence. There are no equations, no complex or wordy descriptions and the activity itself can be understood by all. In the post-processing, however, each student can interpret the activity as deeply as they are able.
- Regular activity can help create a rapport between the instructor and the students. In the activity, the instructor is just another participant and temporarily is not in the role of teacher. In general, the spirit and energy of the class is increased. Even the class dynamics during lecture become more interactive, with even quiet students making tentative contributions. Perhaps most telling, students were found to be sharing (and demonstrating) the activities with friends outside of class.
- With some practice, developing an activity becomes an easy and fun exercise for the instructor.

Challenges of Kinesthetic Learning

- Students can quickly transition an activity to an unproductive tangent. It is therefore important keep the class on task and have ready a clear ending.
- Kinethetic activites will be remembered and powerfully linked to a concept. Developing an activity for a minor concept could give students the wrong perspective on the goals of the course. A poorly designed activity could enhance a misconception. It is suggested that any limitations of the activity be pointed out during or after the activity.
- Many students are not accustom to leaving their seats and participating in an activity. It is possible that some students will feel uncomfortable. It is best to start with low-stakes activities.
- It is not clear how kinesthetic learning will translate to large class sizes.
- Students may initially resist the idea that activities are a vehicle for deep understanding. Instead they may view the time as a mental recess. It may take effort on the part of the instructor, as well as a clear articulation of the goals, to instigate the proper attitude.

"The great aim of education is not knowledge but action." – Herbert Spencer

Student Assessment

Although the observations above are largely positive, they certainly do not imply that kinesthetic learning "works". The following table reports the results from an initial attempt at assessing the method.

Activity during class …

…is fun	4.7
…is helpful in processing course concepts	4.5
…is encouraged in future courses	4.6
… keeps energy levels high	4.8
… helps recal information on test	4.6
… is a good way to introduce new concepts	4.0
… is most effective after a concept has been introduced	4.4

Likert Scale (1=strongly disagree, 5=strongly agree), n=28

Student written comments revealed that successful activities were short, simple and followed up by time to relate the activity back to lecture. The relatively lower numerical score given to using activities to introduce a concept were explored further in discussions with students. The general feedback was that activities "work best" when there is already some background to build upon, even if it is not yet fully developed.

Conclusions

The idea of kinesthetic learning as a sub-set of active learning has received very little attention from the higher education community. The small quantity and quality of data that does exist is largely outside the engineering community. Although the author will continue to explore the use of kinesthetic activity during lecture, future research should be conducted to first develop measures to assess kinesthetic learning in engineering classrooms and second to use those measures to develop best practices.

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