A Kinesthetic Approach to Reviewing Content in the Engineering Classroom

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Abstract

This evidence-based practice paper explores how to implement aspects of kinesthetic learning in the classroom effectively.

In engineering classrooms, most instructors are good at engaging visually and auditorily with students. However kinesthetic learning, movement with a purpose, has yet to become prevalent. Students passively learn while sitting in their seats as the instructor is up at the front of the room teaching. Even as active learning occurs, such as peer to peer discussions, students are still sitting. Learning science has shown that the brain and physical activity are connected. An active body can lead to an active mind. Significant work has been done on how to create intentional movement in elementary and middle school classrooms, but it is limited in higher education settings.

This paper discusses how an "escape room" learning activity has been implemented and assessed in two small-sized engineering programs, York College of Pennsylvania and Iron Range Engineering. Escape rooms are a physical adventure game to challenge players, where they must solve a series of puzzles to escape the room in a given time limit. In this activity, using movement to review content in preparation for an exam can be thought of as an elaborate rehearsal which often engages in higher order thinking skills and greater sensory input. Students walk around the room to solve various conceptual and numerical/mathematical problems hung on whiteboards in different areas of the room. They gather tokens for the correct problems they solve and receive verbal feedback from the instructor on any misconceptions or errors. Once a student has gathered the required number of tokens, they can "escape" the room. The activity is done individually with students on their feet moving around the room for the entire duration. An adaptation of this activity allows students to work in small groups of four to five to discuss and collaborate to solve the problems. This activity has been conducted once a semester in the Iron Range Engineering program since the Fall 2017 academic year and twice a semester in the York College of Pennsylvania program since the Fall 2018 academic year.

Feedback was collected via student surveys, student and faculty reflections. Preliminary analysis of student feedback and faculty reflections indicates increased learner engagement, enhanced review of technical content and a different type of learning experience. Faculty reflections also noted that the activity helps students to self-identify those concepts they had successfully mastered and those needing more review. This activity has brought value to the overall learning process and will continue to be used to improve teaching and student learning in both programs.

Introduction

This evidence-based practice paper outlines how to implement aspects of kinesthetic learning effectively in the classroom through an ”escape room” activity for small-sized engineering programs.

In today’s engineering classrooms, students are often sedentary for the majority of the class period. Learning usually occurs visually, auditorily or through reading and writing. Even as active learning such as a class discussion is going on students are sitting in their seats. However, some students may require movement of some form in order to learn which can also be known as kinesthetic learning. VARK (Visual, Aural, Read/write, and Kinesthetic) is one approach used to categorize these different types of learning styles [1]. Kinesthetic learning allows individuals to experience the information through all five senses of touch, sight, sound, smell and hearing where they can physically carry out activities instead of passively listening or watching [1].

A kinesthetic learning activity modeled around an escape room was created and implemented at the Iron Range Engineering (IRE) and York College of Pennsylvania (YCP) engineering programs to bring another aspect of active learning into the classroom. It is centered around a learning objective of reviewing technical engineering content for a particular course. This activity promoted movement in the body while students are recalling concepts, therefore, creating deeper connections to the material learned. Currently, no classes at either IRE or YCP formally use kinesthetic learning.

Theoretical Foundation and Related Work

Research in brain science supports the strong link between the brain and the body. Studies, such as [2] and [3], have led to evidence showing stress and pain in the body are connected to how the mind processes information in those situations. The brain can be thought of as an extension and reflection of the body [4]. Regular physical activity and academic performance have also been found to be positively linked [5, 6]. Academic performance is not limited to just academic achievement of high test scores but also student behavior in the classroom and cognitive skills such as memory and concentration [6].

In the classroom teachers aim to create a positive, stimulating environment where students are engaged, motivated and challenged. However, some researchers estimate the attention span of the average student during a lecture to be around ten to fifteen minutes [7, 8, 9, 10]. Allowing the brain the opportunity to refocus through movement, done purposely and thoughtfully, can enhance a brain’s function in the way it thinks, learns and remembers [4, 11].

Kinesthetic learning as defined in this paper is the movement of the body with a purpose. Getting students out of their seats while learning does not have to be a full body workout and can be as simple as getting them to jog on the spot for a minute. Providing an emotionally safe space for the mind allows the brain not only to be able to process new information but also for it to work at optimal levels [4]. Engaging students in movement activities can also develop class cohesion in a supportive inclusive environment.

A common question in implementing such activities is classroom management. Initially, students may be extremely reluctant to try something new. It is the teacher's responsibility to provide the motivation and encouragement to students, so they have an interest in participating. One strategy is giving a bit of background to the benefits and connection between movement and learning. Start with a low-stakes activity to get students adjusted to this learning technique. The safety of the students must also be considered when choosing a physical space to use. More details on classroom management techniques are provided in [4].

Kinesthetic learning is becoming common in K-12 classrooms as evidenced by the action-based learning lab [12] and learning readiness physical education program [13]. However at the college and university level, most classes are still in the traditional lecture format and kinesthetic learning is in the form of tactile, hands-on learning through experimentation in laboratories or project work. Some creative examples of movement used in higher education classrooms include demonstrating how neurons propagate in a neural signals and systems class [14] and teaching symmetry in a mineralogy course through dance [15]. Other kinesthetic teaching strategies for adult learners can be found in [16].

One area to incorporate movement in is time spent reviewing content. Every student is different in how often they need exposure on a particular concept before it is learned and stored [4]. Recalling information is crucial for content to go from short-term to long-term memory [17]. Taking the time to review content allows for the brain to make sense of material learned and create connections. This an essential part of the teaching and learning process and should occur regularly in some form. In the book "Learn Better", Boser mentions that in most schools material taught is often not revisited and when it does occur it is mainly a cumulative test at the end of a semester [18]. He suggests that spreading out the practice and learning of a concept over time by having dedicated review sessions to re-quiz yourself on the material yields substantial improvements to your recall and memory of it. There is a growing shift towards revisiting material periodically and using it as a learning strategy [18, 19, 20]. Recalling and retaining material becomes easier when it is connected to movement [11].

Movement during review activities depends on the availability of time and type of movement considered. Activities can range in preparation time, student involvement and teacher-directed instruction. Additional information on activities used specifically in reviewing content can be found in [4]. A kinesthetic learning activity was developed by faculty at IRE and YCP to embedded movement into a review session and observe its effect on student learning. This activity was also briefly introduced in a previous paper [21].

"Engineering Your Escape" Kinesthetic Learning Activity

This kinesthetic learning activity was modeled after the popular social game known as an escape room. Escape rooms are physical adventure games designed to challenge players, where they must solve a series of puzzles and riddles using clues to escape the room in a given time limit. In our version of an escape room, students are "locked" in an area and must solve questions related to the technical material they are learning in order to "escape". All the escape room activities have been used as a form of review to aid in the students' preparation for an upcoming exam.

Activity Preparation:
First, the instructor decides on the time limit of the activity. The author, who has previously implemented this activity, suggests between 60-70 mins. This includes an explanation of rules to the students (5 mins), execution of the activity (approximately 55-60 mins) and a debrief of it with the students afterward (5 mins). The author notes that 5 mins is short in length to debrief but recognizes that students do need time to process and reflect on what occurred during the activity. The debrief time is an opportunity for the students to express what they actually learned and provide informal feedback on the activity to the instructor. At IRE, students are required to write a reflection to be submitted to the instructor within one week of the activity occurring. Some open-ended writing prompts are provided to the students to guide them to reflect not only on the technical material they reviewed but also the activity logistics. An example of one prompt includes: ”How did you feel during the escape room activity?”

Next, the instructor develops questions, related to the material students need to review, that can be factual, conceptual or problem-solving/application. Factual and conceptual questions are usually quicker for students to complete taking between two to three minutes per question. A more involved procedural problem-solving question could take up to fifteen minutes so it can also be broken up into multiple parts while all still related to the same topic. Questions should be designed for short answer responses as it allows the student to express their answer through words, formulas, or diagrams. Depending on the number and style of questions this can be adapted for both shorter or longer class periods. Once the problems are decided on, an answer key is developed so it can be easily referenced by the instructor during the activity. After an escape room question set is created, it can be used again with future groups of students for the same course with no additional instructor preparation time.

Tokens, usually in the form of bingo chips, are given to a student during the activity after the instructor evaluates a student’s answer to be correct. For the student to ”escape” they must acquire a pre-determined minimum number of tokens, which the instructor decides on. For example, answering each question correctly is worth one token and students must gain ten tokens to escape. Instructors must also consider how many attempts a student can have for each question. To keep the students moving around the room to solve a breath of questions the author usually recommends two attempts per question. Students only have to get the required number of tokens before the time limit is up in order to escape so they do not have to go to every question.

The instructor to student ratio is suggested to be one instructor for every twenty students present. This is to ensure classroom management is maintained and timely feedback is given to students during the activity. If there are more than twenty students in a class, other available instructors can assist, or a couple of students can have the ”instructor role” to ensure the ratio is met. This is a resource-intensive activity so it is easier to implement in small-sized classes and programs. At IRE and YCP class sizes are between 8-12 and 15-18 students, respectively. However, it is not used as a regular classroom activity and only occurs one to two times a semester due to the amount of planning and setup required.

Finally, the instructor decides if this is to be an individual or group activity. For an individual activity, there should be a variety of questions both in the content area and depth so students who are stuck on one question can move onto another and use their time wisely. More details on this setup can be found in iteration one and two in the Examples of the Activity section. In a group

setting, group sizes are recommended to be between 3-4 students so they can engage in lively discussion to correct each other's mistakes and everyone has an opportunity to contribute. The author also recommends questions to contain multiple parts where each person in the group is in charge of writing out the answer to one part. This reduces the likelihood of one individual from dominating the entire activity or an individual choosing not to be engaged. Instructors can predetermine the groups or have students form their own groups at the start of the activity. Iteration three in the Examples of the Activity section details how a group version worked at IRE.

Physical Setup of the Escape Room:

The activity can occur in any classroom or area where students can move around freely without desks or chairs in the way. Ideally, the area should have lots of whiteboard/wall space or movable whiteboards that can be brought in. The author suggests picking a space that is not the usual classroom as the unfamiliarity pushes students out of their usual comfort zone. Having students doing something different from their regular passive learning methods should stimulate active learning and engagement where the students are working towards an immediate goal of escaping whether individually or as a group.

If the activity is done individually have the questions printed out on slips of paper which are to be posted on the whiteboards or walls spread throughout the room. For the questions displayed on whiteboards ensure there are enough whiteboard markers and erasers for students to write their answer on the whiteboard. If the questions are posted on the wall, have pencils and paper ready so students can write their response on the paper.

For a group activity have a question set printed out for each group. If the activity is done using whiteboards, designate one whiteboard per team and ensure there are enough whiteboards, whiteboard markers and erasers for all the teams. If the activity is not using whiteboards have the question set posted on the wall in multiple different areas in the space. Students can write their answer using pencil and paper.

As mentioned previously, a student's answers to the questions are entirely written out either on slips of paper or on the whiteboards. In order to prevent a student from learning the answer from someone who has answered a particular question correctly, answers are immediately erased from the board or the papers where the answer is written on is given to the instructor. Students are usually very focused during this activity to get tokens to escape so very little discussion between them occurs unless it is a group activity where they are working together in teams.

An important issue to consider is how to create an equitable and inclusive experience for students with physical disabilities. While many students are able to move around freely, this activity can be difficult for mobility challenged students to fully participate in. One approach to creating a more inclusive activity is to have the students working in groups. Everyone is stationary working at their group's whiteboard and movement only occurs when groups are traveling from one area to the next, similar to what was done in iteration three in the Examples of the Activity section. Another suggestion is to have one able-bodied student in each group designated as the "question-seeker". They are in charge of going around the room to pick a question for the group to solve. They bring the question back to the group's area so as a group they solve it. Once it is solved correctly the "question-seeker" can go around the room again to choose another question.

This strategy has not been used at either IRE and YCP but there are plans to incorporate it in later iterations of the activity.

Carrying out the Activity:

1. Introduce the activity to students and explain the rules. Make the introduction brief if students are not used to this style of learning. One suggestion is to tell the students this is a form of active learning and it is going to be tried out during this class period.
2. Bring students to the escape room area and pass out the necessary supplies such as paper, pencils, whiteboard markers that they require. Then start the activity.
3. Once the activity is up and running, the instructor circulates the room to ensure all students are on task and working.
4. If a student or group thinks they have solved a problem correctly, they raise their hand, and an instructor comes by to assess it. A student or group is given a predetermined number of tokens for the correct answer and verbal feedback if it is incorrect. Students move on to a new problem if the previous problem was solved correctly or after two incorrect attempts at the current one.
5. For a student or group to successfully leave the room a pre-determined minimum number of tokens is to be acquired.
6. Once the time limit of the escape room portion of the activity is up, have students count their tokens. Discuss briefly with the students any questions and feedback they may have about the activity.

Examples of Activity:

At IRE there is flexibility in open spaces and classroom furniture is movable. For the first iteration of the escape room whiteboards were set up in the gym as seen in Figure 1 and this was an individual activity. Students started off making a paper dice to be used during the activity. Visual instructions on how to make a paper dice were made available to the students. Then students would circulate around the room to answer conceptual questions, posted on the whiteboards, related to three engineering areas of electrical, mechanical and business. For their selected engineering topic, they roll their paper dice at a whiteboard to see which conceptual question to answer. Students then wrote the answer on the whiteboard for the instructor to assess and if they were correct, a token representing mastery of that engineering area was given to them. Students were allowed two attempts at a particular question before having to move on to another one. There were three different colored tokens (red, blue and green) corresponding to each of the three different topic areas. Depending on their semester level, students needed a certain number of tokens in each color to escape. For example, a first-semester junior requires three tokens in each color for a total of nine whereas a second semester senior needs six tokens in each color for a total of eighteen tokens. Four faculty members and twenty students participated in this iteration. After tracking the student experience in this learning activity at IRE, using faculty discussions and student feedback, the activity was adapted each subsequent semester while keeping the general idea the same. There were also some adjustments made to question type and content, based on data collected, with the goal of improving the value of the activity but that doesn't mean the harder questions are made easier.

Figure 1: First Iteration of the Escape Room in the School Gymnasium

Figure 2: Second Iteration of the Escape Room in the School Theater

For the second iteration, the activity was moved to the school theater seen in Figure 2. There were four faculty members and twenty students present during this iteration. It was still an individual activity, and the setup and rules were the same as the first iteration, but two changes were made. First, students were allowed to ”phone a friend” meaning they could ask a faculty member or classmate for clarification if they got an answer wrong or were stuck on a question. Also, a ”stock

exchange” system was implemented where students could trade one color of tokens for a different color. For example: 3 blue =1 red. The rates of token exchange would change every ten minutes. The ”stock exchange” system was added as a result of faculty wanting to encourage students to have a breadth of technical core engineering knowledge while recognizing those students who also developed a strong depth in one particular focus area, similar to that of a T-shaped individual [22].

In the third iteration, the escape room area was divided into six different theme areas which were decorated to resemble a hair salon, wedding chapel, submarine, cafe, going on a trip and a kitchen. Faculty also dressed up in each of the themed areas. Two of these themed areas are shown in Figure 3 and 4. This was the first time the escape room activity was done in groups at IRE. Students were in groups of five to six students and each group rotated between three different theme areas with fifteen minutes at each area. In each area, students were asked to solve six different engineering conceptual questions related to that particular themed area. Each conceptual question had multiple sections, and a student was required to write the answer for one section of each question. Faculty would come into each area to assess the answers after the fifteen-minute time limit was up. One token was given if less than 40% of the answers were correct, two tokens for less than 80% and three tokens for 100% correct. For example, if a group got 60% of the answers correct they would still only receive one token as they hadn’t mastered up to 80% of the material. This method was found to push groups to make deeper connections to the material they were recalling in order to get the maximum number of tokens for each question. The winning team was the group with the most tokens after completing three themed rooms in forty-five minutes. Eight faculty members and thirty students participated in this event.

Figure 3: Third Iteration of the Escape Room at the ”Submarine” theme

Due to space and faculty limitations at YCP, only the group version of the activity has been done. Each group has one whiteboard and each student had to write the answer out for one part of a multiple part problem-solving question. The instructor would come by and check to make sure all

Figure 4: Third Iteration of the Escape Room at the ”Hair Salon” theme

parts were correct before students were given another problem to solve. Tokens were also given to each group once a problem was solved entirely correct. To escape the room all the problems, usually between four and five, must be solved correctly as a group. In these activities, there was between sixteen and eighteen students with one faculty member present. Movement was limited as students were standing working on the whiteboards and stayed at the same board for the entire duration of the activity.

Assessment and Feedback

In the Fall 2018 and Spring 2019 semesters, students were anonymously surveyed at IRE before and after the third iteration of escape room activity. All thirty students who participated were surveyed in Fall 2018 and thirteen students in Spring 2019, although twenty-two had participated. The pre-survey had one Likert scale question asking the student’s preparedness level for the exam before the activity. The post-survey had fifteen questions that asked students about their opinions and attitudes after completing the activity. Nine items had response options on a three-point or five-point Likert scale and five were short open-ended questions. Data was collected at YCP during the Spring 2019 semester but still needs to be analyzed so the formal results are not included in this paper. Limited data was collected because of the size of both the IRE and YCP programs, so the sample size is automatically small. The author plans to track the use of this activity longitudinally in order to reach meaningful conclusions.

After analyzing the survey data on the IRE students’ attitudes during the activity, it indicates the following results:

- 93% of the students found learning value through completing the activity.

- 81% of the students found the activity enjoyable.
- 84% of the students felt either neutral or positive during the activity.

A pre and post preparedness question surveyed students on how ready they felt they were for the exam, both before and immediately after the Escape Room activity. 84% of the students surveyed felt adequately or more prepared for the exam after the activity compared to 54% before. More specific feedback on the logistics of the activity is compiled in Table 1.

Table 1: **Student Self-Reported Feedback for Escape Room Activity (n=43)**

Question	No	Neutral	Yes
Were there enough questions (both in amount and content area) to help you review and recall the material?	2 %	24 %	74 %
Would you like the activity to explicitly count towards your final grade? Such as part of the participation portion of the final grade.	19 %	48 %	33 %
Did you like working together with other students during the activity?	0 %	5 %	95 %
Did you like the time constraint given for each round?	14 %	24 %	62 %
Did you like the amount of feedback given by the instructors?	7 %	57 %	36 %

An observation made from the results is students were either neutral or in favor of having this activity counts towards their final grade. One student commented it ”should not be based on the outcome or score” of the activity. This is a change that could be implemented next iteration and tracked for long term assessment of academic performance in the course. The author recognizes the answer of neutral does not give a lot of information or insight into the students’ feelings toward the question as students who picked this could go either way but have no strong feelings one way or the other. The survey will be adapted in later uses to gather more conclusive results.

Also seen in Table 1 and in the students’ comments, many felt that the amount of feedback given by the instructors during the activity was very minimal or was not present at all. Students commented that if their answer was wrong they were not told why it wrong and the areas to improve on. This was partly due to the time constraint of the activity but will be discussed by the faculty before the next iteration.

The most common recurring comment students had to the short answer question of ”what was the most challenging part of the activity” was recalling the information they had previously learned. Students were asked to use concepts or equations they had learned earlier in the semester or in previous classes, so they weren’t always able to remember it quickly. This activity allowed many students to recognize the value to continually review material so it can stay in their long term memory.

In many of the student reflections, it consistently mentions this activity was fun, and they enjoyed working in groups. One student wrote: ”I loved this semester’s escape room! It was fun and made learning easy!”. Another student commented, ”I like how we did groups this year, it made the activity much more engaging and entertaining.” Faculty who have participated in the activity say it is a unique and creative way to do a review of material before an exam. They do recognize the extra preparation and time needed to execute such an activity but the favorable benefits of purposefully using movement to facilitate recall and practice of conveying information outweigh the extra work. The author observed a possible change to iteration three is the elimination of the majority of chairs and desks in the escape room space. It would further promote the movement of able-bodied students around a room as of them were still sitting even though they were encouraged to get up to use the whiteboards.

Conclusions and Future Work

At both IRE and YCP, the faculty will continue to use the escape room activity as they see it as an opportunity to bring a positive, motivating atmosphere to a classroom by getting students up on their feet in an engaging game-like environment while learning. Although it is a resource-intensive activity to prepare and implement, the favorable benefits of creating group learning opportunities and establishing a safe space for students to make mistakes outweigh the additional work. The comments and the survey results are consistent with what the author observed. Next steps include being more strategic with aligning the activity with specific learning outcomes and analyzing the results. For long-term assessment, the author plans to compare students’ exam scores from non-kinesthetic course sections and to track the final grades in the course over time. A deeper assessment approach would reveal if this activity had a substantial effect on the learning process.

After implementing this activity in several instances over a one year period, the author recommends that other engineering educators consider adopting some form of kinesthetic learning occasionally into their courses as an alternative experience in the learning process.

Acknowledgments

The author gratefully acknowledges the support, encouragement, and engagement of the faculty and students at both IRE and YCP.

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