

AC 2008-390: DOES ACTIVE LEARNING PROMOTE UNDERSTANDING AND ENTREPRENEURIAL TENDENCIES?

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Does Active Learning promote understanding and entrepreneurial tendencies?

Abstract

Engineering colleges are interested in finding ways to develop the entrepreneurial spirit within their graduates. Many believe that this will contribute to future job security and economic prosperity in this country. Active in-class learning activities, such as in class problems and discussion, seems to have potential for promoting better understanding by more fully engaging the students. This stimulus then could pique student's curiosities, motivating them to think more deeply and creatively about the subject matter and how it could be applied in an entrepreneurial way to solve modern day problems via technological solutions. A study was conducted in a Junior level core chemical engineering course to determine whether more active learning activities leads to better understanding and retention of the course material and to students exhibiting more entrepreneurial tendencies. One section of approximately 25 students experienced active learning activities for approximately 25% of the in-class time, whereas the other section of the same size experienced active learning approximately 50% of the time. With regards to the types of active learning activities – a similar balance was employed for each section. Exam performances of the two sections were compared against each other to assess the degree to which an increase in active learning promotes understanding and retention. Entrepreneurial tendencies were noted for individual students as they worked on group projects near the end of the semester. Before the projects were handed out, both sections were exposed to lectures on state-of-the-art heat transfer technological solutions to some current problem(s). During these lectures, entrepreneurial characteristics (i.e. creativity and “big-picture thinking” etc..) and skills (i.e. problem identification, market analysis and patent searching etc..) that were exhibited during the conception and development of the new technologies were emphasized. In assessing performance on the projects, it was noted whether the students chose project ideas that extended from the concepts learned during the active learning activities and to what degree those students exhibited entrepreneurial tendencies by identifying and developing creative new technology ideas in the area of heat transfer.

Introduction

Active learning (AL) is an important part of many high school and college classrooms. The core elements of active learning are student activity (doing) and engagement (thinking)¹. Many students prefer to learn or have concepts reinforced through active learning, and believe that it promotes better understanding because “you are using or explaining the concepts as opposed to just listening to them from someone else”². Instructors trying to employ active learning during a lecture or throughout a semester-long course are confronted with many questions however, especially engineering instructors whose profession often requires optimization. What type of active learning exercises should be employed? Conducting experiments and discussions

or solving problems as individuals or in groups are all examples of potential “activities”³. These active learning exercises could also be used to initially teach the material or to extend and/or apply concepts in a more practical or different way. Furthermore, how much time should be dedicated to these active learning activities and when during the 50 minute lecture of a semester long course would these activities be optimally employed to maximize learning, understanding and/or retention of concepts? Finally, how much will the students benefit if the degree to which active learning is employed is optimized, and how can this benefit be demonstrated and quantified? Many of these issues are addressed, and some are evaluated and reported on, in this paper as an optimization study was pursued.

In addition to developing an understanding of the fundamentals, engineering colleges today are more-so than ever interested in finding ways to develop the entrepreneurial spirit within their graduates. Many believe that this will contribute to future job security and economic prosperity in this country. Active in-class learning activities, such as in class problems and discussion, may promote better understanding by more fully engaging the students. This in-turn could lead to the student’s having more confidence with and interest in certain material which could motivate them to think more deeply and creatively about that subject matter and how it could be applied in an entrepreneurial way to solve modern day problems via technological solutions. Such an empowered student then might be motivated to research the technical and even the business aspects and merit of any new technology ideas, perhaps to the extent of that market potential and patent opportunities might be identified. True entrepreneurship with regards to technology embodies the creative, or “seeing the big picture” side as well as the development and implementation side that is often driven by research, motivation and persistence⁴.

A study was conducted in a core engineering course (heat transfer) at Villanova University to determine whether more active learning activities leads to better understanding and retention of the course material and to students exhibiting more entrepreneurial tendencies. The heat transfer course is a mandatory semester-long course for junior chemical engineering students at Villanova. The course is taught as three 50 minute lectures per week. During the first two to three weeks of class, the basics of heat transfer are presented, including an introductory description of the concepts and equations describing the three mechanisms of heat transfer: conduction, convection and radiation. Conduction is then taught in depth for the next 3 weeks of the course, and convection is covered for the following 3-4 weeks. For the remaining month or so of the course, a project is worked on outside of class while equipment (heat exchanger) design/operation is covered during most of the in-class time. At the end of the conduction and convection modules, an in class exam is given just on that material. At the end of the semester, a final exam is given that contains a question on conduction and a separate question on convection. The first part of the project requires the student groups to specify and design heat transfer equipment. The second part of the project provides an opportunity for the student groups to identify the need for a new technology/design involving heat transfer and to develop a plan as to how to develop the technology and ultimately market/implement the technology. For the purposes of the

study conducted in the fall 2007, exam performances of the two sections were compared against each other to assess the degree to which an increase in active learning promotes understanding and retention, and entrepreneurial tendencies were noted for individual students as they worked on this second part of the group project.

Procedure: Description of the study

For the purposes of this study, active learning in the class room consisted of the time when the student were actively solving problems alone or in a group, verbally answering and asking questions to/from the instructor or working on internet-based research or computer simulation. The other class time, not attribute to active learning, consisted of the instructor lecturing, verbally responding to questions from the students and verbally posing questions from the students. During the first two to three week segment (segment A) of the fall 2007 semester (seven 50 minute classes), as introductory concepts were covered, the instructor used the same teaching style for both sections which included spending approximately 37.5% of the in-class time on active learning instruction. During the second segment (segment B) of the course (ten 50 minute classes), as conduction was taught, one section of approximately 25 students (section #1) experienced active learning activities for approximately 27.5% of the in-class time, whereas the other section of approximately 23 students of the same size (section #2) experienced active learning approximately 47.5% of the time. During the third (segment C) of the course (eleven 50 minute classes), as convection was taught, section #2 experienced active learning activities for approximately 27.5% of the in-class time, whereas section #1 experienced active learning approximately 47.5% of the time. Exam performances of two sections were compared against each other to assess the degree to which an increase in active learning promotes understanding and retention.

With regards to the types of active learning activities – a similar balance was employed for each section and for each of the three segments of the course. The instructor employed his typical approach as far as when to introduce the active learning exercises and to what extent (approximately 37.5% of the in-class time). The vast majority of in-class active learning involved problem solving - a commonly implemented active learning activity in engineering courses⁵. The in-class problems always immediately follow the lecture on that material. Typically, the problem would be introduced by the instructor and then the students would be told that they have 5-10 minutes (depending on the problem) to think through the problem, write down the correct equations and begin the solution/calculation process. The instructor is available to answer questions during this time. The instructor then concludes the exercise by presenting the entire solution to the class and answers follow-up questions. Typically, the solution is presented when a few of the more advanced students have completely solved the problem and performed all necessary calculations while the vast majority of the students have completed the problem set-up. The instructor believes that while students can benefit from being helped or listening to a peer explain his/her thinking with regards to the setup or solving of a problem, there can also be a tendency to be less engaged in a group atmosphere and just watch as others do the work. Furthermore, there

are additional benefits to individual problem-solving, in that students can work at their own speed and ask the instructor questions one-on-one. The instructor employs a mix of problems in-class that are mainly solved individually but occasionally in groups. In addition to problem solving, approximately one class period was dedicated to a demonstration on conduction and a computer simulation that helps the students to better understand the effects of chip geometry and flow on convective heat loss from circuit boards⁶.

Entrepreneurial tendencies were noted for individual students as they worked on group projects near the end of the semester. The students for both sections in the fall 2007 were mainly broken up into groups of four students. Each group was given the following exercise to complete:

*Your technical group has also been asked for a proposal from you on a new idea that takes advantage of their companies interest and expertise in the general area of heat transfer. They would like to partner with your consulting firm in the development of the project and therefore encourage you to propose an idea for a product that you are most interested in and believe has significant potential to solve an existing problem/improve an existing condition (i.e. global warming, cooling of electronics devices etc...) while either making money for or improving the public image of their company. You are asked to describe and defend the technical aspects, uniqueness and marketability (i.e. "patentability") of your proposed product, while also providing a very rough estimate of how many people will benefit from or purchase the new product worldwide (i.e. market size) in a 1-2 page proposal. Some ideas that are already in consideration include: 1.) new heat shield design or materials to minimize **convective** heat transfer for space vehicle reentry, 2.) **conductive** heat transfer networks for thermal-masking of land-roving reconnaissance vehicles, 3.) minimize **conductive** heat loss/gain through the walls and windows (and therefore improve temperature control) of low-income homes in desert regions utilizing low-cost available materials, 4.) utilize **convective** heat transfer to improve temperature control of low-income homes in tropical regions utilizing low-cost available materials/resources. You can choose one of these ideas, or one of your own. The technical focus for your idea should rely most heavily on **EITHER conduction or convection** (please indicate which in your writeup).*

This part of the project gives the students the opportunity to develop and utilize their entrepreneurial skills by: assessing other existing designs and understanding their limitations (i.e. cost, performance etc.), accessing patents, identifying experts in industry or academia and learning from them (i.e. by reviewing papers or communicating through phone or email etc.), and assessing the business market for such a new technology etc.

To prepare the student's for this part of the group project, the students were exposed to one lecture on new/novel conduction technologies at the end of the second segment of the course, and then the same on convection at the end of the third segment of the course. Both lectures were given by invited speakers who were experts in their fields,

and were seen at the same time by both sections. Both speakers noted the entrepreneurial efforts associated with the conception and development of the technology, as well as the characteristics (i.e. creativity, motivation etc.) of those responsible for the innovation. The first speaker discussed conductive heat transfer networks for thermal-masking of land-roving reconnaissance vehicles, and the second speaker discussed new heat shield designs and materials to minimize convective heat transfer for space vehicle reentry. The last 10-15 minutes of both of these class periods was an open forum for the students to ask questions of the invited speaker and comment on the state-of-the-art in the technology area presented by the guest speaker and to brainstorm with classmates on alternative approaches. The instructor promoted a classroom atmosphere that encouraged participation and creativity, where any ideas presented were greeted with respect and encouragement by the other students, the instructor and the guest speaker. Such an environment is conducive to the creation and/or development of entrepreneurs and entrepreneurial ideas⁷. Also, as a preparation for the group project, the students in both sections were also trained together briefly on using the US trademark office's official website (USPTO.org). This resource is useful in finding the nature and detail of new technology patents, including those dealing with heat transfer.

Results

Surveys for the fall 2007 and previous years indicated that with this instructor, the learning of the material in this heat transfer class is mainly due to in-class instruction, followed closely by homework problems and lastly by reading the text book. The survey results also indicate that the students in the class spend on average 1.1 and 3.6 hours per week reading the textbook and working on assigned homework problems respectively.

In-class time allocation

For the study, the instructor prepared a schedule before each class of the desired time allocation for the classroom activities. These activities included lecture and active learning exercises. The actual time allocated was noted immediately after each class by the instructor and then totaled for sections #1 and #2. This was done during each of the first three segments (Introduction, conduction and convection) of the course. In attempting to spend more time with one section on active learning than the other, at times the lectures were given faster, with some detail on peripheral points not elaborated on. The results for segments A and B are presented below in Table 1:

Table 1: Instructor-monitored allocation of in-class time for segments A (Introduction to Heat Transfer) and B (Conduction)

In-class Activity	Segment A: Sections #1 and #2	Segment B: Section #2 (more AL)	Segment B: Section #1 (less AL)
	%	%	%
Instructor - lecturing	57.0	47.0	67.0
Instructor - asking questions	7.5	9.0	6.0

Instructor - answering student questions	3.0	3.0	3.0
Students - setting up problems individually	13.8	19.0	8.5
Students - solving problems individually	3.8	5.0	2.5
Students - setting up problems in a group	5.5	7.0	4.0
Students - solving problems in a group	1.5	2.0	1.0
Students - involved in experimental demonstrations or computer simulation	4.0	4.0	4.0
Students - exploring through experiments/researching	4.0	4.0	4.0

Ten fewer minutes (i.e. 20% of the 50 minute class) were spent on lecture (i.e. 47% versus 67%) in the section (#1) receiving more active learning. The students in the section (#1) receiving more active learning spent most of this time working on problem solving. The same amount of time for both sections was spent on the last two activities (“demonstrations” and “exploring”), since the sections were combined for those days. A calculation was made to estimate that the actual (instructor-monitored) percentage of the class that the instructor spends for active learning. This active learning time was calculated as being: 100% minus one-half of the percentage of time spent by the instructor on lecture plus one half of the percentage of time spent answering or asking questions (since this activity can be student or instructor directed). Using the same calculation just described, the instructor spent less time (27.5%) with section #1 and more time (47.5 %) with section #2 on active learning during the conduction segment (segment B) of the course. A similar result occurred during the third course segment (segment C) on convection, except section # 2 received only 27.5% of classroom time on active learning and section #1 received more (47.5%) active learning. For segment A of the course, both sections 1 and 2 received approximately 37.5% in-class time dedicated to active learning activities.

Surveys were completed by the students followed segments A, B and C of the course during the fall 2007 semester. The purpose of the surveys was to assess whether the change in time spent on active learning was noticed by the students as being a significant change. The survey results are presented below in Table 2 again for segments A (introduction) and B (Conduction):

Table 2: student survey average results: allocation of in-class time for segments 1 (Introduction to Heat Transfer) and 2 (Conduction)

In-class Activity	Segment A: Sections #1 and #2	Segment B: Section #2 (more AL)	Segment B: Section #1 (less AL)
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<i>Section #1</i>	<i>%</i>	<i>%</i>	<i>%</i>
Instructor - lecturing	57.2	49.2	63.1
Instructor - asking questions	10.2	11.2	7.8
Instructor - answering student questions	6.6	8.1	6.4
Students - setting up problems individually	10.3	12.4	8.9
Students - solving problems individually	4.6	6.3	3.9
Students - setting up problems in a group	3.1	4.2	2.7
Students - solving problems in a group	1.0	1.5	0.9
Students - involved in experimental demonstrations or computer simulation	3.5	3.6	3.4
Students - exploring through experiments/researching	3.5	3.4	3.3

Interestingly, the results of the student survey (Table 2) show qualitative agreement with the instructors assessment (Table 1) of in-class time allocation. For example, section #2 noticed a decrease in lecture time from 57.2% during the first 2-3 week segment to 49.2% during the second (conduction) segment. This perceived change was only a slight underestimation of that noted by the instructor of 57.0 % to 47.0%, but did show that the students on average noticed a significant increase in AL. Similar results occurred during the third course segment on convection (segment C). These results do clearly indicate however that the students noticed a change in the amount of active learning used.

Assessment of understanding and retention

Exam performances of the two sections were compared against each other to assess the degree to which an increase in active learning promotes understanding and retention. The first exam covered segments A and B of the heat transfer course. In fact, the first question was based solely off of the introductory material presented in segment A, when the instructor used his standard instructional approach (37.5% AL). The second question on the exam was of similar weight and was based solely off of the conduction material from segment B, in which section #2 received 47.5% AL and section #1 received only 27.5% AL. The average score for first question on the first exam was 89.1 (± 10 %) for section #1 and 83.8% (± 10.6 %) for section #2, indicating a significant (5.3%) difference in the average performance of the two groups when the same teaching formula was employed. This result was consistent with the observed difference in the GPAs for the students in the two sections, with the students in section #1 having an average GPA that is 4.9% higher than the students in section #2. This difference in exam performance between the sections can also be expressed as a ratio of the average exam performance for section #2 divided by the average exam performance in section #1. This exam performance ratio was 0.94 for the first problem on the first exam. For the second

(conduction) problem on exam #1, the exam performance ratio was again 0.94, indicating that spending 47.5% of in-class time on active learning (section #1) versus 27.5% of the time did not seem to effect how the sections performed on average relative to each other. The results of the second exam were similar to this in that again the ratio of section #2 to section # 1 remained consistently at 0.94 (± 0.01) for all of the questions on the segment 2 (convection) course material. Together, the results from exams 1 and 2 indicate that the slight but significant increase/decrease (i.e. 10%) from the instructor's standard teaching approach (37.5% of in-class time on AL) did not seem to effect the degree to which the material was learned or understood as exhibited by performance on exams given immediately after the material was taught.

Four separate questions were posed on the final exam to test retention of the material that was presented during the semester. The first question was based solely off of the introductory material presented in segment A, when the instructor used his standard instructional approach (37.5% AL). This material was covered approximately 3.5 months before the final exam was administered. The second question on the final exam was based solely off of the conduction material from segment B, in which section #2 received 47.5% AL and section #1 received only 27.5% AL. This material was covered approximately 3 months before the final exam was administered. The third question on the final exam was based solely off of the conduction material from segment C, in which section #1 received 47.5% AL and section #2 received only 27.5% AL. This material was covered approximately 2 months before the final exam was administered. The fourth question was based solely off of the material presented in just prior (within a month) to the final exam, when the instructor again used his standard instructional approach (37.5% AL). The average scores for these final exam questions are presented in Table 3:

Table 3: Final exam performance

	Question 1 (introduction)	Question 2 (Conduction)	Question 3 (Convection)	Question 4 (Pre-final exam)
Section # 1	76.6	83.3	88.9	95.7
Section # 2	71.7	82.1	81.8	89.7
Performance ratio	0.94	0.99	0.92	0.94

The data in Table 3 indicates a trend in that the lowest scores were achieved on questions 1 and 2 which dealt with material covered at the beginning of the semester, and better scores were achieved for material covered closer to when the exam was given (i.e. questions 3 and 4). It is also again apparent (Table 3) that the average scores for section #1 were higher than section #2 for each of the final exam questions. In fact, the performance ratio of the scores for questions 1 and 4 were again 0.94, identical to what was noted previously for exams 1 and 2. Interestingly, the performance ratio for question # 2 of 0.99 was significantly different and greater than 0.94, and indicates nearly

comparable performance between the sections for the first time on any exam question all semester. In other words, without the additional active learning the average exam score for the conduction question on the final exam would have been (0.94×83.1) or 78.1 instead of that observed (82.1). This represents approximately one half of a letter grade improvement over the expected grade. This suggests that while understanding of the conduction material did not seem to be affected by increased time spent on active learning based on the results of exam #1, the students in section # 2 did seem to retain the conduction material better than those in section #1. The results from final exam question 3 seem to support this conclusion, to a lesser degree. The performance ratio on question 3 of 0.92 is slightly lower than the characteristic 0.94 ratio, indicating that perhaps the students from section #1 were better able to retain the convection material because they learned it via more active learning. It seems possible then that this ratio may have been even lower than 0.92, if the material had been covered further in the past, since a more significant change in the performance ratio (0.94 to 0.99) occurred with the conduction material which was covered earlier in the semester. These results do then suggest that spending approximately 20% more time on in-classroom active learning, at the expense of primarily traditional lecture time, does not result in improved understanding as evidenced by performance on exams given immediately after the material is taught. These results do however indicate that that spending 20% more time on in-classroom active learning, at the expense of primarily traditional lecture time can improve the retention of the material, especially if significant (3-4 months) of time has passed since the student was exposed to the material in the class room.

Assessment of Entrepreneurial tendencies

Entrepreneurial tendencies were noted for individual students as they worked on group projects near the end of the semester. The ideas presented by the twelve groups in the Fall of 2007 included the use of: geothermal energy to heat homes and provide steam for industry, solar energy to assist in the boiling/purification of water, novel nano-heat-fins to remove heat in electronic devices such as the X-box, straw as a low-cost home insulator and an alternative face-shield material in ski goggles to minimize fogging. Interestingly, none of the twelve groups chose to try to extend one of the two “new-technology” topics presented by the two guest speakers earlier in the semester. In fact, each group presented an original idea which contained specifics that were not discussed in class. Some of the better proposals showed *creativity* in the identification of a market need (i.e. the anti-fogging ski goggles, and the low-cost purification of water), while other proposals exhibited *creativity* in the specific selection of a material/technology that could be utilized to solve an existing problem (i.e. the use of straw as an available low-cost home insulator). Table 4 indicates how many of the twelve project proposals in the two sections contained elements demonstrating some *creative* entrepreneurial activities. Surprisingly, Table 4 indicates that a minority (5/12) of the proposals were in the same area (conduction or convection) in which they experienced more active learning instruction. The majority of ideas for both sections (i.e. 3/5 for section #1, and 4/7 for section #2) were in the area of conduction. Additional active learning in one specific technical area then may not generally cause the students to choose to act as an entrepreneurial in that same area.

Table 4: # of proposals demonstrating certain *creative* entrepreneurial activities

	Original idea	Technical area chosen (conduction or convection) is the same area in which additional AL instruction occurred	Identified a legitimate market need or technology application	Provided a smart specific choice of a new material or technology
# of proposals (out of 12)	12	5	11	7

In general, the proposals that were most novel and creative, tended to also be the proposals that were *well developed* and researched. In fact, the five top proposals came from the group of seven proposals identified in Table 4 as “providing a smart specific choice...”. These five proposals also in reasonable detail addressed three important activities in new technology commercialization⁸: 1.) identification of other existing ideas/designs from the literature or from a patent search, 2.) assessing the technical feasibility of proposed ideas through technical arguments or calculations, and 3.) defining the potential market (i.e. the number and type of potential customers) and product costs. For example, the group interested in tapping into geo-thermal energy researched and reported technical details on the best locations for this as well as required distances to run piping to the heat source and estimated temperatures. One group, proposing the use of straw as an inexpensive home insulator, researched and reported the price and availability of straw as well as the population of low-income families in the Midwest United States. Interestingly, three of the top four projects in section #2 were conduction based and two of the top three projects in section #1 were convection based. This result then seems to indicate that additional active learning in one specific technical area (i.e. conduction or convection) may stimulate some fraction of the students in that class to produce high quality entrepreneurial activity, well above that exhibited by the students working in areas where active learning was not used as extensively in instruction. The high quality activity being demonstrated by the students exhibiting both *creativity* and being *motivated to develop* new-technology ideas.

Conclusions

The results of this study suggest that spending approximately 20% more time on in-classroom active learning, at the expense of primarily traditional lecture time, does not result in improved understanding as evidenced by performance on exams given immediately after the material is taught. This is indicative of the active learning benefit reaching saturation at the approximate level of 25% of in-class time. In this study, section #2 received the additional active learning instruction while studying conduction (course segment B) and for the only time all semester matched the performance of section #1 for

a final exam question dealing with conduction. These results indicate that that spending 20% more time on in-classroom active learning, at the expense of primarily traditional lecture time can improve the retention of the material, especially if significant (3-4 months) of time has passed since the student was exposed to the material in the class room. The study also yielded some interesting results with regards to how active learning might promote entrepreneurial activity. The additional 20% of active learning in one specific technical area (i.e. conduction or convection) resulted in higher quality entrepreneurial activity, as compared to that exhibited by the students working in project areas where active learning was not used as extensively in instruction. The high quality activity exhibited by these group of students tended to include both *creativity* and *motivation with regards to the develop* new-technology ideas.

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