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Next-Generation Classroom Design at WPI

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![WPI logo]

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Abstract

Active learning (AL) is a teaching pedagogy that seeks to improve student engagement and performance in class. Currently, Worcester Polytechnic Institute has no classrooms designed for this style of teaching. We conducted interviews with WPI faculty and administration, along with other schools with successful AL initiatives, to investigate the feasibility of active learning classrooms. Ultimately, we developed specific recommendations for implementing AL spaces at WPI, along with strategies that would help to optimize their performance.

Executive Summary

Active learning (AL), a set of teaching techniques that seek to engage the student in the learning process, is becoming increasingly prevalent in college courses throughout the nation because it has been proven to improve students' grades, motivation, enthusiasm, and retention. Classroom design has been shown to have a significant impact on the learning benefits that can be achieved, with classrooms specifically designed for student engagement and group work showing the greatest benefits. WPI currently has no classrooms designed to facilitate AL; professors who wish to use AL techniques must make do with less than desirable environments. More than 250 schools across the country have already implemented ALCs, including Massachusetts Institute of Technology, Rensselaer Polytechnic Institute, and North Carolina State University. If WPI does the same, it will help the school stay competitive with other top-tier institutions in the nation.

Project Goal and Objectives

The goal of our project was to investigate the feasibility of implementing ALCs at WPI. In order to achieve this goal, we used these objectives:

1. **Assess the current climate of AL at WPI.** We conducted a survey directed at WPI faculty to assess the current level of AL use at WPI and the interest in AL in the future. We used the results of this survey to conduct interviews with 21 professors to learn about their AL techniques more in-depth and their perceptions of the pros and cons of WPI's current classrooms. We also interviewed members of the administration in the Academic Technology Center (ATC), Dean of Undergraduate Studies, Facilities, and Scheduling offices in order to identify what requirements they had for classrooms at WPI.

2. **Compose concepts and implementation strategies for ALCs at WPI by drawing on what we've learned from WPI stakeholders and what we have learned from other schools.** Rather than creating a full design, we focused on identifying constraints and

creating specifications for ALCs. Along with the administrators we mentioned above, we also talked to two experts in AL and ALCs from other universities. Put together, these guidelines should give Facilities a clear picture of how they need to go about designing and implementing ALCs.

3. **Perform an initial cost analysis of our design concepts in order to investigate their feasibility versus traditional lecture halls.** We did a basic cost analysis comparing the tables, whiteboards, and other basic classroom features. While this estimate can't fully account for the whole cost of the room, which may require significant work in other areas (such as HVAC or carpet replacement), it does compare the specific elements that make an ALC unique and thus allow us to compare the costs to more traditional rooms.

Summary of Findings

1. **WPI faculty already use many forms of AL.** Our survey of the WPI faculty received a very high response rate of nearly 40% (171 responses out of 440 total faculty). Out of these, 91% (151) said that they used some form of AL. In our survey we asked respondents to indicate which, if any, forms of AL they used. Student group-work and in-class problems were the most reported types of AL, with over three-quarters of respondents saying they used them. This shows that AL is already widespread among WPI faculty.

2. **Some WPI classrooms already meet AL needs, but there are improvements to be made.** A majority of professors who use AL in medium sized classes (40-60 students) said flexible classrooms such as SL305 work well for the AL they currently do. The reason those classrooms work is the furniture which is made up of easily movable tables and chairs. Unfortunately, this is not true for every classroom. In our survey, 76 respondents (50% of the teachers who use AL) said that changes to classroom design would help their use of AL techniques, while another 43 (28%) said it may help, depending on the change. Professors complained about seating density preventing group

work, the inflexibility of classroom spaces and fixed seating, and lack of technology that would facilitate AL.

3. **From the administrative perspective, the feasibility of ALCs is tied to how effectively they can be utilized.** WPI has been witnessing a gradual increase in student population (30% increase from 2008 through 2014). As a result, class sizes for certain courses and the number of courses have significantly increased. Through our interviews with administrators it became clear that it is advantageous for classrooms at WPI to be fully utilizable in order to support the growing number of courses offered as well as the different styles of teaching and learning. One thing to consider is that until there are enough teachers at the school who can effectively use AL to get the most out of an ALC, it is unlikely that it will be 100% utilized.

4. **ALCs need to be implemented in conjunction with support from administration.** Administration plays a key role in ensuring that new rooms can be used effectively. Only professors who are interested in AL and have learned how to effectively use ALCs should be scheduled for these rooms. There should also be support for faculty who use, or want to use, these rooms. This support has been accomplished at other schools in different ways. North Carolina State University brought in outside experts on AL to initially teach their professors how to use ALCs. Iowa State University has a very formal support system for professors using their ALCs, while the University of Indiana-Bloomington uses informal peer-to-peer support groups, similar to the Faculty Learning Groups that WPI currently has.

Summary of Recommendations

1. **We recommend that WPI create studio classroom spaces to promote AL.** These classrooms would be optimized for AL, rather than trying to make them suitable for both AL and lecture-based teaching. An example classroom layout is shown in Figure 1. The round tables allow students to easily collaborate with each other and also give easy access to the professor so they can observe student work and answer questions. Whiteboards

around the perimeter of the room give students ample space to work problems out in groups, while smaller whiteboard tablets allow them to solve quick problems at their tables.
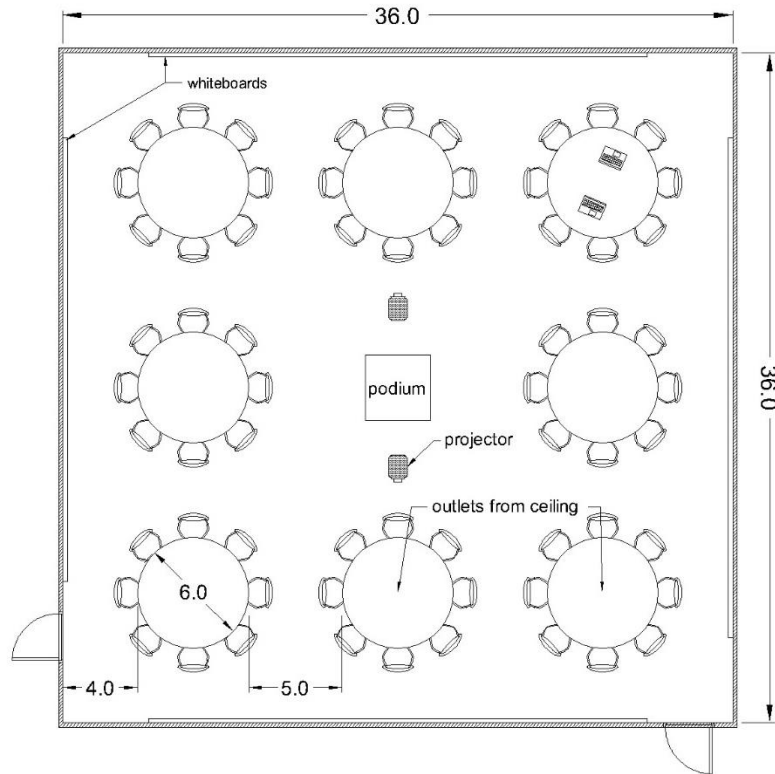

Figure 1. Studio concept applied to SL305

In order to ensure that these rooms can be effectively used we recommend that WPI bring in outside experts that can help train our teachers before the room is constructed. Teachers can also go and observe classes in a successful ALC at another school so they can see how the room should optimally be used first hand. After this initial training period our own faculty should be able to take over and help to spread AL and train new professors using our existing Faculty Learning Communities. This approach should enable the rooms to be effectively utilized immediately by drawing on the experience of teachers at other schools and help to offset the reduction in seating capacity that it will experience.

Our group has done some initial estimates on cost per square foot for construction of an ALC. The analysis accounted for the tables, chairs, whiteboards, and multiple

projectors with screens, as we were trying to focus specifically on parts of the room that are specific to AL. In order to easily compare the data we compared the furniture cost of current WPI classrooms with their active learning counterparts. We ultimately determined that the cost of a studio classroom layout is not much greater on average than the cost WPI's current classroom layouts. The only major difference would be the cost of providing more power outlets for students. These costs, however, can vary greatly from case to case depending on a few different factors. So it was impossible to come up with an all-encompassing cost. The outlets are also not a necessary part of our design.

2. **We recommend that WPI renovate one of our existing lecture halls into a hybrid lecture hall.** With two rows per tier Salisbury Labs 105, one of our smaller lecture halls with 60 seats, closely resembles the hybrid lecture halls at schools like Purdue. However, it requires a few small changes to make it a true hybrid. By removing the lip and modesty panel and extending the back table in each tier, shown in Figure 2, students could turn around and collaborate between rows. Adding a set of tablet whiteboards for student use would make group work even easier by giving students whiteboard surfaces that they can use at their tables. Running power for students under the tables would also help. Lastly, replacing the blackboards with whiteboards would increase contrast and allow for more color in teacher presentations. When put together these minor changes would allow a room that is well-suited for basic active learning activities without impacting its use as a traditional lecture hall in any way or reducing seating capacity. In order to ensure that it is being used at its full capacity, teachers who can use the AL nature of the room should be prioritized during room scheduling.
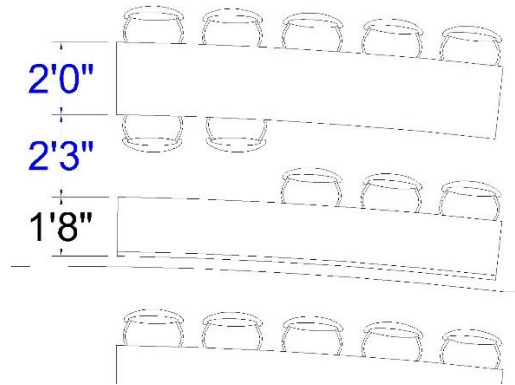
Figure 2. Detail view of recommended table changes in SL105

3. **We recommend that WPI implement a comprehensive course evaluation system incorporating multiple types of course observation and evaluation.** Different types of observation will provide various data that, when put together, can help to tweak classroom and course design to better optimize results. First, the course evaluation survey given at the end of classes should be expanded to gather feedback on classrooms. This will provide subjective information that, when coupled with feedback from teachers, will help determine how students feel about the room and teaching style. Second, objective data on student learning goals can be gathered by comparing test and course grades and by using subject matter competency exams. This will allow student learning to be effectively compared between AL and traditional courses. Lastly, direct observation of courses, using a calibrated observer with a system like COPUS, can give objective information on classroom activities and student interactions. We recommend that WPI have a number of observers trained to take classroom observations and start an extensive program of classroom observation in order to improve classrooms and course design. Together, these different approaches should significantly improve both AL and traditional classes in the long term.

4. **We recommend following the general suggestions for classroom renovation to promote the teaching and learning experience at WPI.** We have identified a number of renovation suggestions, such as adding more power outlets, using flexible furniture whenever possible, choosing whiteboards over blackboards, investigating compatible screen sharing technology, and maximizing the writable surface space when placing

projector screens. These are based on our research and interviews with other schools and if they were followed closely when WPI is renovating classrooms it would help to improve student engagement and learning experience, even in non-AL classes.

Authorship

Section	Major Contributors				Editors			
	AC	AM	KO	RS	AC	AM	KO	RS
Executive Summary		x			x	x	x	x
1.0 Introduction	x	x			x	x	x	x
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2.1 Important Terms in Active Learning				x		x	x	x
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3.2 Identifying Administration Needs & Interests	x				x	x	x	x
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4.1 Active Learning at WPI		x		x	x	x	x	x
4.2 Considerations for Active Learning Classrooms at WPI			x	x	x	x	x	x
4.3 Notable Active Learning Initiatives at Other Schools	x					x	x	x
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5.1 Studio Classrooms		x		x	x	x	x	x
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1.0 Introduction

Student engagement with material is vital to the learning process. In recognition of this, many colleges and universities are implementing active learning programs where students take an active role in the learning process. Over 250 colleges and universities have already implemented so-called "active learning classrooms" (ALCs) which are specifically designed to support the active learning (AL) process (NCSU SCALE-UP website). ALCs are designed to promote group-work and interactivity among students and between students and the professor. This stands in contrast to traditional lecture halls where professors simply lecture to the class. ALCs and teaching strategies have been shown to yield significantly better results than more traditional models by averaging grade improvements of about one standard deviation which is equivalent to a 7% grade boost on a traditional grade bell curve (Prince 2004.) They also have benefits for student motivation, enthusiasm, and retention, ultimately greatly improving the student learning experience.

Despite these benefits, WPI still has yet to implement any classrooms designed specifically for AL. Numerous professors at WPI have tried, to varying degrees of success, to integrate AL into their courses, but these efforts have been stymied by WPI's current classrooms, which are designed for traditional lecture teaching. Recently, the school has taken steps to make AL a more viable strategy such as the introduction of new technology and flexible furniture into existing rooms. However, these changes can only do so much to improve classrooms that are entirely teacher-focused and do little to encourage student engagement.

There are many reasons WPI has yet to implement ALCs. Student enrollment has swelled massively, with undergraduate population increasing by 30% (958 students) between 2008 and 2014, which has resulted in our classrooms and campus being filled to capacity (WPI Division of Enrollment Management, 2008, 2014). ALCs, however, generally have lower seating density than traditional rooms which makes it difficult to justify replacing one of our current rooms. ALCs are also poorly suited to traditional lecture classes and it is unclear whether we have enough professors using AL to fully utilize a room. Even if they were using AL already professors would likely need additional training and resources in order to effectively use the rooms given the significant differences between traditional classrooms and ALCs. Lastly, ALCs can be very expensive due to the large amount of renovation and technology that need to go into

them. These difficulties have made ALCs a daunting challenge for WPI administration and one that they have not chosen to tackle yet.

Some work has been done on improving classroom spaces at WPI. Last year, a team of WPI students used data gathered from students and faculty through surveys and interviews to identify areas of the classroom that could be improved to assist the teaching and learning experience. However, their main focus was on improving podiums, projectors, whiteboards, and other incremental improvements to existing spaces rather than large scale classroom design for the purpose of AL. There have also been discussions about putting studio classrooms into the Foisie Innovation Studio, a proposed renovation of the old WPI gymnasium. However, plans are still under development for this project and these classrooms wouldn't be implemented for several years at the earliest. More research work will be needed to determine the practicality of widespread use of ALCs at WPI.

In order to promote AL at WPI our project investigated the feasibility of alternative classroom spaces designed specifically for AL. We started by analyzing the needs of the WPI community through surveys and interviews with faculty and administration in order to determine what the community required in a classroom. From this, we created a set of design guidelines for our concept classroom. Then, drawing on information from other schools, we worked to create a concept design for a classroom. We analyzed our design to ensure that it met all of our design specifications and will be practical and useful for the WPI community. Ultimately, our project provides concrete suggestions on how WPI can implement AL spaces that will meet the needs of its faculty and administration.

2.0 Background and Literature Review

In this chapter we begin by defining the important terms used in our research. We then discuss the advantages of active learning (AL) and how it has been implemented at other universities followed by how other universities use modern classrooms to optimize AL. In conclusion, we will introduce classroom design at WPI and its need for AL.

2.1 Important Terms in Active Learning

This section will define each term used in our research and briefly explain their significance in the scope of modern education. However, AL and each of its variants do not have standardized definitions. For the purpose of this research paper we will be using the terms defined by Prince in his 2004 seminal study:

- **active learning (AL):** any instructional method that engages students in the learning process. Felder (2009) describes AL as anything course-related that all students in a class session are called upon to do other than simply watching, listening, and taking notes. In other words, it is a broad term that encompasses a few types of instructional methods and is often contrasted to lecture-style learning.
- **collaborative learning (CLL):** any instructional method in which students work together in small groups toward a common goal. Students are usually assessed as a group. Includes "think-pair-share" or "turn to your neighbor and discuss..." Students may work with partners in-class, but not in a team, throughout the course.
- **cooperative learning (CPL):** a more structured form of group work where students pursue common goals while being assessed individually. Typically students are put into teams to accomplish a long-term project.
- **problem-based learning (PBL):** an instructional method where relevant problems are introduced at the beginning of each class and used to provide context and motivation

2.2 Educational Benefits of Active Learning

Active learning (AL) covers a large variety of different teaching styles and techniques with significant overlap and many different variations. As a result, it is quite difficult to find evidence that consistently demonstrates benefits of AL as a whole rather than targeting a single implementation. In his seminal meta-analysis of large meta-studies on the subject, Michael Prince, a leader in research on AL in college classrooms, found consistent and significant increases in student grades, motivation, and engagement, regardless of the type of AL (Prince, 2004). This is impressive seeing as there has been relatively little impact on student performance with any other teaching style. Even changes as simple as introducing short breaks for discussion and reflection into lecture have been shown to raise quiz grades by around 8%.

In this section, we will discuss the benefits that two major forms of AL, collaborative/cooperative learning and problem-based learning, have to offer and what they need from classrooms to be most effective. Prince's work will serve as a base reference to compare the various types of AL. We will also review major case studies for each style and discuss what sort of requirements they have to be implemented effectively.

2.2.1 Collaborative/Cooperative Learning

In both collaborative and cooperative learning students work together to learn the material; the main difference is the scale. CLL is generally fairly informal and utilizes small groups, often pairs, while CPL employs larger groups. There are many different forms of both which can take place either solely outside of class (group homework) or by using group work in class during lecture. Both have similar class structures and require similar classroom considerations although they can differ significantly depending on how they are implemented. This section will discuss the effectiveness of the two strategies and review what elements of classrooms are necessary for effective implementation.

Research has consistently shown that both collaborative and cooperative learning are highly beneficial for students. The smallest effect size among the meta-studies that Prince analyzed showed grade boosts from the 50th to 70th percentile, equivalent to raising their grades from a 75% to an 81%, and lowered the attrition rate in technical programs (Prince, 2004). Cooperative learning has shown even larger benefits: raising grades from 75% to 85%. He observed effect weights of roughly 0.55 between four major meta-studies.

CPL/CLL has been shown to improve students' performance and satisfaction. Richard Felder, a professor of Chemical Engineering at North Carolina State University, studied his implementation of cooperative/collaborative learning to a group of students over a series of five classes (Felder, 1995). Most of the students continued through all of the classes. He mandated group homework for all the students and allowed them to form their own groups with 3-4 students (although he now recommends creating groups for the students.) He also used a wide variety of in-class group exercises which allowed him to judge the students' understanding and adjust his lessons appropriately. His classes overwhelmingly rated the mandatory group homework as beneficial with a 98% positive response rate. The response to in-class group-work was slightly more mixed but still impressive with a 78% positive response rate. Retention rate among the students was very high and there is anecdotal evidence of increased performance in other classes due to students collaborating even when it wasn't required. Grades were shifted heavily towards the higher side of the bell curve changing the median grade of the class from a C to a B.

MIT has also done detailed studies examining the benefits of AL in their Technology Enhanced AL (TEAL) classrooms. In a comparison between a lecture-based electromagnetics course and an AL-based course in a TEAL room, they identified significantly higher gains for students in the AL course (Dori, 2005). When doing AL, average students had an increase of 46% in the number of correct answers on a comprehension exam after the course than before. In contrast, the traditional lecture control had only a 26% increase. They also compared the effect of class size on the TEAL room's effectiveness by holding a smaller section over Fall 2001 (n=176) and a larger section during Spring 2003 (n=514). Students who usually do very well in class showed little variation in performance between small and large class sizes. However, low and intermediate performing students had much more significant increases in comprehension in the

smaller section with 51% and 55% increases respectively compared to 39% and 43% increases in the larger section. They do not discuss the cause, however.

Classroom Requirements

Each form of collaborative and cooperative learning has different classroom requirements. The collaborative group homework implemented by Felder doesn't require different classroom design since the collaboration is mainly outside of class. Instead, the main requirement is strong self-monitoring to ensure that the groups can effectively work together. In Felder's class, there was cooperative small-group work that was implemented successfully in a traditional lecture hall. Felder had his students solve simple problems, explain concepts, summarize what they had learned from the lecture, come up with questions, and help explain the lecture to each other (Felder, 1995). This was often as simple as students working with the person sitting next to them which is an easy way to introduce basic collaborative learning in a traditional classroom. Peer instruction, another form of collaborative learning pioneered by Eric Mazur, is easily implemented in standard lecture halls (Mazur Group, 2014). Students think about presented problems individually and then debate them in small groups with the people sitting next to them to reach a consensus. This can be used in practically any learning space and is very easy to work into traditional lectures.

This is not to say classroom design has no impact on AL; in-class collaborative learning can be affected significantly by the design of the classroom. A teacher at the University of Minnesota taught two sections of an introductory biology class in different classrooms in an attempt to gauge the effectiveness of ALCs (Cotner, 2013). This study directly compares the effects of collaborative learning between a traditional lecture hall and an AL studio classroom thus eliminating the uncertainty caused by comparing different classes or models for AL. The course curriculum, professor, and exercises were left the same between the two studies. However, observers noted that the teacher behaved differently in the ALC by spending less time lecturing and focusing more on guiding the class through group work. Students reported higher levels of engagement and satisfaction with the room. In the traditional lecture hall students performed roughly as predicted by their ACT scores, averaging 77.8% versus the predicted 78.5%. In contrast,

students in the studio classroom significantly outperformed expectations, averaging 76.5% instead of the expected 71.8%.

This increased performance is attributed to decentralization of the classroom which places greater accountability on the student for their AL experience. Since there is not a podium that all of the students face, traditional lecture is impossible so students must rely on the group learning in order to learn the material. Some of the authors' suggestions for other ways to decentralize classrooms include adding whiteboards for students to use and giving students wheeled chairs in order to allow students to move and form groups.

2.2.2 Problem-based Learning

Problem-based learning is a teaching/learning approach that relies on open-ended problems to provide opportunities for student learning (Wang, 2004). It uses guiding questions to frame the students learning in terms of a challenge to solve. PBL has a very complicated set of interactions that can significantly impact its effectiveness. This section will discuss the factors that must be taken into account for a successful implementation of PBL and any considerations necessary for classroom design.

Benefits

Problem-based learning is a broad form of AL with a wide variety of implementations (Prince, 2004). Prince broke it down into a variety of different types and also identified a number of different factors that contribute to how effective it can be, shown in Table 1.

Table 1. Effect sizes for academic achievement associated with various aspects of problem-based learning (Prince, 2004)	
Characteristic	**Effect Size**
Individualized	0.23
Cooperative	0.54
Small group	0.31
With non-expert tutors	-0.74
Self-paced	-0.07
Self-directed	-0.05
Using problems	0.20
Inquiry based	0.16
Instruction in problem solving	0.54
Inductive	0.06

There are a few major conclusions that can be drawn about AL from this data. One conclusion is that the base result of individual PBL has a positive effect with a weight of 0.23. However, this effect is much smaller than those of CPL/CLL. There is also a very large positive effect associated with educating the students about problem solving. Since the major focus of the class is the investigation of problems as the framework for learning objectives, it is beneficial to teach students proper problem solving techniques. The other notable takeaway is regarding teacher development: Tutors who are not experts in the field which they teach lack an intuitive understanding of the material so it is hard for them to train students to be active problem solvers.

Research shows that while the lack of structure in problem-based courses can be frustrating for students it also helps to build valuable problem solving skills. A two year case study at

University College Dublin investigated PBL's effects on students in a series of civil engineering courses (Ahern, 2010). In two major transportation courses they presented large, unguided problems to the students who worked in groups of five to seven to break down and analyze the problem. Work on the project was primarily in tutorials with facilitators available to guide the students. Third-year students were given one problem and fourth-year students were given two problems. Most of the 35 third-year students were also in the fourth-year study, although the fourth year class was larger by 15 students. The problems were deliberately above the students' level of knowledge so they had to perform independent research. After finishing the projects, students presented their work to the class in lieu of traditional evaluations.

Feedback from the students was limited but positive. Most students felt that while the lack of structure was frustrating it also helped them engage with the material and improved their research and teamwork skills. While they did not release data on grades they did note that students engaged better with the material in the PBL course than they had previously. They also noted a lack of well-trained facilitators which caused frustration in some of students. This result is consistent with Prince's data.

Improving students' research abilities was a major goal of the PBL exercises. Students initially relied too much on internet sources and didn't validate their quality. The fourth years repeated this for their first project, but improved significantly better on the second after receiving feedback. This shows that PBL exercises can be more useful when they are close enough together for students to build their skills.

Classroom Requirements

Similar to collaborative/cooperative learning problem-based learning doesn't necessarily require significantly different facilities than traditional lectures. In-class work could be limited solely to a lecture and individual problems which could be easily accomplished with a standard lecture hall. Engagement with the problem could be limited solely to homework and could be either individual or in groups. However, Prince found significant benefits to collaborative work in addition to the problem-based learning (Prince, 2004). While he doesn't break up studies based on

how the group-work is performed it is likely that it would also be more effective if held in an ALC similar to the standard collaborative study done by the University of Minnesota (Cotner, 2013).

When done in class, problem-based learning becomes much more dependent than standard collaborative learning on the integration of technology (Chang, 2012). Students need to be able to investigate the problem freely, which necessitates web access, computers available for student use, and power outlets that are accessible to students. Furthermore, since all the groups are engaged on the same major problem, it is very useful for different groups to be able to push their screens to each other or to the professor for feedback as well as have microphones so they can present to the class. This sort of technology enables class-wide collaboration rather than just group-wide collaboration and allows all the students in the class to compare and debate different solutions.

2.3 Technology and Infrastructure of Classrooms for Active Learning

With so much research supporting the use of active learning (AL) in class, universities and colleges throughout the US have attempted to foster AL environments in their classrooms over the past years. In this section we will begin by introducing studio classrooms, which are the most common type of ALCs found in most schools, and AL lecture halls at Purdue University. Then, we will provide general designs of these types of ALCs.

2.3.1 Studio Classrooms

Some of the pioneers in ALCs are North Carolina State University's (NCSU) Student-Centered AL Environment for Undergraduate Programs (SCALE-UP) classrooms and MIT's Technology Enabled AL (TEAL) classrooms, which are an adaptation of NCSU's classrooms. These classrooms are also known as studio classrooms because they incorporate cutting edge technology into the classrooms. Currently there are over 250 colleges and universities in the US that possess some adaptations of SCALE-UP classrooms. A google map picture in Figure 3 shows the current SCALE-UP sites in the US. Figure 4 shows a TEAL studio classroom at MIT.

Figure 3. A map showing the locations of SCALE-UP classroom in the US (Source: NCSU SCALE-UP website)

Figure 4. A TEAL classroom at MIT (Source: MIT iCampus website)

Infrastructure

An example of a SCALE-UP or studio classroom is shown in Figure 4. Generally in a studio classroom the instructor's station is located in the middle of the room so that he or she has easy access to any part of the room. Wide round tables, each of which has 6 to 9 chairs on castors, populate as much area of the class as possible while leaving ample space for the instructor to walk

around freely and engage with students. The surrounding walls are covered with projectors or 65 to 80 inch LCD monitors which can share both the instructor's computer screen and any of the students' laptop screens. Dry-erase surfaces are also provided for each table and are located on the walls adjacent to each table. After running some basic calculations on layouts from the University of Minnesota we found that their largest studio classroom has around 27 square feet per student, with over 100 seats.

Technology

Most schools have whiteboards for student use since they allow the students to easily collaborate and share work with each other. There are a few different approaches to this. Wall mounted whiteboards are the usual approach. Glass whiteboards are the nicest and erase very well, but are also expensive. More traditional whiteboards also work well, but are less durable. Some schools have even experimented with tables that are covered in white board material. Another way to allow students to share their work is with whiteboard tablets, like the University of Wisconsin Milwaukee does. There are racks on the side of the room with small, portable whiteboards that students can take. Students can then put their work back up on the rack for display. This system makes the classroom more flexible since students aren't limited to working at the wall or on a wheeled whiteboard. NCSU has found bathroom tiling sheet works well for improvising these whiteboard tablets and is very cheap (SCALE-UP website).

The number of classroom technology features equipped in the student tables may vary depending on the needs of the classroom and budgetary constraints of the individual schools. Many schools incorporate computers into the tables. Some schools, like Northern Michigan University, incorporate document cameras into the tables, although this is rare. Student tables in some studio classrooms may even be furnished with lab equipment depending on the course that will be taught in these rooms, like MIT's TEAL classrooms that hold Electromagnetism I courses and SCALE-UP classrooms in the Physics Department of Old Dominion University.

In August 2010, the University of Minnesota spent $69 million opening up the Science Teaching and Student Service (STSS) building that seats 1639 students. There are 17 classrooms, including 10 ALCs, each of which can accommodate between 27 and 126 individuals, one of which is shown in Figure 5. After the building was opened they conducted two comparison studies which were discussed in the Classroom Requirement section of Collaborative/Cooperative Learning. Observations concluded that the ALCs increased students' engagement in the learning process and helped students to outperform final grade expectations which resulted in greater learning outcomes. A third comparison study was also conducted to investigate the impact of the type of pedagogy used in the ALCs on student learning. A faculty member taught the same course twice in an ALC using the same course materials and assessments. The first course was delivered in a lecture-based style while the latter capitalized on the AL features of the room. The results showed that students in the second course outperformed those in the first ("Active Learning Classrooms", University of Minnesota).

Figure 5. An ALC at University of Minnesota

Similar to the studies conducted at the University of Minnesota, the assessments for TILE (Spaces to Transform, Interact, Learn, Engage) classrooms at the University of Iowa have also shown that students who took the same class in a TILE environment earned higher grades that those in a traditional classroom ("Assessing learning in a TILE classroom", 2013). For the TEAL

classrooms at MIT, studies have indicated that students who had previously taken classes in these rooms showed greater strive for academic performance and knowledge retention (Dori & Belcher, 2005).

2.3.2 Hybrid Lecture Halls

While studio classrooms are most suitable for AL on a small scale there is also the need for AL in large classrooms such as lecture halls. Also, since lecture halls have a sloped floor it would be very costly and difficult to transform these halls into studio classrooms that have flat floors and round tables. In an attempt to foster AL environment in large classrooms as lecture halls, Purdue University has created two types of collaborative lecture halls ("AL Center" Purdue University, 2013). Other universities have similar systems, like Northern Michigan University (Northern Michigan University).

Infrastructure

The first hall is for small teams (3-person), is 4500 square feet in size, and has 180 seats, which comes out to 25 square feet per student. As shown in Figure 6 below, Purdue's AL lecture halls have 60" wide tiers which are equipped with a series of partial-round 42" radius tables that serve teams of three students. Each table is 6" away from the next and mounted with power outlets below the desktop. Apart from these features this hall is very similar to a normal lecture hall with the instructor's station and a dual 16:10 projection screen in front of the room.
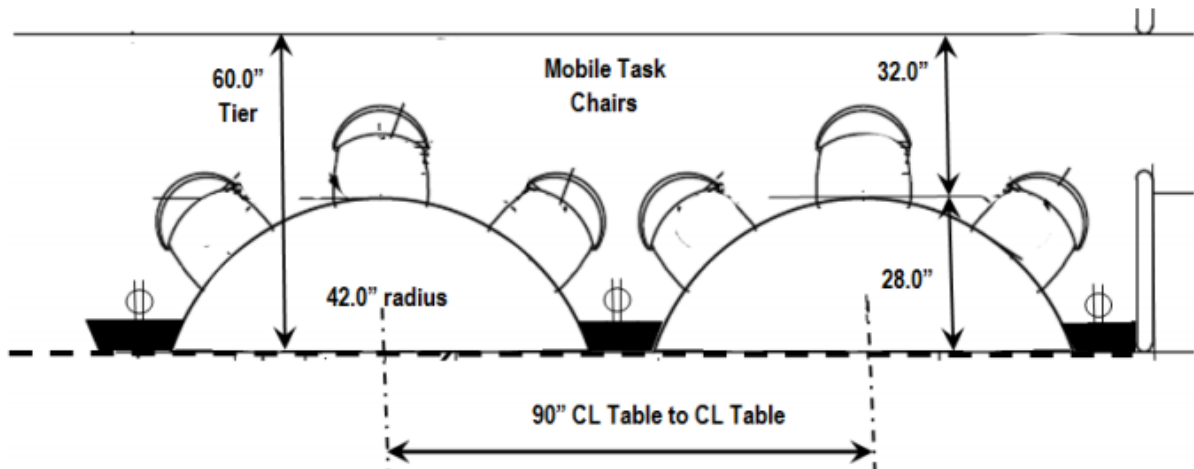
Figure 6. Collaborative lecture hall for small teams, Purdue University

The other type of collaborative lecture hall is dedicated towards large teamwork, has 120 seats, and is 3000 square feet in area, which comes out to 25 square feet per student. This hall is furnished with two rectangular shaped tables per tier as shown in Figure 7. All rows are straight and include a narrow front strip table, which is a minimum of 18" wide, and a wider rear collaborative table, which is 30" wide. These rows also include non-fixed swivel chairs which allow students to face the rear of the room and work in teams of any manageable size (4, 6, or even 8) at the wide collaborative table in collaborative mode and face forward at the narrow front strip tables in lecture mode. The front and rear tables are also identical in length and quantity of chairs to support 1:1 teamwork in addition to the formation of large teams.
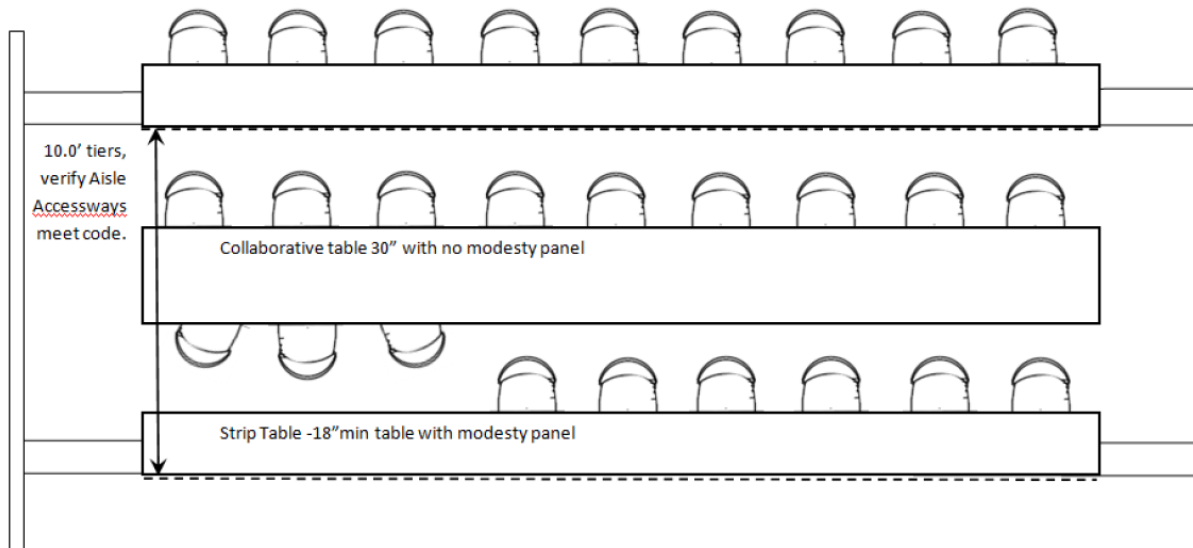
Figure 7. Collaborative lecture hall for large teams, Purdue University

Technology

In terms of classroom technology, these lecture halls closely resemble traditional lecture halls with one or more large projection screens and the instructor's station at the front of the hall. Unlike most WPI lecture halls where power outlets are located mainly in the side walls these halls are unique in the respect that every student table has power outlets below the desktop enabling easy access to the power outlets. These student tables also provide a Hearing Loop system, which allows a hearing aid user to better pick up the sound spoken from the instructor, and Student Response System (such as clickers). There are also microphones spaced out along the tables so that students can address the class to ask or answer questions.

Successful Implementations

These lecture hall designs were described in an academic program statement named "Active Learning Center" by Purdue University in 2013. Since this is relatively new no research data has been collected on these halls. However, these designs provide an excellent example of

how classrooms can be built or renovated to incorporate AL into traditional teaching and room styles, rather than fully replacing them.

2.4 Classroom Design at WPI

In this section we will introduce and categorize the different types of relevant learning spaces at WPI followed by an overview of how the current classroom renovation process works. Lastly, we will explain why AL is important in the context of WPI.

2.4.1 Types of Learning Spaces

There are two main types of learning spaces at WPI that we are going to focus our project on: lecture halls and classrooms. WPI has several different designs for both lecture halls and classrooms which we will categorize here. Generally, lecture halls tend to be more diverse than classrooms. The biggest type of lecture hall has fixed seating upon a tiered floor, as shown in Figure 8. Small tablet-style desks are attached to the arms of each chair. There is a chalkboard and one or two projector screens along with a podium for the lecturer at the front of the room. The other main type of lecture hall has curved tables set on a tiered floor facing the front of the room with chairs for students to sit in, as shown in Figure 9. These lecture halls tend to be smaller. Again, there are chalkboards, whiteboards, and projector screens at the front of the room along with a podium for the instructor.

Figure 8. AK 116, large lecture hall at WPI

Figure 9. AK 219, small lecture hall at WPI

All classrooms have the same basic design: movable furniture set facing a blackboard or whiteboard, projector screen and podium at the front of the room. The differences between classrooms are the size of the classroom and whether the classroom has personal desks as shown in Figure 10, or tables and chairs for students as shown in Figure 11.

Figure 10. A classroom in Olin Hall with personal tablet-style chairs

Figure 11. A classroom in Salisbury Labs with movable tables and chairs

2.4.2 Current Renovation Process

There is not currently a strategic plan in place for classroom renovations. Rather, most improvements are condition driven. (C. Salter, personal communications, September 4, 2014). The Facilities Department is in charge of all renovations, maintenance, or improvements. Aesthetic improvements such as new paint or carpets are done as needed based on visual inspection. The facilities department relies on faculty and student feedback to point them towards rooms that need these aesthetic improvements. These improvements can usually be done quickly during break or other times when the room is not in use.

Large-scale renovation projects are a joint venture of the facilities department, architectural design firms, and outside contractors. The facilities department coordinates the work of all three entities. After deciding which room will be receiving renovations they partner with a design firm to draw up plans for the new room.

These in-depth renovations take a significantly longer amount of time than aesthetic improvements and also carry a higher price tag. As a result they are much less frequent than technological or aesthetic renovations. First of all, since class sizes at WPI have been growing in recent years with no increase in learning space, classrooms are getting more and more use each year. Taking even one room out of commission for an extended amount of time greatly increases the strain on other rooms. Secondly, getting the money for these renovations is not guaranteed. The Facilities Department has to use most of their allotted budget just on maintenance to keep classrooms functional; they have very little room in their budget for full-scale renovations. As a result, smaller rooms become candidates for renovation. If they are out of commission during the school year it is much easier to relocate a small class than a large one. Also, due to their size, renovations to small rooms are typically cheaper and quicker. Even though smaller classrooms are more likely to be renovated they are not immune to budgetary constraints.

One possible solution to this problem is through gifts or donations to the school. For example, Goddard Hall recently received renovations because of a large gift given to the school for that purpose. However, not every room in the building was renovated. Most people would assume Goddard Hall doesn't need any more renovations. However, to someone with more knowledge of the situation, such as the Facilities Department, it is clear that the remaining rooms need renovation. Without the public perception that they need renovation it is hard to raise the capital to perform those renovations.

Upgrading technology is a more regimented process with each room being updated with the most recent technology every four to six years. The decision on what technology to implement in classrooms rests with the ATC. Some of the technology they currently employ in classrooms is lecture capture cameras, digital pens, computers and projectors, document cameras, and clickers.

2.4.3 Why Active Learning Spaces at WPI?

WPI would greatly benefit from the addition of AL based classrooms. As previously stated, research demonstrates that ALCs are beneficial to student engagement and proficiency. There is also additional data that shows that the WPI community both wants and could use ALCs as there are currently no classrooms on campus that can provide the same environment.

Last year an IQP team similarly focused their project on improving the learning spaces at WPI. They chose to do so by making suggestions to the ATC about "improving the implementation of classroom technology and improving the design of the podiums" (Alwash, Grills, Hinrichs, & Wasserman, 2014). They conducted surveys and interviews of professors and also surveyed the student body. Upon completion of their project, their two main recommendations were to change the teacher's podium design in order to create more space on the podium and to move projector screens in order to maximize space on the blackboard.

They also had one question about AL studio classrooms in their survey. They showed the respondents a picture of a studio classroom at the University of Iowa and asked the respondent to gauge their interest on a scale of very interested, somewhat interested, not interested, or no preference. Sixty-three percent of professors responded either very interested or somewhat interested. Eighty-two percent of students gave the same answer to that question. This question was not directly related to their project; they just wanted to gauge the interest of the WPI community. They provided a recommendation that some classrooms at WPI should be converted into studio classrooms, but did not elaborate further on how to go about those renovations (Alwash et al, 2014).

The National Survey of Student Engagement (NSSE), a national benchmarking instrument, shows that WPI would benefit from efforts to enhance AL although we are comparable to or ahead of many institutions in several academic categories. The NSSE attempts to evaluate two critical features of collegiate quality. The first is the amount of time and effort students put into their studies and other educationally purposeful activities. The second is how the institution deploys its resources and organizes the curriculum and other learning opportunities to get students to participate in activities that decades of research studies show are linked to student learning (NSSE, 2014). The benchmark comparison results compare one institution, in this case WPI, to the mean of all other institutions in the study. In 2009, WPI was rated about equal or slightly above the top 10% of schools in the categories of "Level of Academic Challenge" and "Enriching Educational Experience". However, it was rated lower than the top 50% of schools in active and collaborative learning. This suggests that WPI is among the leaders in some forms of education, but does not come close to competing with the leading schools out there in terms of active and collaborative learning.

3.0 Methodology

The goal of this project was to provide feasible recommendations for active learning classrooms (ALC) design at WPI. We planned to translate the needs of the WPI community into tangible recommendations for ALC design. We decided that the most effective way to achieve this goal was to seek general feedback from the WPI community at large and to solicit more in-depth information from those with a thorough knowledge of the subject. We split our population of interest into several different groups because we wanted to gather different data from each group and the information each could provide was unique to their role at WPI. The following is a list of objectives we set in order to accomplish our goal:

1. **Assess the current climate of AL at WPI.** We conducted a survey directed at WPI faculty to assess the current level of AL use at WPI and the interest in AL in the future. We used the results of this survey to conduct interviews with 21 professors to learn about their AL techniques more in-depth and their perceptions of the advantages and disadvantages of WPI's current classrooms. We also interviewed members of the administration in the Academic Technology Center, Dean of Undergraduate Studies, Facilities, and Scheduling offices in order to identify what requirements they had for classrooms at WPI.

2. **Compose concepts and implementation strategies for ALCs at WPI by drawing on what we've learned from WPI stakeholders and what we have learned from other schools.** Rather than creating a full design, we focused on identifying constraints and creating specifications for ALCs. Along with the administrators we mentioned above, we also talked to two experts in AL and ALCs from other universities. Put together, these specifications should give the Facilities Department a good idea of how they need to go about designing and implementing an ALC.

3. **Perform an initial cost analysis of our design concepts in order to investigate their feasibility versus traditional lecture halls.** We did a basic cost analysis comparing the tables, whiteboards, and other basic classroom features. While this estimate can't fully

account for the whole cost of the room, which may require significant work in other areas (such as HVAC or carpet replacement), it does compare the specific elements that make an ALC unique and thus allows us to compare the costs to more traditional rooms.

Before we could collect any information from WPI faculty or administration we had to be approved for exemption from the IRB (Institutional Review Board). Our methods were appropriate for exemption because we are only releasing data that will specifically impact our classroom design. Names will not be associated with any responses in our report without explicit permission. We stated that subjects would be given the option to provide contact information in the survey but it was not required. We filled out a form describing our project and our intent for each data gathering method and attached a copy of our methodology. The IRB approved our methods for exemption and we were free to begin sampling the WPI faculty and administration.

3.1 Identifying Faculty Needs & Interests

The faculty of WPI are major stakeholders in our project because they are ultimately the ones who will be teaching and designing their courses in these classrooms if they are created. Faculty also have a considerable amount of influence on renovation decisions around campus, according to Chris Salter of the Facilities Department at WPI. We wanted to make sure the faculty's voice was heard so we created a structured approach to our objectives. Thus our data-gathering was guided by the following research questions:

a) How many faculty members are interested in utilizing AL spaces?
b) Is the effectiveness of AL based courses limited by the current classrooms and what kinds of new classroom features would help?
c) What technology is desired by faculty?
d) What type of classroom layout is desired by faculty?

To properly sample the faculty about these questions, we decided to split our data-gathering into two parts. The first part was a general survey to capture a small amount of information from a broad range of faculty and the second was a series of targeted interviews to capture a large amount of information from a small subpopulation of faculty.

3.1.1 Faculty Survey

The first step in identifying the needs and interests of WPI's faculty was to conduct a general survey. The survey we conducted had two specific objectives. The primary objective was to identify who uses AL. This was an important objective because it would give us a pool of faculty we could choose from to interview later on. The secondary objective was to find out how many faculty are interested in ALCs. This was an important objective from an argumentative standpoint because it is an effective way to express the demand for ALCs at WPI.

The first objective, identifying who uses AL, was achieved by asking two very simple questions. The first question asked whether faculty used AL currently in class. We included the brief definition of AL we displayed in the Important Terms section of the Background chapter to avoid any confusion. If they responded 'yes' they were directed to a question that asked which kinds of AL they use. There were a handful of options with descriptions next to each to avoid confusion. After checking off all that applied and answering a couple other questions the respondents were directed to a page where they were encouraged to leave their contact information so they could be contacted for an interview. This objective helped us later on with our faculty interviews. The survey can be found in Appendix A.

The second objective, finding out how many faculty are interested in AL, was also achieved by the same question at the beginning of the survey. All the faculty that responded saying they were either currently using AL or were interested in using it in the future were counted towards this number. We even gave them the option of specifying under what circumstance they would use AL, if they weren't already.

We chose a survey as our method of gathering this information because it would provide quantitative data that is well-organized and ready for analysis. We used Qualtrics to make and

administer our survey to all WPI faculty via email. We were able to extract a spreadsheet of all the WPI faculty emails from the online directory and use Qualtrics to send out personalized emails to each faculty containing an individual link to our survey. We sent out our survey emails at 6:00am on a Monday because we thought it would increase the chances of the professors seeing it in their inboxes and that they would have a few spare minutes to fill it out. We also set up Qualtrics to automatically send out reminder emails to those who hadn't yet filled out the surveys after one week. The advantage of surveying faculty before interviewing them was that we could use the results to make our interview questions more targeted toward each specific professor. For instance, if a particular professor indicated that they use PBL but not CPL we would adapt our interview questions to explore their reasoning behind this.

There are advantages as well as disadvantages to our approach. One downside is that since it was a voluntary response survey there was probably reporting bias. Due to the voluntary nature of the survey, it likely oversampled subjects who had strong opinions about the topic and under-sampled subjects who did not (Smith, 2012). Due to this, we cannot make any accurate broad or sweeping claims about the amount of WPI faculty using AL methods; however, this was not the main purpose of our survey. One factor of our survey that worked strongly to our advantage was a very high response rate of about 37% (171 out of 440 faculty in the sample). Since it only consisted of three questions, faculty probably did not feel inconvenienced by taking our survey. Any non-responses were only likely due to a faculty not seeing the email or bothering to open it. Some could have felt uncomfortable leaving their name linked with their responses. However, in our survey professors had a choice to give their names if they want to be contacted for further research; it was not required and wouldn't be reported with the final results. Our survey was also unbiased in the sense that each faculty member had an equal opportunity to participate because it was sent out to all of them at the same time. The sample was independent because the participation and response of each unit was not affected by the participation or response of other units (Smith, 2012). In conclusion, our survey performed very well in accomplishing our objectives.

3.1.2 Faculty Interviews

Our next step in identifying the needs of WPI faculty was using the results of our survey and other data collection methods to conduct targeted interviews. The content we explored in these interviews included but was not limited to specifics on how professors implement AL, any difficulties they encounter (through current classroom design specifically), and any ideas the faculty may have about improvements of WPI classrooms. All the information we sought through these interviews was qualitative as we had already captured all the quantitative data we needed from our surveys. We understood that the professors were busy so we did not want to waste time with unnecessary questions.

Of the 115 faculty who said they use AL, 66 left their contact information for interviews. We knew that there was no way we could possibly interview 66 faculty members in a short span of six weeks so we sent about 30 of them emails with links to an online scheduling program called Acuity Scheduling while also informing them that the interviews would not exceed 30 minutes. Our target sub-population was faculty who use AL in class. Intentionally selecting the subjects of our interviews made this a purposeful sampling method. It was effective for our purposes at this stage because we were interested in gathering information on and capturing the voice of a particular sub-population (faculty who practice AL) rather than the voice of the entire faculty population (Maxwell, 2008). As mentioned before, we chose to use a form of diversity sampling. This type of sampling involves intentionally selecting a diverse range of subjects to capture a wide range of views (Smith, 2012). This means that since there were too many professors for us to interview, we used the survey results to select a diverse range of professors to interview. For example, we chose to interview an equal number of professors from each department. We scheduled an interview with each professor who indicated they practiced some sort of AL in class; more specifically targeting the faculty that said they use AL very often.

The Acuity scheduler allowed the professors to sign up for time-slots during the day and made sure none of them got double-booked. This tool was very simple for professors to use and saved us a lot of scheduling difficulties. We also made an Outlook event for each interview and sent a confirmation email to each professor. About a week later we sent out the Acuity scheduler to an additional 20 faculty members who seemed to us like they had good information to share

based on their survey responses. In the end we were able to interview 20 in person and supplemented this with five online interviews. These online interviews were just another survey we made using Qualtrics that had all of our interview questions on them with open-response boxes underneath them. The online interviews helped us sample faculty who weren't able to meet due to time constraints or were off-campus for the term.

We felt that interviews were the best way to capture this information because there was opportunity to ask more in-depth and open-ended questions, ask follow up questions, and get clarification. The questions we asked each individual professor were often tailored to them given their responses on the survey. This helped us save time and focus on the opinions and knowledge of each professor. The interviews were semi-structured and consisted of five open-ended questions. The interview protocols can be found in Appendix A. Semi-structured interviews allow the interviewers to follow topical trajectories in the conversation that may stray from the predetermined list of questions. This flexibility gave professors freedom to talk more in-depth about the particular aspects of AL which they know best. We had two interviewers present so that they could both think of additional questions and ask for clarification when needed. The pair of interviewers were free to ask more targeted follow-up questions when desired. As we did not have much experience in interviewing we felt it was best to work in pairs. One interviewer would be in charge of asking questions and the other in charge of note-taking.

In order to analyze the interviews, we identified a number of items that came up commonly and counted how many professors mentioned them. This qualitative analysis is known as text analysis and used commonly for data analyzing for open-ended surveys and interviews (Ten Kleij and Musters 2003). Because our interview questions were open-ended, emerging patterns and themes were detected by the number of the common elements that were mentioned by professors. This included requested design elements, common complaints about the existing rooms, and different types of AL that professors used.

3.2 Identifying Administration Needs & Constraints

The administrators of WPI are major stakeholders in our project because they are ultimately the ones who will carry out the implementation of our concept classroom and all the work required along the way. Like faculty, administrators also have a huge influence on renovation decisions around campus. The administration knows all the obstacles and constraints that we may encounter in achieving our goal so we wanted to make sure we captured all the information they had to give. We set out the following research questions to make sure our information gathering was thorough and structured:

- What are the utilization requirements of WPI classrooms?
- What are the capacity requirements?
- How flexible must classrooms be in order to accommodate other styles of teaching?
- Are there any other obstacles involved in classroom renovations?

To identify any administration needs and constraints that lie in our way, we interviewed administrators from each WPI organization involved in classroom planning and design: the WPI Facilities Department, Administrator of Academic Programs Charles Kornik, Academic Scheduler Cathy Battelle, Dean of Undergraduate Studies Art Heinricher and the Academic Technology Center.

Through interviews we learned more about the effect of the growing student population at WPI and how it will affect classrooms in the near future. Lecture-style classrooms are more efficient than studio classrooms in terms of seating density so the seating requirement of the classrooms may prove to be a very limiting factor to our design options.

Another foreseeable requirement was classroom flexibility. In other words, how extreme can our renovations be? If we renovate a classroom to suit AL methods of teaching, does it also have to be suitable for old-school, front-facing lectures? Through our interviews with Charles Kornik and Cathy Battelle, who are academic schedulers at WPI, we acquired an idea of how

classrooms are used around campus. They provided us with valuable information on this but we also consulted the Facilities Department.

These are research questions targeted at the WPI Facilities Department. These were mostly concerning classroom design and design process. The rest of this section details the process we used to come up with answers to these questions.

a) What are the constraints on the renovation and construction of classrooms?
b) How would our recommendations for ALCs fit into the plans for future renovation or construction of classrooms?

We interviewed members of the Facilities Department in order to determine what the limiting factors of classroom renovation and construction are. In addition to financial limitations we wanted to find out what else could be a factor such as the length of the renovation or the procurement and adaptation of new technology. We also wanted to discover how our design could potentially fit into WPI's classroom planning process. Most of those concerns apply to both renovation and construction but there were also concerns specifically regarding construction. The greatest concern is that WPI simply doesn't have the available space to build new classrooms.

To investigate the classroom design process at WPI, our group met with Alfredo DiMauro, the Assistant Vice President of Facilities Operations at WPI. We discussed what they would need from a classroom design in order to get a better idea of what our project deliverable should be. Additionally, we discussed some of the plans for the Robert A. Foisie '56 Innovation Studio, a proposed renovation to the old WPI gym. There are plans to put a large studio classroom space in this new space. However, the plans for this building are very tenuous right now. Lastly, we talked about how cost estimates should be done in order to get a good initial idea of the cost of the room relative to other classrooms. We also got classroom blueprints from the facilities department which we used to better calculate the space available in current WPI classrooms.

We chose interviews as our method of gathering this information because it allowed us to get all the details of each research question. Since we were gathering more factual information rather than opinionated, we did not need to use any statistical data gathering methods like a random

survey. The only concerns were what constraints and obstacles we may encounter through our design process. These interviews were much less structured than the interviews we conducted with the faculty because the classroom design constraints of WPI were really quite foreign to us so it was hard to make many specific questions. These interviews mostly consisted of us asking a couple of very open-ended questions and the administrator telling us everything there is to know about their specific role in classroom design. Since we spoke in person to the administrators and were far from experts on this topic, we hoped they would tell us a few more constraints that we hadn't even thought of yet. Our interview questions and protocols can be found in the Appendix B. Ultimately the information gathered from these interviews will help us keep our design concept realistic and tangible within the constraints of WPI.

3.3 Consulting Other Schools

The following are research questions that we asked other schools in order to learn more about their AL experiences.

- **What were the needs they identified for their classrooms?** We can compare this with the list of needs that we have identified to see how their classroom design may or may not meet WPI's needs.
- **How did they try to go from their needs to a concrete design for their classrooms?** WPI doesn't have a formal design procedure that we can follow in creating our concept and it would be very useful to see how other schools do classroom design (C. Salter, personal communication, September 4, 2014).
- **What decisions did they make in order to meet those needs?** What sort of technology and layouts did they use? Identifying specific solutions that they employed will give us a good starting point for coming up with design concepts for WPI.
- **How are the classrooms employed?** Have there been any difficulties getting proper utilization or performance out of them? Were there any issues that have come up with the classrooms and how have they dealt with them? What sort of metrics and evaluation systems do they use to figure out how they can improve the rooms?

When choosing schools to investigate we prioritized schools with major initiatives to implement AL, rather than just using it in a single classroom, since they'd have a more structured approach to classroom design and could provide more useful input. We identified these schools based on our background research and picked schools that had done significant amounts of research or had otherwise pioneered ALCs. We also got suggestions for other schools to contact from University of Indiana Bloomington and NCSU. Overall we tried to talk to a large variety of different schools that approached AL in different ways. Table 2 shows a list of the schools and people we contacted.

Table 2. Contacts at other schools		
School	Contact	Reason Chosen
Northern Carolina State University	Robert Beichner (faculty)	Founded the SCALE-UP program
University of Indiana Bloomington	Beverly Teach (Mgr, Learning Environments & Technology Services) Julie Bohnenkamp (Director of Learning Spaces) Greg Siering (Director of Center for Innovative Teaching and Learning)	Major initiative to install ALCs across campus
University of Minnesota	Jeremy Todd (Director, Office of Classroom Management)	Recommended by UI Bloomington
Massachusetts Institute of Technology	Peter Dormashkin (faculty)	Made some of the first technology-focused ALCs. Also close enough that we could visit
Purdue University	Tomalee Doan (Head, HSSEB Division)	Has AL lecture halls, recommended by UIB
University of Iowa	Jean Florman (Director, Center for Teaching)	Recommended by NCSU for their faculty development programs

Ultimately the most responsive were NCSU and UI-Bloomington. We had phone interviews with Robert Beichner and Greg Siering. We continued contact over the last term of our project and got further feedback. Other schools were less forthcoming, but still willing to help. University of Iowa and University of Minnesota both gave us information about their classrooms, although we didn't have interviews with them. We followed up with some more specific questions during the last term of our project as they came up.

Our interview protocols and results for these contacts can be found in Appendix C. We left them as open ended as possible, since one of our goals here was to identify things that we didn't know already and find out what they had found to be important while they were implementing ALCs.

3.4 Creating Concept Classrooms

The purpose of this objective was to create an outline for a concept classroom, based on those used by other schools, which we can apply to any of WPI's classrooms. This serves several purposes. It allows us to make concrete recommendations for classroom redesign without having to compose a full design and layout for every possible classroom. Secondly, it provides a model for classroom design that may be done in the future. Since our concept will be adjustable, it's not tied to any specific room; any future classrooms can use it as a guideline for a more specific design.

3.4.1 Classroom Features and Furniture

The most prominent part of any classroom is the furniture occupying it. In most cases the furniture is what distinguishes one classroom from another. We deliberated on what kind of furniture and other features our concept classrooms should have based mostly on designs that other schools had done. Through interviews with experts with other schools we learned what types of classroom designs had been successful and used similar furniture and features in our concepts.

The following items were our main considerations when choosing what kinds of furniture and classroom features to recommend.

> **Tables:** We spoke to Robert Beichner of NCSU who is an expert in active learning and studio classroom design. We also considered input from WPI faculty about what group sizes they typically use in their collaborative in-class activities.

Chairs: Robert Beichner of NCSU was also our primary resource here. The WPI Facilities Department stressed cost reduction which steered us toward using chairs that WPI already has on campus which fit the constraints given by Beichner.

Podiums: The placement of the teachers' podiums was largely influenced by Robert Beichner of NCSU. Our project was not necessarily concerned on the specifics of the podiums as last year's IQP was primarily focused on their design. However, we did receive very insightful feedback from Prof. Elisabeth Stoddard of WPI about how to optimize the podiums for studio classrooms specifically.

Whiteboards/Blackboards: WPI faculty were our main reason for recommending whiteboards over blackboards. The SCALE-UP classrooms designed by Robert Beichner featured extensive implementation of them which we included into our design. The tablet whiteboard idea was also directly from NCSU's SCALE-UP design.

3.4.2 Classroom Technology

Technology in the classroom is also important, especially in state of the art classrooms such as the ones we are recommending. Our aim in this section was to identify what sorts of technology WPI would be best served by. We took the technologies most commonly suggested by WPI faculty and evaluated them against our background research and information we've gathered from other schools in order to figure out how effective these technologies are.

The following items were our primary focus when we deliberated on the best technology to implement in these classrooms.

Software: In our interviews we faculty we talked about what software or other computer technologies would be able to help them with active learning techniques. We talked to the ATC about what has already been implemented, what they are planning on implementing, and what they've tried that doesn't work.

Computers: The main deliberation we had about computers was whether the school should furnish each room with computers or whether students should supply their own. We talked

to a few schools who use each method as well as discussing the realities at how each would work at WPI.

Microphones/sound dampening: In our interviews with NCSU and IU-B we discussed how noise affects an active learning classroom in both a positive and negative way. We discussed when microphones are necessary and when they are not and the best ways to implement sound dampening in noisy rooms.

Projectors/displays: In our meeting with the ATC we discussed the price and issues associated with installing projectors as well as deliberating about how many projectors would be appropriate. We also weighed the advantages and disadvantages of projecting onto a dedicated screen or onto a whiteboard.

Power outlets/internet connectivity: In order to effectively use computers there needs to be power and a connection to the internet. We discussed with the ATC and the Facilities Department the difficulties associated with installing extra power outlets and ethernet ports and talked about the advantages and disadvantages of wired internet connectivity versus Wi-Fi.

3.4.3 Providing Concept Classroom Recommendations

Identifying the type of classroom to design was the last step before composing the actual concept design. At that point we already had information from faculty and administration at WPI on what they want from an ALC as well as suggestions and input from other schools on what has worked for them and how they went around implementing it. Additionally, we had already identified what kinds of furniture, features, and technology would work best in our concept classrooms based on that information. We then integrated all that information, identified specific forms of classrooms that would be best for WPI's needs, and created a more detailed concept for what an ALC at WPI could look like.

Our aim when making this concept was not to produce an exhaustive, detailed design for a single room. Instead, we made a rough outline of goals, general guidelines, and modular layouts that can be applied to a wide variety of classrooms. We provided a set of design principles and

goals that clearly established what a detailed design needed to take into account as well as modular sketches and layouts. Additionally, we applied these design guidelines to several actual WPI classrooms to show how an ALC could work at WPI if a classroom was renovated according to our recommendations.

3.5 Conducting Cost, Benefit, and Utilization Analysis

The next step we took after we composed a design concept for ALCs was to analyze the implementation issues of this concept and the potential benefits it will contribute to the learning environment at WPI.

3.5.1 Cost Analysis

To estimate the cost of potential renovations per our design concept, we had to first gather information about the furniture and other features we planned on adding to the room. The Facilities Department provided us information about the cost of some recent classroom renovations on campus. We were able to find the prices of the tablet arm chairs used in Olin Hall classrooms on the internet. Our design concepts were created using AL furniture we found online from major companies like SteelCase and Smith Systems so the prices were readily available. We input these prices into a spreadsheet to compile the total cost required to realize our design concepts in select rooms around campus. Using our data we were able to compare the cost of the current classroom configurations to the cost of our design concept. Our ultimate costs did not include labor as we could not find any information on it, but the labor involved in implementing our design concept would likely be the same as with any of the current classroom configurations.

After coming up with cost estimates we were able to determine how well each of the classrooms will fulfill our requirements and the needs of the faculty and administration, including size, location, seating capacity, utilization, and flexibility.

3.5.2 Benefit Analysis

It is difficult to predict the benefits that a certain room design will provide in advance as it depends very heavily on the way that the room is used. As such, we laid out expectations for the benefits of the rooms by interviewing faculty who will teach in them and getting their perspective on how the rooms will help them. This helps to prove that the classrooms will be a boon to WPI, providing further support for their construction.

However, it is also important to ensure that we have an effective way of measuring these benefits. As we learned from other schools, having an effective system for measuring how well classrooms are functioning is critical as it allows the rooms and classes to be optimized for best results (see section 4.3 for more information.) As such, we proposed systems that can help WPI to track how effective their ALCs are. This would ensure that the classrooms are well utilized going forward and help to justify further AL initiatives by showing their benefits.

3.5.3 Utilization Analysis

To prove that these new classrooms would not significantly impact overall school capacity we had to show two things. First, were there enough faculty at WPI interested in using these rooms to ensure they would be fully utilized? Our faculty survey helped us determine how many WPI professors were interested in using renovated rooms design for AL. Additionally, we took our concept classroom designs to five WPI faculty who were most interested in AL in order to determine whether these specific designs would be useful to WPI.

The second main concern that needed to be addressed was whether the proposed spaces would significantly lower classroom seating. We analyzed this using classroom density and seating utilization data from a 2015 study by Computer Science professor Craig Wills, along with the calculated square feet per student for our proposed designs. Since some of our classrooms, like lecture halls and folding-arm chair rooms, can't be effectively used at 100% seating capacity, we corrected for this in our analyses. Put together, these data help justify the feasibility of ALCs at WPI.

4.0 Findings

In this chapter, we will discuss the results of our research into active learning classroom design and their feasibility. First, using the results from our faculty interviews and surveys, we will show the overwhelming support from faculty for classroom renovations and present the difficulties that they report using active learning in existing classroom spaces. This will demonstrate the necessity of active learning spaces at WPI in order to provide an optimal learning environment. Second, we analyze the concerns that administration presented concerning classroom capacity and utilization and demonstrate that active learning classrooms (ALCs) could be implemented without impacting student capacity. Lastly, we lay out the recommendations for classroom design and implementation strategy that we received from other schools with successful active learning classroom programs and discuss the trade-offs between building classrooms to meet current faculty need versus designing optimal classrooms for active learning. Put together, these findings help understand the pressing need for active learning spaces at WPI and alleviate concerns regarding their drawbacks.

4.1 Active Learning Climate at WPI

During our surveys and interviews with faculty we found overwhelming support for ALCs and identified key issues that cause difficulties for AL in current classrooms. We identified numerous types of AL currently used by faculty and found that, in the majority of cases, its use was limited by the design of the classroom.

4.1.1 Demand for Active Learning Classrooms

WPI faculty already use many forms of AL. The responses from our survey showed that 91% of our respondents used at least one type of AL. In our survey we asked respondents to indicate which, if any, forms of AL they used. Their responses are shown in Table 3. Student group-work and in-class problems were the most reported types of AL, with over three-quarters of respondents saying they used them.

Table 3. Use of AL methods at WPI		
AL Method	Frequency of Response	
	# of responses	% of total
Solving in-class problems	108	73%
Brief pauses to discuss presented material	101	69%
Framing material with relevant problems	72	49%
Student group-work	116	79%
"Think-pair-share"	59	40%
Clickers	18	12%

We would also like to note that the definition of AL we used was broad so many different forms of AL fall under the categories listed above. Self-reporting can also cause accuracy issues as professors may misunderstand the categories, have an inaccurate perception of the sort of teaching that they do, or exaggerate in order to look better. However, we believe that these effects don't significantly distort our findings. First, we intentionally left the categories very broad in order to capture all sorts of AL, helping to prevent misunderstanding of the categories. Second, the survey was anonymous, which removed any chance of embarrassment.

Our high response rate also helps show that the WPI faculty is very supportive of AL. While the proportion reporting use of active learning is likely unrepresentative of the whole faculty population and can't be extrapolated due to response bias, it shows that at least 151 faculty (34%) are currently using AL. Additionally, of the 16 faculty who said they do not use AL, nine said they would be interested in trying AL in the future and another six said they may be. This shows that interest in AL is strong at WPI, with a large base of faculty who are using it at some level.

Since our definitions of AL were very broad, they did not do a very good job of characterizing different uses of the same technique. We learned more about the different uses of

techniques in the open response section of the survey and during interviews. Here is a range of examples:

- An engineering professor's students solve example problems in class based off of a topic covered in lecture.
- A professor in the business department has students form groups and share laptops in order to compete against other groups in an online simulation.
- One humanities professor forms groups for the duration of the course and has these groups work on problems spanning multiple classes.
- A biology professor uses students in a simulation to explain predator/prey scenarios and the spread of disease.
- One foreign language professor has students act out a story they read and gives commands for students to act out.
- A business professor has students draw their leadership style as art.

Classrooms can be improved to better facilitate AL. On our survey, 76 respondents (50% of the teachers who use AL) said that changes to classroom design would help their use of AL, while another 43 (28%) said it may help, depending on the change. Professors complained about seating density preventing group work, the inflexibility of classroom spaces and fixed seating, and lack of technology that would facilitate AL.

Tellingly, of the fifteen respondents who said that they would be more likely to try AL techniques, three cited classroom design changes as something that would make them more likely to investigate AL. Another one said they wanted to learn more about types of AL and techniques. This suggests that there is a significant population of teachers interested in AL that are still untapped and that classroom changes and more professional development programs could further increase interest.

Some WPI classrooms already meet AL needs. A majority of professors who use AL in medium sized classes (40-60 students) said flexible classrooms such as SL305 work well for the AL they currently do. The reason those classrooms work is the furniture which is made up of easily movable tables and chairs. One professor noted: "I tend to teach in classes where there is moveable furniture and I move it depending on the day. If all classrooms had that sort of

flexibility that would be great." This response was echoed by another professor: "Most of what I do works best in classrooms with moveable furniture, some of which we do have already. Moveable tables and chairs work well." They did report that they had difficulty getting the classrooms they wanted as there are only a handful of these new spaces on campus. Other rooms, especially with the tablet arm chairs in Olin and Higgins, are much more limiting.

However, only professors with smaller classrooms and using AL as a supplement to their teaching rather than as the main pedagogy reported that they had workable classroom spaces. Several professors with over 100 students per class reported significant difficulties with AL, stating that it was difficult to communicate directly with the students in lecture halls and the tight spacing of lecture-style seating made group work very difficult. While other schools have successfully implemented studio classrooms with over 120 students, WPI has no options for group work over about 60 students.

4.1.2 Classroom Features Suggested by Faculty

During our faculty interviews professors expressed their desires for many different classroom features. Since it would be impractical to implement every single suggestion, we summarize the most popular suggestions below. Full responses to surveys and interviews can be found in Appendices A.

Movable furniture was the most common suggestion from faculty. Easily movable furniture is very important to the common types of AL used at WPI because it allows professors to arrange the furniture in different ways depending on how they are teaching in class. Eighteen of the twenty-one professors we interviewed, as well as seven survey respondents, mentioned movable furniture as something they'd like to see in a classroom designed for AL. This requirement is important both if students are sitting in chairs and writing on tables or if students have individual desks. Movable tables can be aligned in rows for lectures or moved together to allow groups to sit together and collaborate. It would seem that tablet armchairs are a good choice for movable furniture in this situation, but the small surface provided by the tablet desk makes class difficult for students. WPI students often have many materials they need in class (laptop, books, notebook, graphs, etc.) but these desks don't allow enough room for them all.

This is especially true in AL classes where students have more supplementary materials than in a plain lecture class. The chairs are also quite difficult to move around. The furniture currently at WPI that best meets these specifications are the tables and chairs in rooms such as SL305 shown in Figure 12. Both the tables and chairs are on wheels and very light which makes them very easy to move. The tables are also large enough that students and groups have plenty of space to work.

Figure 12. SL 305, large flexible classroom at WPI

It's important to have a lot of whiteboards for student use. Seven of the professors we interviewed thought that having whiteboards for student groups to use would be helpful. Two different designs were suggested. One would be to have whiteboards along walls in the classroom. The other was to have smaller movable white boards that teams could use at their tables. The request for lots of whiteboard space was echoed across many disciplines. Professors in chemistry, business, GPS, math, chemical engineering, and biology, among others, were some of the professors who desired whiteboards.

Technology shouldn't be implemented unless it's easy to use with effective training. Professors had differing interests in types of technology. Many different technologies were mentioned, but the overarching theme was that professors only wanted technology that would actually be useful and could be used effectively. Seventeen of the professors we talked with

emphasized the need to train professors on installed technology to ensure that it is used. They also stressed good maintenance and proper interface integration to avoid confusion and clutter.

Here are some examples of specific technologies professors wanted:

- Screen-sharing technology. This would work in two ways. The first is to allow the professor to send their screen to students' screens and the second is to allow students to send their screens either to the main projector or to the professor's screen.
- Sound propagation devices, i.e., microphones and speakers throughout the class.
- A camera that could automatically take pictures of handwritten notes on the board.
- SMART Boards
- Live video in room for distance learning and video conferencing.
- Mobile technology similar to a podium that would allow them to write on the screen while walking around the room.
- A recording device on the document cameras already present in the room. Notably, this function already exists in some rooms, which helps support professors' point that training on technology is very important.

There were also common complaints about classroom design not necessarily related to AL. Most significantly, projector screens often cover a significant part of blackboards in rooms. This leaves professors little room to write on the board and as a result most are forced to choose between the two. An IQP last year made suggestions regarding this subject. However, faculty still have complaints about it, indicating the need for faster work to fix this problem.

4.2 Considerations for Implementing ALCs at WPI

Through our interviews with administration we were able to identify a number of design constraints specific to WPI. Any concept design that we create will have to recognize these constraints in order to be feasible for WPI to implement it. In this section, we outline the different administrative needs and restrictions that will affect classroom design and implementation.

Classrooms will have to be fully utilized to be feasible. Currently, WPI has 41 classrooms with the number of seats in each room ranging from 25 to 225. According to Chuck Kornik, the administrator of Academic Programs at WPI and a former Academic Scheduler, WPI has not seen an expansion in classroom space over the past few years. However, WPI has been witnessing a gradual increase in student population (30% increase from 2008 through 2014). As a result, class sizes for certain courses and the number of courses have significantly increased. It is advantageous for classrooms at WPI to be fully utilizable in order to support the growing number of courses offered as well as the different styles of teaching and learning. For our purposes, "fully utilizable" means a classroom would be able to be used for the whole work day.

Not every current classroom is used constantly, so future classrooms would not necessarily have to be used all day either. Our proposed ALCs layouts and designs are so different from those of a traditional classroom they might not be comfortable or even utilizable for some WPI professors. For example, round tables are considered to be the best for AL in classrooms. However, some WPI professors do not like the idea of round tables in classrooms since they do not want the students to be facing their backs. Even with this consideration, there are enough faculty interested in studio classrooms to fully utilize them.

Classroom usable seating capacity cannot be reduced. Another constraint related to the growth of WPI's student population is that the seating capacity cannot be reduced. In addition to being very different in layouts and designs from those of a traditional classroom, ALCs also demand large square feet per student. Square feet per student is calculated by dividing the area of the room with the number of seats in the room. The results of our research can be found in Table 4. Our research on studio classrooms, which are one of the most popular forms of ALCs, shows that they generally require 25 - 30 square feet per student. We also did measurements and research on some of the WPI classrooms and found that classrooms with movable tables and chairs (e.g. SL305) have roughly 24 square feet per student. Lecture halls and classrooms with tablet arm chairs provide around 8 - 12 square feet per student. Moreover, Chuck Kornik mentioned that even though there have always been complaints about tablet arm chairs, such as the area of tablets being too small and the chair being very hard to move around, it is likely that WPI will still continue to keep them due to the very low square feet per student

they offer which is needed to support the growing student population and number of courses offered.

Classroom	Classroom Type	Square feet per student
An ALC at University of Minnesota	Studio classroom	27
An AL Lecture Hall in Purdue University	Hybrid lecture hall	25
SL 305	WPI modular classroom (movable rectangular tables and chairs)	24
HL 154	Tablet arm chairs classroom	12
SL115	Traditional lecture hall	8.5

Table 4. Square feet per student for classrooms at WPI and other schools

ALCs can still be implemented at WPI without significantly reducing the classroom capacity. ALCs are generally filled to 100 percent occupancy because it can cause collaboration problems if the room is not filled up to capacity due to the uneven distribution of students in groups (R. Beichner, personal communication, December 11, 2014). In contrast, through our interview with WPI administration, we found out that academic scheduling usually tries to fill current rooms to only ⅔ occupancy. This means for a classroom with 100 seats the maximum class size or maximum occupancy can be only 67 for WPI classrooms while the maximum class size is 100 for a similar ALC. Therefore, there is a possibility that an ALC with 67 seats can be designed in the place of a 100-seat classroom at WPI.

4.3 Lessons Learned and Advice from Other Institutions

Our background research found a lot of information on other schools' active learning classrooms and what they had done. In our interviews and emails with them we learned about the processes used by other schools to design the classrooms and how the classrooms have functioned in practical use. Most significantly, they cautioned against trying to satisfy all the needs that faculty and administration currently present as it would lead to compromises in room functionality that would inhibit use for active learning.

4.3.1 Classroom Requirements and Design Process

Building classrooms for the current needs of faculty won't yield the best active learning classrooms. One of the major takeaways we got from other schools was that teachers and students aren't necessarily able to give effective design input if they haven't worked in an ALC before. Also, Robert Beichner cautioned us to not let what our teachers demand impact our designs too much (R. Beichner, personal communication, December 11, 2014). If our goal is to completely change pedagogy then the room that we design will not probably meet the faculty's current needs since those needs will be for a lecture-based room. It is instead better to draw from the experience of other schools who can tell us what worked and what didn't work and then train professors to effectively use the rooms. Similarly, students who have only had lecture-based courses can't provide effective input on AL pedagogy and generally have very little knowledge of what works in rooms that they haven't used.

Beichner's advice is very relevant at WPI. First, few of our teachers have experience using AL as their primary pedagogy so they can only talk about issues faced when using AL some of the time. Second, none of our professors have actually used ALCs before so they can only say what didn't work in traditional classrooms, not what did work in AL rooms. This sort of negative design process is not very useful in guiding the overall design process.

Classroom utilization will go down initially and it is important to be prepared for this. Until there are enough teachers at the school who can effectively use AL ALCs won't be fully utilized which could affect the limited WPI classroom space negatively. This was much less

of an issue at NCSU and University of Indiana Bloomington as they are both land-grant universities that have a lot more land than WPI and aren't nearly as restricted as WPI. This is especially significant in light of our previous finding. If we don't design a room to meet faculty's current teaching style it is less likely that there will be teachers who can effectively use these rooms. This makes it very difficult to pioneer a new type of classroom.

However, there are steps we can take to mitigate this. First, Greg Siering recommends giving first priority to those faculty who can effectively use the ALCs when scheduling these rooms. Second, getting enough teachers trained and prepared to effectively utilize the room prior to construction will help ensure it is effectively utilized. Doing sit-ins at other schools that already have ALCs and bringing in outside personnel to help train our faculty could also significantly offset the lack of teachers who know how to use the rooms. This would also help work around the fact that the rooms weren't tailored to their current teaching styles.

Additionally, due to the number of faculty who are interested in active learning, this won't be a significant factor at WPI. An aggressive faculty training program will ensure that ALCs are fully utilized which will minimize impacts on classroom space.

It is important to be very explicit and focused with design needs. ALCs are very different than any other sort of room that WPI currently has. Therefore their design requirements are also very different. As such, if the people designing the rooms are not familiar with the requirements they might not be able to design them effectively. In our conversation with Robert Beichner, he told us a story from NCSU when the facilities design group, who weren't familiar with putting projectors anywhere but the front of the room, accidentally hung light fixtures in the way of some of the projectors around the room (R. Beichner, personal communication, December 11, 2014). This error wasn't caught until after the room had actually been built. Therefore, making sure that everyone in the design process understands the requirements and purpose of the room would help to prevent issues like this. The WPI facilities group does have some familiarity with AL design which will help with this, but it is still an important thing to keep in mind.

The development of ALCs needs to be driven by both administration and faculty at different steps of the process. There are several major steps in the implementation of ALCs.

First, a school should implement a small number of rooms, often just one, in order to test how effective they are. This sort of change is driven by professors who are interested in AL designs. Once they are shown to be successful, administration can join in and start pushing to expand the AL program. A good example of this is NCSU where the first few ALCs were pushed forward by Robert Beichner and a number of other professors. Administration was much more reluctant to implement the rooms and forced some compromises on them such as ensuring that the designs could also be used as computer labs. After the first classrooms proved a resounding success administration started to get more interested and has been active in pushing for several new rooms.

University of Indiana Bloomington was very fortunate when starting their AL program: AL lines up very well with their newest strategic initiative, causing the program to be heavily pushed by administration from the outset. At this point, UIB has had a major push to implement ALCs all across their campus and turned as many of their spaces as possible into collaborative learning areas. They've also reorganized all of the technical and facility support for their ALCs under their IT department, helping to ensure that it is effectively maintained.

When planning our AL goals, Greg Siering at UIB suggested we be very specific with our intent for transforming pedagogy, since how radical we want to be significantly affects our design process. ALCs can be set up in many different ways to match differing degrees of AL. Some types, like studio classrooms, are suitable only for AL which makes them a harder sell to administration and less likely to be implemented across campus. Other types, like AL lecture halls, are fairly simple adaptations from existing rooms and could be easily integrated into existing spaces.

WPI's current faculty support system could be adapted to handle AL. While some schools like University of Iowa have very formal groups for helping to design AL classes, others like NCSU have informal faculty support groups that help their teachers figure out how to design their classes effectively in ALCs. We described our current system to Professor Robert Beichner, who said that our faculty learning communities would likely provide enough help for professors. He recommended that we might want to bring in professionals from outside WPI who have AL experience until our own faculty are experienced enough to sustain the program. He also mentioned that having faculty-in-training attend sit-ins of effective classes could be very helpful.

Greg Siering at UIB agreed, stating that faculty learning communities are the most effective way to support AL programs. As a result, it will be relatively easy to create self-sustaining faculty interest in the ALCs and keep them fully utilized once they are fully up and running.

A comprehensive set of metrics using different tools is essential to getting the best performance out of an ALC. Robert Beichner at NCSU highly recommended extensive classroom observation and evaluation which allows schools to tweak their classroom designs and teaching styles to be more effective. When a school that is new to AL pedagogy, such as WPI, implements an ALC they have to figure out how to use it and live feedback is invaluable to that process. This also allows them to be compared to traditional classrooms and teaching styles, which can help make the case for more ALCs in the future.

There are several different observation protocols that different schools use to directly observe and record the different types of learning that are used. NCSU uses the Reformed Teaching Observation Protocol (RTOP) (R. Beichner, personal communication, December 11, 2014). University of Indiana Bloomington uses the Classroom Observation Protocol for Undergraduate STEM, or COPUS system (G. Siering, personal communication, November 19, 2014). These protocols provide a useful way to record activity in the classroom in a standardized and objective manner assuming the observers have gone through appropriate training. This is especially helpful for conducting research on classroom design and teaching styles. Greg Siering also recommended that we set up some sort of automated data collection tool to help ease the process.

In addition to these observation protocols, surveys of students can help to optimize courses and increase engagement. Student learning can be effectively judged with a number of standard subject tests designed to gauge student comprehension. In the long term, a combination of these techniques can judge the effectiveness of ALCs and classes versus more traditional methods and improve the classes and room design.

Making the classrooms flexible means making them non--optimal for AL. A flexible classroom is able to perform many functions, but it cannot perform any single function, such as AL, better than a room dedicated to that function, in this case an ALC. NCSU has conducted significant research on table design and has found that 7' diameter round tables work very well

for most AL environments. Each table seats three groups of three students. To do this testing, they created a series of ALCs using each for actual classes to determine table effectiveness (Beichner, 2007). They ultimately determined that round tables are best for AL. However, these tables can't be used for any other sort of teaching, especially if there is significant technology in each table, which would make them difficult to move around. In fact, University of Minnesota spent quite a bit of money getting flexible tables for their 120 person AL room, but they have rarely needed to move them around, since the default layout works well.

Additionally, according to many experts such as Robert Beichner and Sehoya Cotner, presenting the ability for teachers to do lecture in a classroom is counterproductive. One of the major reasons that ALCs help promote AL is that they place a greater onus on the student to take responsibility for their own education, a message that a multipurpose room would fail to get across. Lastly, because WPI currently has very few professors who use solely AL, it's likely that any multipurpose room may just get used for traditional lecture most of the time, thus defeating the purpose a dedicated ALC.

4.3.2 Design Choices and Use

The choice of table impacts the functionality of the room. Beichner described a few of the different sorts of tables that are common and some of the results of their testing into optimal table design. NCSU has studied table design extensively, creating four different SCALE-UP iterations with different layouts ranging from rectangular tables to paddleboard desks and the now-archetypical round tables (Beichner, 2007). First, for general use, he recommends 7' diameter round tables that seat nine students, divided into three groups of three students each. Smaller tables are less space efficient because they don't pack as well and thus have lower seating capacity, while larger tables are too big for students to effectively communicate across. If these round tables do not fit in the room, smaller five-feet-diameter D-shaped tables located against the walls and have a flat screen display mounted on the wall, can be used instead (Beichner Personal Communications).

If the room is supposed to be flexible, he recommends trapezoidal tables which can be grouped into hexagons. When they're broken apart, they can form rows for lectures. The disadvantage here, however, is that transitioning from rows to hexagons takes time and is

difficult. He also cautions against the type of split tables that University of Minnesota has, saying that the added flexibility was rarely used since the round shape was best and that they were far more expensive than the normal tables.

Lastly, he claims that thin-backed plastic chairs were much better than thick padded ones, since they're three inches thinner on average. This saves space and gives the teacher more room to walk around.

Whiteboards and computers are very important as supplementary technology.
Beichner suggests having as much whiteboard space along the walls as possible. Glass whiteboards especially are very nice to work with and last a very long time. As an alternative to glass whiteboards, he suggested using white bathwall, which is very cheap, can be easily cut to size, and can simply be replaced every few years. Having smaller tablet whiteboards for the students is also very useful and can be made out of the same white bathwall. Additionally, students can write with whiteboard markers on the windows if they're short on space.

Beichner recommends that each table or group have one computer. If there are more, it becomes a distraction. NCSU uses laptops, since they can be moved around and visibly closed to ensure that everyone is paying attention. He highly recommends using screen-sharing technology of some sort so that students can share their work easily. However, this isn't necessary for small rooms, since students can just look across the room. This sort of system could possibly be set up at WPI with students bringing their own laptops.

Rooms must be designed with student-faculty communication in mind.
Communication between students and the teacher becomes increasingly difficult, especially as classroom size increases. Both NCSU and UIB were careful to stress the importance of good systems for communicating. NCSU chose their 7' diameter table largely because it was the right size for the sub-groups to talk to each other without needing to raise their voices. Sound absorbing tiles on the ceiling and floor are sufficient in smaller rooms while larger rooms will probably want a microphone for the teacher so that he can attract everyone's attention when necessary. Very large rooms may even want microphones for each of the groups so they can talk to the whole class.

5.0 Recommendations

We recommend that WPI tackle the problem of creating spaces for active learning (AL) on several different levels. First, we will discuss the creation of spaces dedicated specifically for AL in the form of studio classrooms. Equally important to the actual classroom design, we'll propose implementation and training strategies that will allow WPI to effectively use these rooms immediately. Second, we'll talk about renovations to an existing classroom, SL105, which will provide a hybrid AL-lecture hall which is suitable for either form of teaching. This space will be suited for professors who use AL as part of their lecture to improve student engagement, rather than using it as their primary teaching pedagogy. Lastly, we'll make general suggestions for administration and design principles that can be applied to all renovated classrooms moving forward in order to help promote AL across the campus.

5.1 Studio Classrooms

Studio classrooms are the purest form of active learning classrooms (ALCs) as they are designed specifically for collaborative/cooperative work. The recommendations below for studio classrooms are mainly based off the SCALE-UP program of NCSU. The knowledge we gained from NCSU was compiled with input we gathered from faculty and administration to make studio classrooms tailored to WPI's needs. These rooms will be best suited for the faculty who can use AL as their primary teaching method.

5.1.1 Specific Design Recommendations

In this section we present specific recommendations for studio classrooms at WPI. We include some examples of how our studio classroom concept can be applied to rooms of many varying shapes as well as specific examples of how studio renovations would look in two current WPI classrooms: Salisbury Labs 305 (SL305), which is a larger classroom with a capacity of 62 students; and Olin Hall 223 (OH223), a smaller classroom with a capacity of 42 students. Scale

drawings are shown in Figures 13 and 14, respectively. Following are recommended classroom features:

Round tables are recommended for large rooms. 7 foot diameter tables can be used to seat 9 students per table (3 groups of 3) or 6 foot diameter tables can be used to seat 8 students per table (2 groups of 4). There should be at least 5 feet between each table and all tables should be at least 3.5 feet from the wall. This allows the teacher to walk around the room and in between tables freely. The round tables make group work easier since everyone can see everyone else, provide large amounts of space to work, and are space efficient since students can sit around the whole perimeter of the table.

As an example, Figure 13 shows SL305 fitted with 8 round tables and a professor podium in the center. Our redesign of this room increases student capacity, from 62 to 64, and according to our calculations costs about the same as its current layout. Cost will be discussed more thoroughly in section 5.1.3, while a full comparison of general seating densities can be found in section 4.2. While studio can't compare to traditional lecture halls in seating capacity, they are competitive with more open room designs like SL305, allowing renovations without sacrificing any seating.

There are a few disadvantages of this sort of room layout. First, the doors of the room can be somewhat cramped since the whole area of the room is used up by tables, slowing entrance and exit. This can be alleviated by making sure that students push in their chairs when done. In larger rooms, students can also be asked to enter and leave with different doors, helping to reduce traffic jams. Next, the lack of open space is also difficult if a class needs open floor space. However, the amount of space that's available on the tables helps ensure that there's enough working area.
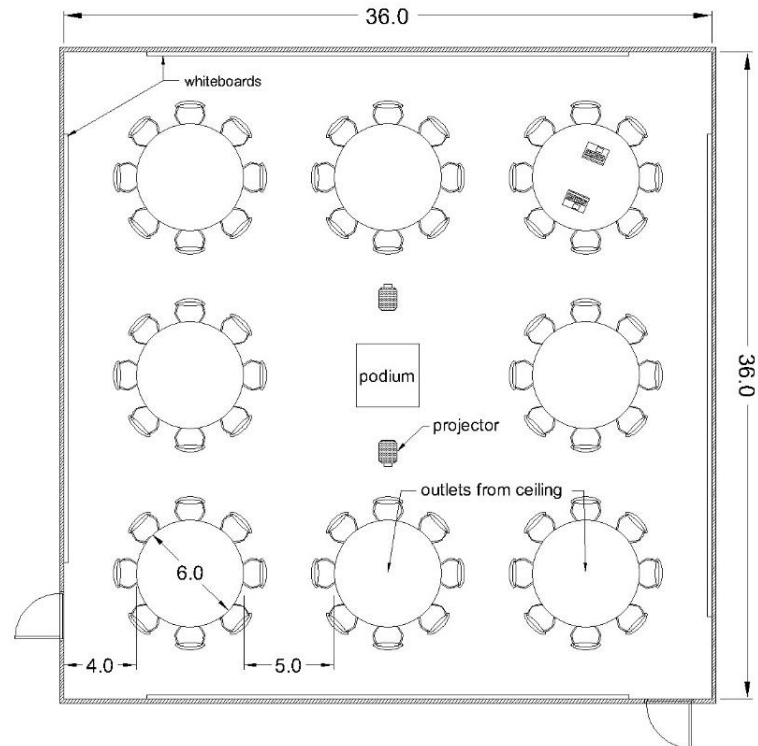
Figure 13. Studio concept of SL305

D-shaped tables are recommended for small rooms. As shown in Figure 14, 4 foot tables should be used for groups of 4 students and 3 foot tables for groups of 3 students (1 group per table). There should be at least 4 feet between each table. These tables are optimal for smaller rooms, since the flat side can be placed against the walls and help take better advantage of the perimeter of the room. This example in OH223 does significantly lower the student capacity, from 42 to 24. However, WPI is currently only filling out classrooms to 55% capacity on average (Wills, 2015). As such, the number of students in this room would remain unaffected.
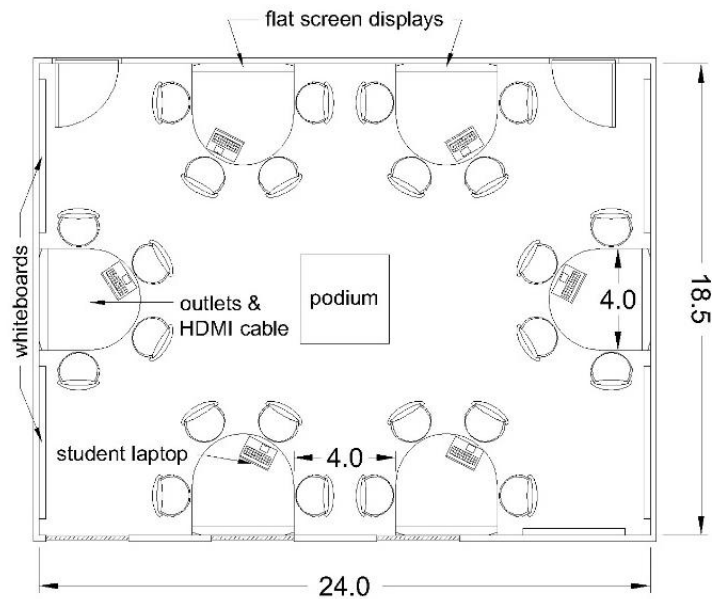
Figure 14. Studio concept of OH 223

Projector screens are recommended for larger rooms. Large rooms are likely to have enough vacant wall space to fit a projector screen as shown in Figure 13. Teachers can use the screen display information for activities or visual aid during brief lectures. The screens must be placed strategically to avoid interference with whiteboards; many faculty identified this as a common issue in current WPI classrooms.

Flat screen displays are recommended for smaller rooms with D-shaped tables. These displays should be placed on the wall at the end of each D-shaped table as seen in Figure 14. Teachers can share their screen to each display in the room during brief lectures. These displays can also be used by the groups to display their own personal laptop screens so all the group members have a good view of the material.

We recommend that students be required to bring their own laptop computers. The majority of WPI students have their own personal laptops so there is no need for WPI to spend money on purchasing and maintaining classroom laptops. However, students only need one laptop per group. The chances of having a group of all non-laptop owners are very slim. Additionally, limiting groups to one computer each increases collaboration and reduces distraction and clutter.

Outlet drops from the ceiling are recommended for rooms with round tables. Power drops are easier to reconfigure than power lines under the floor and if properly done can be very unobtrusive as shown in Figure 13. A drop to the center of each table as well as the teacher's podium will provide all the power necessary without significantly obstructing view and will prevent cables running underfoot that could pose tripping hazards. Outlet drops are one good way of providing power to the tables; however, there are also other alternatives.

Outlets on tables are recommended for rooms with D-shaped tables. Having the outlets routed from the wall to the table makes the plugs easily accessible to students sitting at the table as shown in Figure 14. Instead of having to reach around to one side or underneath the table, the outlets are easily accessible to everyone.

The teacher's podium should be placed at the center of the room. WPI's current podium design will work very well for studio classrooms given that they are already packed with all the technology one needs to control a classroom. However, it is important that they are located in the center of the room so that teachers can easily address students as they are doing group work and to avoid creating a front of the room. When all the students are an equal distance from the teacher, it is easier for the teacher to help each one, but in rooms where teachers teach from the front of the room, students sitting in the back tend to be much less engaged. However, the most important reason to keep the podium centralized is to avoid creating a front side to the room, which would promote lecture teaching and decrease student focus. Research by the University of Minnesota suggests that one of the primary benefits to ALCs is that they put greater accountability on learners for material, rather than allowing them to expect passive learning (Cotner, 2013). This mirrors with what a member of WPI administration told us: when students walk into a lecture hall, they're conditioned to sit quietly and absorb information. Avoiding this impression and placing the onus on the students for their own learning is paramount for an ALC.

Large whiteboards should be mounted on any unused wall space. This allows groups to solve problems on the wall closest to their table while allowing the teacher to monitor their methods and progress. Teachers can also use these whiteboards for brief lectures in between activities.

A rack of small tablet whiteboards should also be implemented in the room. Groups can solve problems in private and then share them with the class or teacher. In large rooms, groups sitting at tables in the center of the room may have trouble using the whiteboards along the wall so tablet whiteboards can be used in this case. Groups without access to whiteboard space may use tablet whiteboards instead. They can also be used if the teacher wants to write information on the board while the students work. Some rack designs could also be used to display the tablets side-by-side after students have completed their work.

Chairs should have rotatable bases on casters. This allows students to turn to their group or to the teacher quickly and easily. There are even some of these chairs that have foldable tablet writing surfaces so students can turn around and take notes during brief lectures. However, the chairs that WPI currently uses in Salisbury Labs are perfectly fine for general studio classroom uses: These chairs are mounted on 5-spoke swivel bases with casters and have thin plastic backs. Thin plastic-backed chairs are ideal because they are 3" thinner on average than chair with padded upholstery, allowing teachers and students to move around the room more easily.

Figure 15. A movable and rotatable chair in SL 305

Microphones may be helpful in larger rooms. A microphone on the teacher's podium helps the teacher get students' attention when the room becomes loud with collaborating students. It also helps teachers project their voice without having to yell to carry their voice, just like in a traditional lecture hall. Microphones can also be helpful when installed into the students' round tables so the students can speak to the teacher and rest of the class without having to yell.

Additional sound dampening measures should be taken. Most WPI classrooms have some form of sound dampening in the floor, ceiling, mounted on the walls, or any combination of the three. However studio classrooms tend to get louder than normal classrooms due to all the students collaborating and additional sound dampening can help prevent groups having to yell over each other.

5.1.2 Faculty Feedback

In order to see if our designs would work for the WPI community, we went back and interviewed five of the faculty who had been most enthusiastic about active learning initially. Feedback on our studio classroom design was very positive. All of the professors commented that they thought the round tables would work well for easy communication. Another professor commented that they "love the ability to walk around and work with the small groups." Their views about the centered podium were generally positive. While one faculty member claimed that they don't like having their back to their students, but could certainly adapt to teaching from the center of the room. Two other professors thought that a centered podium would suit their teaching style very well as they like to pace around the room as they speaks to students; although they acknowledged that there a quite a few other faculty that have less "mobile" teaching styles and would find the positioning uncomfortable. A professor from the chemistry department liked that "everyone is more equal, no hiding in the back of the room." He also claimed that "the ability to group people for an entire term to work on long term projects would be pretty helpful." Almost all the professors we interviewed had positive feedback about increasing the amount of whiteboard space along the walls of the room.

The faculty also pointed out some further suggestions to the studio classroom design. A professor from the humanities department thought that our idea of using the current podiums would be problematic as they are designed for lecture style teaching and are too tall and bulky for this classroom. A podium that is shorter would better suit her active learning applications because it wouldn't block students' views of her as she is speaking. She claimed that the current podiums have little room for notes and suggested having a small square table next to the podium for this. This professor also suggested a taller chair so that the students can see her easily from anywhere in the room. More research should be done on active learning podiums, as it was

outside the scope of our project.

Another suggestion for the classroom was individual student tablets (like iPads) for students to work on paired with a podium that has the ability to control them remotely. The economics teacher we spoke to had similar input about the tablets and said that he has seen this technology used at other universities using a special brand of software. The chemistry professor suggested using multiple projectors facing different directions in the larger room so that every student has a decent view of the material. We thought this was very reasonable and decided to add it to our design since it would not increase the cost very much. This professor also thought that projectors may not be necessary if every group had a tablet computer screen at their table (making 2 tablets per table), similar to the ones featured at many of the podiums in classrooms around campus. One other professor commented that some sort of tablet that professors could use to run presentations and draw on the projector while walking around the room could be very useful.

Faculty at WPI are very enthusiastic about the prospects of active learning classrooms and are eager to explore different ways of using the classrooms. When an ALC is implemented, we foresee no issues in finding faculty who can use it, further helping to alleviate concerns about classroom space.

5.1.3 Cost Analysis

Our group has done some initial estimates on cost per square foot for construction of an ALC. The analysis accounted for the tables, chairs, wall whiteboards, and multiple projectors with screens, as we were trying to focus specifically on parts of the room that are specific to AL. In order to easily compare the data, we compared the furniture cost of current WPI classrooms with their active learning counterparts. Table 4 shows the relative costs for renovations in SL305, while Table 5 shows the costs for OH223. Costs for WPI's classrooms were based on historical classroom renovation data and estimates from retailers as referenced in Appendix E, while costs of AL used information from the SCALE-UP databases.

Table 5. Relative costs of classroom renovations in SL305

Studio Classroom Renovations				Current Layout of SL305			
Item	Number	Cost per	Total	Item	Number	Cost per	Total
Tables	8	$1,100	$8,800	Tables	30	$450	$13,500
Chairs	64	$373	$23,872	Chairs	62	$373	$23,126
Whiteboards	6	$400	$2,400	Whiteboards	2	$400	$800
Projector	2	$3,000	$6,000	Projector	1	$3,000	$3,000
Total cost			$41,072	Total cost			$40,426
Cost per student			$642	Cost per student			$674
Cost per ft²			$28	Cost per ft²			$27

Table 6. Relative costs of classroom renovations in OH223

Studio Classroom Renovations				Current Layout of OH223			
Item	Number	Cost per	Total	Item	Number	Cost per	Total
Tables	6	$710	$4,260	Tables	0	n/a	$0
Chairs	24	$373	$8,952	Chairs and desks	42	$150.00	$6,300
Whiteboards	4.7	$150	$705	Whiteboards	3	$400.00	$1,200
Flat screen (42")	6	$400	$2,400	Projector	1	$3,000.00	$3,000
TV mount	6	$320	$1,920				
Total cost			$16,317	Total cost			$10,500
Cost per student			$680	Cost per student			$250
Cost per ft²			$37	Cost per ft²			$24

Our initial estimates show that the costs of the different types of rooms are fairly comparable. The SL305 layout is almost exactly the same as the current cost, as the tables are cheaper per student. The OH223 renovations are considerably more expensive, due to the flat screens and more expensive chairs, at about fifty percent more expensive for the square footage and more than twice as expensive per student. However, the room is still quite inexpensive as it's so small and switching to cheaper chairs could significantly reduce the room cost.

These cost estimates are only intended as providing an initial estimate prior to detailed design. We aren't able to come up with a cost estimate for running power to tables, since it will depend heavily on the existing space and specific technical demands of the design. Similarly, we

can't predict costs for renovating room architecture, upholstery, environmental technology, or labor costs. However, most of these costs are common to both AL and more traditional renovations. Other costs, such as small tablet whiteboards and projector screens, are fairly insignificant compared to the overall cost of the room. The cost estimates are merely to provide a baseline estimate for outfitting a classroom prior to specific design.

5.1.4 Implementation Strategy

Any room can be adapted into a studio classroom, but a larger room is better than a smaller one. Studio classrooms are more space efficient as they grow in floor space. For example, a 35'x46' room can fit 88 students with 18 ft^2 per student, while a 35'x35' square room can fit 64 students with 19 ft^2 per student. A 35'x24' room would be even worse, seating only 40 students with 21 ft^2 per student. See Appendix D for more information.

Bring in outside assistance until WPI faculty are trained on how to use the rooms. In order to maximize the effectiveness of studio classrooms, the faculty teaching in these classrooms must be properly trained. Studio classrooms are designed for a very specific type of learning. If the faculty don't know how to effectively teach using AL and instead try to use a different style, such as lecturing, any advantage of studio classrooms is lost. In order to make sure there are enough faculty to fully utilize any studio classrooms that are implemented we recommend identifying an initial core group of faculty to take the initiative on AL. Since no faculty at WPI have experience with studio classrooms we recommend bringing in outside experts on the use of studio classrooms to train this group of faculty. The training should include teaching techniques, the theory behind the pedagogy, and how to set up a curriculum for classes in a studio classroom. Ideally this training would occur during the summer before the first use of studio classrooms and may also involve faculty observing classes at nearby schools with successful AL rooms, such as MIT. This will allow the faculty to have enough time to properly set up their courses. The outside expert or experts should only be needed for this initial group of faculty, after which they should be able to train more teachers.

5.2 Hybrid Lecture Halls

While studio classrooms are optimal for AL strategies, they are also limited to only AL. Right now, few professors are prepared to use AL as their sole teaching pedagogy, instead supplementing their lectures with activities to increase student engagement. In order to provide a space that is effective for these teachers, we propose that WPI renovate SL105, one of our smaller lecture halls with 60 student capacity, into an AL lecture hall.

5.2.1 Recommended Use

We recommend that WPI renovate one of our existing lecture halls into a hybrid lecture hall. SL105, one of our smaller lecture halls with 60 seats, is the only lecture hall at WPI to have two sets of tables per tier, rather than just one. This is very similar to hybrid lecture halls like Purdue's and some minor changes could make it very good for collaborative learning while still allowing full use for traditional lectures and leaving the classroom seating unaffected. Eight of our twenty interviewees said they taught classes that would fit neatly in SL105 and there are likely other professors using AL in that size range that we didn't interview which would help to ensure that it's well utilized. GPS classes are also well sized for this room and require group work. We are confident that if this room was renovated for AL it would be fully utilized.

We recommend modelling it after Purdue's Collaborative Lecture Halls for large teams. They are designed to have groups of between four and six students. Professors in lecture halls complained about difficulties forming groups. This renovation to SL105 would help to solve this issue for smaller classes while simultaneously serving as a model for later, larger lecture hall renovations. Similar renovations could be applied to other rooms at WPI. However, they would be vastly more expensive since the room would need to be re-tiered. Figure 17 shows the current layout of SL105, while Figure 18 shows our proposed changes. New classroom features are indicated in blue.
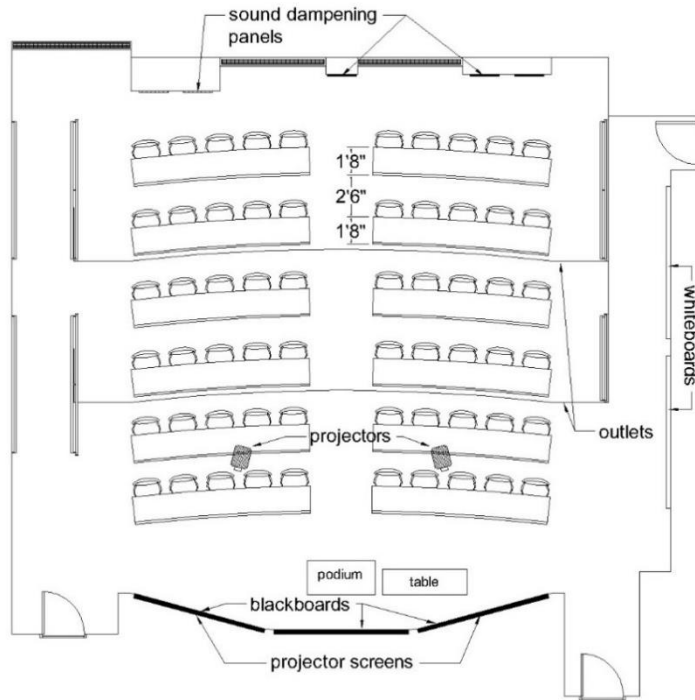
Figure 16. Full view of current layout of SL105
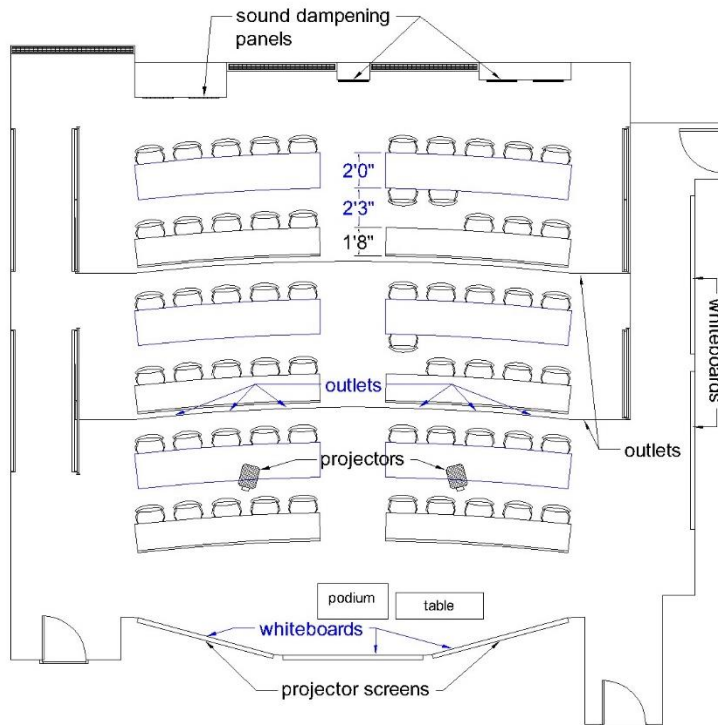
Figure 17. Full view of proposed changes to SL105

It is difficult to estimate cost for this renovation as labor is likely to be the most significant part of the cost. However, we don't anticipate significant costs as the design changes are fairly minor. Only half the tables need to be modified and the chairs don't need to be changed at all. Relative to the cost of a full room renovation these costs are very low.

5.2.2 Specific Design Recommendations

Minor changes to the tables will allow for much better collaboration. As shown in Figure 19, removing the lip and modesty panel on the back table on each tier will allow for students to turn around and work together in small groups. We would also recommend slightly extending the rear tables, from 1'8" to 2' to provide more workspace. Extending the tables will reduce the clearance for the front tables' chairs slightly. This could be an issue with thicker backed chairs, but the chairs in the room have thin plastic backs which give sufficient clearance even with the reduced width.
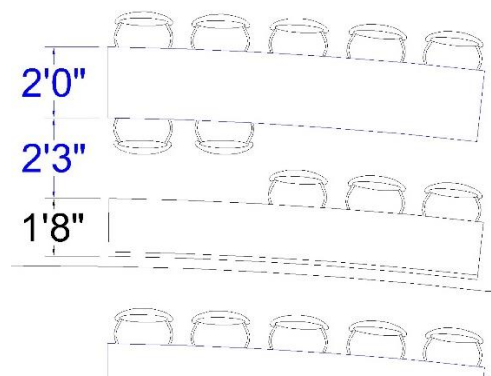
Figure 18. Close-up view of proposed table changes in SL105

We recommend that the blackboards be replaced with whiteboards in accordance with teacher preference. Very few faculty favor blackboards over whiteboards and it would be better to replace the current blackboards if there's renovation going on anyway. Replacing the blackboards will eliminate contamination from chalk dust, which can damage expensive electronics. Whiteboards are also superior for color choice, image contrast, and lifetime. Modern glass whiteboards especially have very long life-spans, which helps to offset their high costs.

A set of small whiteboard tablets can help students collaborate at the tables. SL105 already has a number of whiteboards around the outside of the room that students can use during class. However, these are less useful for group work in the lecture hall-style room, as access is more difficult. Giving the students smaller, portable whiteboards that they can use in their seats would provide a more convenient method of collaborative group work and give students a medium to share their work with each other. There should be at least twelve boards, so that each group can have one. They can be stored in some form of simple rack in the corner of the classroom.

Add more power outlets in the rows for student use. Currently there are only two outlets in each tier, one located at each end. This only provides four outlets for 60 students. Adding more outlets, distributed along the tiers, will make it easier for students to use laptops during class. This enables students to collaborate digitally and share their work with the rest of the class. Power lines could be easily run along the underside of the tables, so this change should be easy to implement.

Adding more sound dampening to the room will help make collaborative learning more feasible. While there is some sound dampening in the back of the room already, adding more sound dampening could be useful to ensure that the room doesn't get too noisy. We recommend that WPI bring in an acoustic engineer in order to figure out how the space can be optimized for group work.

5.2.3 Implementation Strategies

Hybrid classrooms can be implemented immediately. However, professors who use AL should be given priority in assigning hybrid lecture halls. Since these rooms can also be used strictly as lecture halls, there is not necessarily a need to train professors to use them. Any professor would be able to teach in them without any additional training. However, professors who currently use AL techniques will be able to make better use out of hybrid lecture halls.

Faculty learning communities should educate professors on how they can use these new spaces effectively. While the rooms will still be usable for traditional lectures, professors

should take advantage of the rooms to keep students engaged by using appropriate AL techniques. It should be faster and easier to teach faculty how to use these techniques. That is because these techniques are only being added onto lecture; there is not a complete overhaul of the curriculum.

5.3 General Suggestions for Classroom Renovations

In this section, we present a list of general considerations that can make WPI learning spaces more conducive to student engagement and group work and improve teaching and learning experience at WPI in general. Most of the suggestions stem from the classroom difficulties and desired features mentioned by WPI faculty during our faculty interviews and a few are from interviews with other schools that are leaders in using AL pedagogy and implementing ALCs.

Place more power outlets around the room for student use. One very common problem found in most WPI classrooms is that there are not enough power outlets for student use. For example, SL305, which is one of the best rooms for group work, holds 60 seats but only has fewer than 8 power outlets and more than 4 of these are located at the front of the room far from the students. Actually, it is not so surprising that there are not a lot of power outlets in such rooms since they were designed for traditional lecture which does not require students to use their laptops in class. However, in an ALC where group work is the main form of learning, being able to use laptops in class not only grants students accessibility and connectivity via the internet but also facilitates group work. However, since these electronic devices, such as laptops, can become a major source of distraction in classrooms, limiting one computer or laptop to one group can be a great way to not only reduce the amount of distraction but also to keep the members of the group more cohesive.

Use whiteboards instead of blackboards. Through our interviews with WPI faculty, we have also learned that most faculty preferred whiteboards over black/chalkboards and suggested that whiteboards should be the standard in-class workspace. They mentioned that the chalk dust has become a major nuisance, especially for those who have asthma and allergies to chalk dust. They also stated that chalkboards are harder to clean at times than whiteboards and this has caused

students to not see clearly what is written on those chalkboards. Additionally, one other advantage of using whiteboards than blackboards is that there are certain kinds of whiteboards that can be projected onto from a projector while there is really no possibility to project onto a blackboard. Having whiteboards that can be projected onto might also be able to solve the issue of projector screens taking up black/whiteboard space discussed previously.

Use flexible furniture when possible to create multi-purpose rooms. During the faculty interviews we observed that WPI faculty have very positive responses towards classrooms with movable furniture in terms of being easy to implement AL technique. The classrooms they mentioned are the upper SL classrooms, such as SL305, which have movable rectangular tables and rotatable chairs on casters. The flexibility of these rooms also enabled the faculty to do not only group work but also lecturing, which is still the predominant way of teaching at WPI. Also through our interviews with WPI faculty, we noticed that even the professors who favor group work a lot in class would still like to lecture for a few minutes between AL activities. Therefore, having flexible furniture that can allow teachers to easily switch between lecturing and group work activities would be a great fit for promoting teaching and learning at WPI.

Add dry-erase surfaces along all of the walls of the room. Giving students plenty of space to work can be a good way to facilitate group-work. Additionally, classrooms with lots of workspace can be used outside of class for homework and project work, like tech suites, which gives them a lot more utility. This in-class workspace can be achieved by either having whiteboards on all walls of the classroom or actually painting the classroom walls with whiteboard paint. While having the walls painted with whiteboard paint can give students more workspace than adding more whiteboards on the surrounding walls, there might also be concerns regarding hygienic classroom looks if the these whiteboard painted walls were left unerased after being used. Also, whiteboard paint can be more expensive, costing 225 dollars for 50 square feet, as well as less durable, than standard whiteboards.

Place projector screens where they do not take up blackboard space. One of the most encountered problems during our interviews with WPI faculty is that when the projector screen is in use it covers most of the usable blackboard/whiteboard space. For example, when some

professors have PowerPoint slides on the concept of the class material on the projector screen they would also like to use the writable surface space to explain the concept introduced on the slides or work an example out on the blackboard spaces. In short, WPI faculty desire to be able to use both of these tools at the same time. However, in some classrooms at WPI, such as Higgins Labs 114, this is not possible since the projector screen covers up most of the writable spaces. This problem can also become a potential hindrance in the implementation of AL especially when screen sharing technology has become available at WPI. One potential scenario would be when a student has shared a problem on the projector screen that she would like the professor to work out in class, but with the screen is covering most of the writable black/whiteboard space the professor will not have enough workspace to work with which can potentially affect student-faculty interaction in a negative way.

Investigate a user-friendly screen-sharing system. During our interview with faculty we also noted that screen sharing technology is among the most desired features that WPI faculty want to see in their classrooms. Ideally, screen sharing would allow students to view the teacher's screen on their laptops or on the monitor at their table as well as to share their laptop screens across the room via the class projectors. Through interviews with the WPI ATC we learned that they have looked into several possible screen sharing systems but so far have not found one that will be compatible with WPI security systems. Therefore, we recommend that the WPI networking team continue on investigating how a secure and user-friendly screen-sharing system could be implemented at WPI since such technology will be able to make WPI classrooms more conducive to AL.

Establish a formal course evaluation system incorporating multiple types of course observation and evaluation. It's important to have multiple types of course and classroom evaluation as they examine different things. Currently at WPI, students are asked to fill out course evaluation surveys near the end of the course. These surveys cover the effectiveness of the instructor's teaching and labs, but do not ask students about course and classroom design or the effectiveness of the current classroom features. We recommend that these surveys be extended to gather information on student satisfaction with classrooms and courses. While they aren't effective

for gathering objective data, as they are heavily colored by student perceptions, they can help to gather information about student satisfaction and see how they like AL compared to lectures.

Second, comparing data on student learning objectives allows us to compare AL courses and classrooms with more traditional approaches. This can be accomplished with subject matter tests and grade comparisons and will help to gather objective data on the learning benefits of AL. This data can be used to help tweak course design in order to improve student learning and also help make a case for the further extension of AL. We suggest that WPI have students take subject matter tests before and after the switch to AL in order to provide quantifiable information on student learning.

Lastly, direct observation of courses, using a calibrated observer with a system like COPUS, which stands for Classroom Observation Protocol for Undergraduate STEM, can give objective information on classroom activities and student interactions. This data is very important because it can help administration to understand how classroom features and teaching styles affect behavior and engagement. We recommend that WPI have a number of observers trained to take classroom observations and start an extensive program of classroom observation in order to improve classrooms and course design. All put together, these different approaches should significantly improve both AL and traditional classes in the long term.

5.4 Conclusion

Put together, these suggestions will vastly improve WPI's AL facilities. Studio classrooms will provide dedicated AL spaces that are optimized for student engagement and group work, without needing to sacrifice seating and with comparable cost. Hybrid lecture halls will be useful for hybrid teaching styles that do not fully rely on AL or traditional lectures. Meanwhile, basic changes to standard room design will help those teachers who use AL and group activities only occasionally. This range of different room types helps to accommodate the varying needs of WPI faculty and provides effective classroom spaces for all different types of learning. Ultimately, this will facilitate changes in pedagogy that will help WPI adapt to new forms of teaching and remain a world-class university.

6.0 References

University of Iowa. (2013) Accessing Learning in a TILE classroom. Retrieved October 10, 2014, from http://tile.uiowa.edu/news/assessing-learning-tile-classroom

Northern Michigan University. Active Learning Classrooms. Retrieved October 10, 2014, from http://www.nmu.edu/ctl/classrooms

Ahern, A. A. (2010). A case study: Problem-based learning for civil engineering students in transportation courses. *European Journal of Engineering Education, 35*(1), 109-116.

Alwash, M., Grills, J., Hinrichs, R., & Wasserman, B. (2014). Recommendations for the Classroom Technology and Layout at WPI. Worcester, MA: Worcester Polytechnic Institute.

Beichner, R., Saul, J., Abbott, D., Morse, J., Deardorff, R., Allain, R., … Risley, J.S. (2007). The Student-Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP) project. *Research-Based Reform of University Physics*, edited by E. F. Redish and P. J. Cooney.

Belcher, Y. J. D. a. J. (2005). How Does Technology-Enabled Active Learning Affect Undergraduate Students' Understanding of Electromagnetism Concepts? *The Journal of the Learning Sciences, 14(2), 243–279*.

Chang, C.-C., Jong, A., & Huang, F.-C. (2012). Using Electronic Resources to Support Problem-Based Learning. *Journal of Educational Computing Research, 46*(2), 195-206.

Copp, C., & Frank, M. (2014). Drafting a University Master Plan for Learning Spaces: Educause. Retrieved from http://www.educause.edu/events/eli-online-fall-focus-session-re-imagining-learning-spaces/2014/drafting-university-master-plan-learning-spaces

Cotner, S., Loper, J., Walker, J., & Brooks, D. C. (2013). "It's Not You, It's the Room"— Are the High-Tech, Active Learning Classrooms Worth It? *Journal of College Science Teaching, 42*(6), 82-88.

Felder, R. (1995). Cooperative learning in a sequence of engineering courses: a success story. *Cooperative Learning and College Teaching Newsletter, 5*(2), 10-13.

Kleij, Ten. "Text analysis of open-ended survey responses: a complementary method to preference mapping," *Food Quality and Preference*, vol. 14, no. 1, pp. 43-52, 2003

Harvard University. (2014). Peer Instruction. Retrieved 2014-10-10, from http://mazur.harvard.edu/research/detailspage.php?rowid=8

Han, J. H., & Finkelstein, A. (2013). Understanding the effects of professors' pedagogical development with Clicker Assessment and Feedback technologies and the impact on students' engagement and learning in higher education. *Computers & Education, 65*, 64-76.

WPI Division of Enrollment Management. (2008). 2008 Fact Book: Worcester Polytechnic Institute.

WPI Division of Enrollment Management. (2014). 2014 Fact Book: Worcester Polytechnic Institute.

Maxwell, J. A. (2008). Designing a qualitative study. The SAGE Handbook of Applied Social Research Methods, SAGE, Los Angeles, 214-246.

University of Minnesota. Active Learning Classrooms. Retrieved from http://www.pkallsc.org/assets/files/UniversityofMinnesota-ActiveLearningClassrooms.pdf.

National Survey of Student Engagement. (2014). About NSSE. Retrieved October 6th, 2014

Prince, M. (2004). Does Active Learning Work? A Review of the Research. *Journal of Engineering Education, 93*(3), 223-231.

Northern Carolina State University (2011) SCALE-UP Site. Retrieved from http://scaleup.ncsu.edu/

Smith, M. K. (2012, August 28, 2012). Biased Sampling and Extrapolation. *Common Mistakes In Using Statistics: Spotting and Avoiding Them.* Retrieved 10/9, 2014, from https://www.ma.utexas.edu/users/mks/statmistakes/biasedsampling.html

Purdue University. (2013). The Active Learning Center: A Classroom Library Building. Retrieved from https://www.smas.purdue.edu/pdfs/Academic%20Program%20Statements/Active_Learning_Center.pdf

Wang, L., Ertmer, P. A., & Newby, T. J. (2004). Increasing preservice teachers' self-efficacy beliefs for technology integration. *Journal of Research on Technology in Education*, 36(3), 231-250.

Wills, Craig. (2015). Classroom Utilization Study: Worcester Polytechnic Institute. Retrieved from http://web.cs.wpi.edu/~cew/share/classroom15.pdf.

Appendices

Appendix A: Faculty

Faculty Survey

86% of respondents said they use some form of AL (95% confident that the true percentage of faculty that use some form of AL is between 82% and 90%, assuming population size: 485)

Q. 1	Do you use any AL techniques in class? AL is anything students are called upon to do to help them engage with the material, outside of watching, listening and taking notes in class.		
#	Answer	Response	%
1	Yes	156	91%
2	No	16	9%
	Total	172	100%

Q. 2	What AL activities do you use? (Check all that apply)		

#	Answer	Response	%
1	Having students solve problems in class	46	78%
2	Pausing briefly during lecture to let students discuss the presented material	51	86%
3	Introducing relevant problems at the beginning of each class to provide context and motivation	31	53%
4	Having students work in groups toward a common goal	54	92%
5	"Think-pair-share" or "turn to your neighbor and discuss..."	59	100%
6	Clickers	13	22%

If there are any other AL techniques you use, list them below (please be descriptive.
Mock situations, competitions, competitive exams and more
Role playing, group critiques
role plays, acting, games, etc.

I have students do exercises, such as an analysis of their own interactions using the learning pathways grid or selecting a Visual Explorer image to discuss their own sense of who they are as a leader in a group, or the river of life.

student presentations, student-led group discussions, "read and discuss" sessions, etc.

shout-out sharing if a group finds a particular source or technique that can be used by other groups working separately on

projects.

using computer labs and instruction on certain software packages to engage with the material

I ask questions and call on students by name.

Workshops where students actively practice research activities in small groups and/or provide each other with feedback.

Student presentations

I teach a small graduate class. We meet in a small conference room with a log VGA cord and each student brings a laptop. I can then pass the cord around and so even for short presentations my students can show not just tell. I know that in some public schools where every kid has a IOS device they can use Apple TV to project their device on the screen wirelessly. I think that that would be a great innovation at WPI. It would have to be something that works with laptops and hand held device. Imagine I could take a photo of my work on my phone and then project it immediately to the projector. OR as with my class the students project how they used the online tool.

present assigned topics

giving team oral presentations on assigned topics in class, based either on work done in class or work done outside of class.

A project accounts for about 1/3 of the grade for my grad classes. The topics are not assigned by me -- they are chosen by the students -- and there is much back-and-forth in choosing the project and as it proceeds through the semester.

Molecular models to visualize the structures and shapes of molecules in organic chemistry

Index cards: all students are asked to write responses on their own before being asked to comment in class

Respond to your neighbor: students sometimes ask questions in class and typically the instructor answers; in this technique students are asked to respond to classmates questions before, or as part of, an instructor response.

Students are asked to write short reflective pieces on the spot in class and then read them.

Students are sometimes asked to "go to the board" to present their thoughts in class.

Students are sometimes asked to read aloud from the text.

Air time: I keep a running tally of who has and who has been talking in class. I use this mental air time pie chart to help select student respondents.

Case studies

Case studys and clicker case studeis (these may be covered by the questions above), Giving out objects students can redeem for bonus points when the ask or answer a question.

By the end of the term the students are required to submit a professionally completed project that requires creativity, mastery of the covered material, ability to apply the theory to real life situations.

in class writing, have students "read" a tough text in class paragraph by paragraph in groups, with summarizing session on the blackboard, enact a trial transcript, group presentations, students take turns leading seminar class

I frequently have several students at a time come to the board to write exercises.

case discussions and case-based projects

two simulations and role-play-based case

Asking students relevant questions about the material to set context for moving forward.

Question/answers

Discuss issues in creativity, and then use software in our lab to allow them to work creativily.

I use the chat for online students

I use the discussion board

poster presentations: tape to the wall and discuss; role play interviews

This questionaire seems to assume that lectures are the normal for classes. That's not the case for me.

Other active methods: whole group discussion, small group discussion, role playing debates, interpreting a primary document like a political cartoon, field trips.

HAve students teach material, lead discussion in the class

1. Students are required to come prepared to the class by reading the reading assignments before each lecture.

2. Each student is asked to bring 2 creative/unique questions from the readings.

3. Students are put in groups of 7 or 8 and asked to discuss their individual questions for the first 15 minutes in the class

4. Each group is asked to come up with one challenge question for the instructor/rest of the class.

5. Some of the challenge questions may appear on the test so that it provides them incentive to pay attention in the class.

videos as examples and have them discuss; in-class activities that illustrate a particular concept

I have students help provide material for discussion (for example, they find examples of World War propaganda online and post it to the CMS so we can discuss it in class). I also have students interact with one another on the CMS discussion boards - they can ask each other questions, comment on class discussions or the readings for homework, etc.

I make use of online design tools, research examples from journals

Having students create their own classroom activities that will help other students learn. Having students give presentations. Having students select some of the course readings.

I use discussion board by starting a thread about a case study and encourage them to brain storm with other students in the class!

I use role-playing and simulation activities in my class, as well as other games.

Discussion of readings

I ask teams to prepare demonstrations and experiments relevant to the material covered in class (for economics classes). They present these demonstrations in class.
Lots of partner work, group work, mini-presentations. On occasion, a debate.
Group discussion
Lab time
Incorporate critical thinking problems in addition to more straightforward wrote problems
Discussion of issues in a HUA course.
Design games in which students work in teams to design, build, and compete with small constructions (e.g., paper tower or airplane)
use writing assignments in class to assess understanding of material.
Writing paper on business book. Preparing their own business plan to start up their own engineering business.
Role playing
asking students questions in class
I use an automated name selection system to ask review questions in a rapid fire fashion.
Discussion type exams instead of written exams.
Having students participate in demonstrations of major class concepts

Present research articles in teams.
I use hands-on activies using testing modules, for example, students collect data and analyze them using data acquisiton systems.
Computer-based exercises at a computer lab; guest speaker; plant tour
Assigned cases before class
role play
Take the floor and show problems and solutions to the class for comment, critique and advice
class discussion
Regularly use large (@ 25 person discussion) of assigned reading for half to whole class
I use the flipped classroom model where lecture/theory is provided online and class is devoted to problem solving, exercises, and applications.
interactive software - Maple for example
Students present material, projects. Students solve problems in groups.
role playing
I choose individuals and ask them short questions that require them to think about the subject.
Model classes after seminar format in which there are no lectures and only discussion.

Teaching students how to identify problems in one another's works and provide meaningful feedback that enables them to be the authority.

Working with students to create grading rubrics so that they can articulate all of the outcomes and evaluate based on those

I'm sure there's more

Asking for student volunteers to help with demos in the classroom

I raise a question. I ask the students to think for a moment, and then have them all hold up hands with some number of fingers to see which answer is preferred.

In history of biology classes I bring in materials to simulate what the actual work of scientists and naturalists in the past would have been like, and have the students work on solving 18th and 19th century problems in natural history such as classification of organisms and comparative anatomy.

In all classes I have students discuss questions from the readings for class in small groups, and then in the larger group.

Students work together on research projects and make presentations.

Students create visual diagrams in class about things from the readings that are complicated.

Occasionally we have debates, or students work in groups to represent various positions from controversies in the past, for example the Scopes evolution trial.

Whatever else I can think of to get people talking and moving.

roleplaying, asking students to become discussants for oral presentations,

prepare and review posters, discuss papers read at home

I use actual activities. Different demonstrations or videos and we discuss them.

Q. 3	Would changes in classroom design make your use of AL techniques more effective?		
#	Answer	Response	%
1	Yes	76	50%
2	No	32	21%
3	It depends (please specify)	43	28%
	Total	151	100%

It depends (please specify)
U-shaped seating, instead of rows, would be beneficial.
I tend to teach in classes where there is moveable furniture and I move it depending on the day. If all classrooms had that sort of flexibility that would be great.
Most of what I do works best in classrooms with moveable furniture, some of which we do have already. Moveable tables and chairs work well. Not sure what to do for large classes.
be sure the chairs in some classrooms are very simple and easy to pull into a circle or small groups. Nothing fancy!
I teach in different classrooms, so they are all set up differently.

it would depend on the types of changes (unsure)

It might, but I can't think of how.

Some classrooms have movable chairs and tables and some don't. Movable furniture is helpful.

Classrooms with fixed theater seating do not work well for group effort.

Would be nice if any in-class PC's video could be routed to the main projector.

Virtual or physical?

I dont know

Of course it depends; what change are we talking about. The most important single change in most classrooms at WPI is the need for mobile desk so that there can be a quick and easy rearrangement of work space in response to the needs of the activity.

To simulate a work place environment I suggest the oportunities for more team interactions.

not sure, but there is room for improvements

arrangements that facilitate small group work

on how you might change classrooms

I can make it work in current structure. there might be better desk/seating layouts and multi-screen options that might help.

I need to get online students more involved in the live interaction because most of my students are online

I hope so. Iam doing it for the first time this term (B14). It seems very promising as of now.

Classrooms with long tables work well; auditorium-spaces are harder because students have to actual move seats instead of slide chairs around

If it is applicable to online teaching platform

Standard lecture hall can make group work difficult

Virtually no seminar type classrooms on campus

Actually, I do not know how, but I would be happy to explore opportunities...

More modular classroom design would help with in-class small group discussions (ability to easily move desks and chairs around).

Some classrooms are better suited for group activities with movable chairs/desks

More than half my students are ADLN and participate in an asynchronous manner.

I'd like to ensure the podium and tables do not create a division between myself and the students.

Not having the students packed into the classrooms so tightly!

This does not seem like a "yes/no" question.... Tables where students can face each other.

fixed seats are tough

pod seating in small groups with computers that project so groups can cross communication and share notes right to course website	
Depends on the AL task and the changes	
I would like to see more classrooms on campus where students could gather around a table for purposes of discussion.	
I just started at WPI and so far have only taught one graduate class. I haven't had time yet to explore AL techniques.	
Movable seating has the most impact for this. Some classrooms have this, others don't	
A differently designed classroom would really help with this only if class sizes were lowered, but even with current large lectures, it would likely help a bit	
Not sure what you mean by the question. To have a projector that only occupies 1/2 the whiteboard so that additional problems and student work can be presented would be very helpful	
depends on what the classroom changes are. I'm having a real hard time with the Bluray players to work which is unfortunate.	

Q. 5	Would you be interested in trying AL techniques in the future?		
#	Answer	Response	%

1	Yes	9	50%
2	No	3	17%
3	Maybe/Undecided	6	33%
	Total	18	100%

Q. 6	Is there anything that would make you more likely to try AL techniques? For example, professional development to help you implement AL, or if classroom designs were changed to better facilitate AL.
Text Response	
If we had space to form students into small groups, that would be helpful	
I would certainly be open to learning more about this subject, including techniques that could be applied.	
Mobile apps that students can use after being authenticated to avoid need to physical clickers	
I should not answer any questions as I have been retired from WPI for 15 years.	
If they can be used in online teaching	
The design of current classrooms used for most ME courses are poor for traditional learning. The screen covers up the board. The ventilation is noisy.	

Faculty Interviews

Interview Form

Interview Replies

Interviewer

☐ Aaron

☐ Adam

☐ Kaung

☐ Reed

Professor Name

[   ]

Department

[   ]

Professor E-mail

[   ]

Date/Time

[Month ▼] [Day ▼]   [Hr ▼] : [Min ▼] [AM ▼]

Background

[   ]

How are you currently using active learning techniques? What are your past experiences with AL?

[   ]

How do the current classrooms affect your implementation of AL? Example? What difficulties do your students face when using AL in current rooms?

What are your thoughts on new active learning classrooms at WPI? Please explain.

What do you want to see in an AL classroom?

What requirements do you have for your classrooms? seating and capacity, presentations, etc.

Interested in being contacted later about design concept feedback?

☐ Design concept

☐ Project presentation

Other Notes

Interview Results

Q 1. How are you currently using AL techniques? What are your past experiences with AL?
Constantly count who's paying attention and speaking and interacting. Need to keep good mental counts of how much every student interacts. Pay attention to who hasn't been speaking, how the layout of the class affects it. Then think about how you can get the people who aren't speaking to speak. Have them write cards with info. Think pair-share. Have people get up and present. Summarize chapters, make sure that everyone has to speak. Very little electronics. Make sure that the students engage with each others, respond to each other.
Small room, senior level. Has lecture and lab time. In lecture used powerpoint, blackboard. Wants students to physically dismantle a component to learn how it works. Uses both solo and group work. The more examples and hands-on problems->students learn better. Actually seeing how something works is better than imagining how something works About 50-50 lecture-interactive. Small lectures mixed with group work.

Graduate business school, simulation excercies, role-playing ->two most active. Traditional simulation on laptops, TechMark: collaborative groups in classroom, work submitted through one interface, work is physical paper based. Groups up to 6, five consecutive classes, split with lecture, classes capped at 30, only 9 students now

Group work using laptops and small tables. Similar to GPS where groups solve problems over the course of many classes

Fairly small classes 17-18, AL=problems and examples, uses clides/sketches/charts/whiteboard,

EB1002, environmental biology. Large course

Clickers and clicker cases. Some small amount of trying to have students work together. In Flupper, hard to have students talk to each other, because students were

Generally around 150-160 students.

Gives rubber crayfish for bonus points, throws them at people to keep people engaged and willing to contribute. Had good results for student interaction. 120/150 students engaged.

Wireless can be an issue when a lot of students need to do online stuff.

Small game simualtions, had predator/prey simulations, disease spreading

Tries to never lecture.

Lab class has one lecture a week, both courses does lecture capture for everything. Tries to work on a flipped classroom model. One of the first people to do course-casting (Echo.) Blackboard quiz before class, talk about the things that people did poorly. A couple clicker quizzes a week, no other exams.

New method, started this term, no explicit plan. Students felt bored with plain lectures, not a "true" flipped course, give challenge questions day before and they get 10-15 minutes to discuss, team sof 7 or 8 students, exchange ideas, teach each other, take over for discussion or

lecture. Try to post lectures on myWPI to make it a true flipped classroom. Students required to bring questions to show they read chapters

Teaches graduate courses in creativity on leadership. Undergrad on working in diverse environments. Tries studio pedagogy (like art or industrial design.)

Uses a variety of arts based methods like theatre exercises, drawing, Visual Explorer. Email him asking us to send us a video of what he does (it's 2 hours long.) Wrote an article called "Material Matters" Math Statler, theory of the use of materials in learning. Lego vs clay for sculptures for learning

Groups people by assosciametrics, line up based on charcteristics

Students do a lot of drawing, needs table space

Environmental STudies and Policies. Pair and share, directed writing for group discission. Uses roleplaying Gov1320, international politics. Does simulations, gives roles to students, have them negotiate. Lots of moving around and talking to other students. Outside of those its mostly just discussion, not really any lecture. Students get split up into small groups for discussion. Seminar, Socratic method. Even in normal classes, there might be small activities.

Writes on the board a lot, no powerpoint.

Does it to keep students engaged because political science is not most peopel's interest, need to keep them engaged. Suits political science well

Intro to Materials Science, uses AL extensively. Forms students into teams of five. Students sit with their teams and start each class with a team quiz, they go through material that they reviewed outside of class and then move onto more advanced problems. Teams are called on to present responses. Lots of student group work. Has been doing it for fifteen years, students are very open to this sort of learning and very positive about it. Generally 75-145 student, generally around 125.

Used to own a factory and has 20 years of business experience, so mostly teaches MBA. Mostly teaches Achieving Effective Operations, wihch has a lot of basic cut and paste info, not useful to have lectures on it. Uses online quizzes to go through the basic material. PHD was on education as manufacturing. Tries to do single part flow for the students. Lectures are generally mostly about personal business experience. Mock events in class, like kaizen events, sets himself up as a welder for the company, is uncooperative in order to show that not everyone is an engineer. The purpose is to get actual experience and show how to get respect.

Time wise simulations for one-piece flow, making a clock as an example.

Tries to do a lot of group work (50/50 split, wants to step it up) work on example problems, groups of 3-4. Playing around with video lectures at home.

Uses 3d projection system in AK116. Wakes people up and gets them kind of excited. Used in biochemistry classes.

Uses chemistry demos as much as possible, gets someone from the class to help.

Tries to be energetic and keep the students awake.

Hasn't done this, but could be optimal to have a flipped classroom to get lecture at home

Wants to record class, not interested in Echo. Currently uses Camtasia with Microsoft Journal to record his screen on his (very old) touchscreen laptop.

Records review videos for math classes so people can study themselves.

Gives problems in class, tries to be interactive and have a conversation (at least in the smaller classes.) Encourages people to work together.

Not that enthused about computers because they're less active

lot of student discussion, team activities, show results to other students

At old school had whiteboards all around and had students write solutions, used smart board

doesn't use clickers

kind of uses project learning

student poster presentation

teaches systems engineering courses, SYS501, SYS579R, very small grad courses 3-10 people

uses echo360 for lecture capture

Basic economic courses: mix of lecture and activities and projects

In activities, students in group prepare an activity of a topic, demonstrate it to the class (5-10 students per group)

Roughly 50/50 time wise

In projects, students do work outside of class and present it

100 students

Leadership and social entrepenourship: students do icebreakers, discussion and form circles (20 students)

Also does online courses, completely separate

Drama pedagogy- re-enact stories they read

role playing

TPR (Total Physical Response): give commands and students act it out

Has students do problems in class, students work in groups both in and out of class

Architectural engineering classes. Students draw and do design work after some lectures in class. Works very well, works well for any types of lecture

Teaches adult learners, uses same concept.

1/3 lecture, 2/3 working.

Some group projects

Has a TA/PLA to help answer questions

Individual desk reviews, teacher sits with students individually to review their work

Student and instructor demonstrations, student and instructor critiques, gathering and acting on student input to fine tune each course offering.

I've been teaching with AL for > 10 years (group work, open class discussions, I ask leading questions of students to lead them to answers instead of just giving them information, heavy reliance on new technology, etc.).

In larger classes especially, I try once a week to have the class break into 4-5 groups and discuss separate questions, then report back to the whole class, which can then join in the discussion. This keeps everyone on their toes and participating and draws out the shy and reluctant students, who must at least contribute to their small group.

for large (>25) classes -- clickers, for small classes -- group work at board, if necessary at desks

Q 2. How do the current classrooms affect your implementation of AL? Example? What difficulties do your students face when using AL in current rooms?

SL305 is good because the tables have wheels. But because the room has two tables on one side, and natural light and windows.

Olin 118 is bad because tables are fixed and have courtesy panels. Terrible.

Screen covers blackboard space, takes too much time to switch between both by moving screen. Certain activities are hard to do in large classes. Discontinuous surfaces makes it hard to do some of these activities; lack of work space. One side of room can't see past screen. No sound propogation devices, specifically in ME, no integrated speakers (easy to use). Chairs with flipping desks can be improved; hard to move, take up too much space, small classrooms: no space to walk when full of students

Get different classrooms, so she can't get the correct size etc

Mobile furniture is important. The tiny desks and auditorium seating are bad.

Class capture for india is bad because it has a very small range that it captures, doesn't get the class very well.

Static chairs are bad, standing desk?

Bad lighting, can't be adjusted, monitors feedback (SL305)

HL154's AC is really loud.

Goddard 217 is a smaller ampitheatre, worked okay, most are pretty bad.

The ID2050 has difficulties because the clubs take classrooms.

Depends on classroom, encouraged students to get out of the room to get mental break. Stratton: terrible chair-desks, had chairs in circle configuration. Screen in middle disrupts writing space, prefer whiteboard or SMARTboard, never use blackboard on side. At Babson, video screen in back of the room to help speaker

Limited by space, mobility ruined by power cords/extension cords, limited by number of faculty

Limited by screen in center of the board, KH116: doc cam and digipen hard to use. Too easy to hide behind others in a group, one person may just take charge,

Very hard to do group work in lecture halls. Pretty much only in Flupper, very steep.

Smaller classes (60 or so) that are better, SL104, 115, etc. Still can't move around very much.

Teaches in Fuller lecture halls, can't use screens and white boards at the same time, takes too much time to draw everything on board, auditorium is very difficult to form groups in.

Tries to request classrooms with movable desks, SL402. Ofen moves all the furniture to the sides in order to open up the space. WB229 is terrible since you can't move it. Request classrooms works when he pushes a bit. MBA/MBO program, blended online and in class. Most of the class time is outside normal hours, though, so it's less relevant. Temperature control is important, needs to be temperate. Tables are much better than the foldover desks.

Sometimes you just need a huge space

last year in SL114 or 117. Has stadium seating, multilpe boards. Podium can block the board so you need to be aware

Fuller 320. Flat, so people can't see the board very well.

Goddard 227. Long, narrow, terrible. Hard for the professor to move

Having technology is important, but everyone needs to be able to see it. Desks don't need to move, but students do.

SL117 has some modularity because of movable chairs, FL320 has movable chairs, Goddard can't be moved.

In Salisbury 115. Thought that having more students in the class wouldn't be as much of an issue because of the student interaction. Usually requests SL115 even though she doesn't like it as much. Acoustics are okay, less steep slope. Fixed seating and fold up desks are limiting. Has the student groups clustered together, but its hard to have them interact when they're in multiple rows. Hard for the professor to circulate, has to leave rows empty so she can walk around and get by all the groups. Some students comment that the teaching shouldn't be done unless there's

a good classroom, but that's a small number. It would be much more effective with a better classroom.

Individual desks make it difficult to get groups together. Modular tables and chairs are very useful. 15-40 students. Not a fan of of round tables since someone will always be facing away from the professor.

CHE2014: hard to do group work in stratton. Likes multiple projectures and board space.

Upper salisubury labs are pretty good, could use more projectors, though. Has been able to request them this year, so there hasn't been an issue

Class size is the biggest problem, harder to keep people engaged in the bigger classes. Students in the back are cut off and disconnected.

Doesn't like the screen in the middle of the board. Wants to record class, would like to have a microphone for the class as well as his lecture. Specifically wants to be able to record in Camtasia.

Annoyed about having to set up and tear down materials

Doesn't like echo because he doesn't want video of himself or the blackboard, just the computer. Also doesn't want to work on a schedule. Doesn't like clip on mics.

Podium is too small.

Started to convert to bigger desks which inhibit group work because they can't be moved (202)

lack of whiteboard space

projection screen in the center and too tall, can't point on it

concerned with eye contact with students when using white board

hard to move things around, layout isn't flexible

not enough electric outlets

SL001 is horrifically poorly laid out

Stadium seating is very annoying because students can't form groups or move furniture

Wants to be able to walk around, not stuck at the podium

Wants to use clickers for students, tried it a few years ago and it was poorly organized. Is concerned about having a receiver bult into the classroom, would use to do attendance and quick quizzes

Wants to be able to quickly quiz students

Students have online tests in class, can't google

Lighter tables and chairs

Salisbury labs classrooms meet most of the needs, just need interactive system

Screens cover whiteboard

Would like students in U shape

Tables are screwed in, bad for group work

Scheduler tends to know what she likes

Blackboards too messy

Tables too heavy to move around

Tried using groups more frequently, didn't in current classrooms

AV systems very poor

can't see what's on screen while using doc cam or powerpoint

Software classes uses a computer lab. Students can have problems going back and forth between the teacher and their computer screen

KH202, computers aren't facing front

Studio classrooms: have a big divider in the middle of the room, very long and hard to have people see the overhead

Having the classroom set up the way it is with the computer screens in sight at all times makes it difficult to keep students fully engaged with what is going on outside of their computers. There is also little space in the front of the room to gather for discussions and physical demonstrations.

The layout of many classrooms makes AL difficult. It's hard to me to circulate around the room, it's hard for students to work in groups given the existing furniture and setups of the classrooms.

It varies. It's important to have moveable chairs--in many lecture halls, the chairs are fixed in place, and in some medium-size rooms there are tables that can't be rearranged.

see below

Q 3. What are your thoughts on new AL classrooms at WPI? Please explain.

95% of AL stuff can be done in standard classrooms, most of it is mobile furniture.

Modular classrooms would help lab classes; pillars in the way, tables fixed. Class times are too short with a big class; modular classrooms would be too difficult. "Arena-style" sections in tiered tables; separate students during tests.

Hard to have posters displayed because there's not enough space on the walls, things don't stick, etc.

Needs to be able to present IQP, projector layout.

User interface for technology, difficult for Mac users

Podium doesn't have enough space. The little tray that pulls out for the laptop is inconvenient

Needs to have some ability for lecture.

Better support for talking to india

Having multiple screens is advantageous, different content on each screen, presenter notes

Is there a thing as too much technology? Which technology helps, which do we use just because it's cool

Screen sharing might be useful when course turns into full flipped class

Studio classrooms could be useful, display stuff on the walls. Works okay if you can move all the tables and chairs.

Lecture isn't very useful except for advanced topics in small groups

MBA case room isn't useful, for large group dscussion, we don't have them

Studio classrooms would be pretty much perfect for Gov1320, but not required. A little less convinient but workable for other classesPutting more thought into classroom layout and classroom assignment would be very helpful, assigning based on the type of teaching.

Could also just make our existing ones more modular so students can move around.

Defenitely in favor, her use would really be benefited. STudents could work better in groups, look at each other, look at shared papers, maybe have a shared monitor.

Video distance lecturers to get more experience. Asynchronous vs synchronous time, makes sure there's always some synchronous time, for distance learning stuff. Blended residency days with distance learning stuff being presented remotely. Have recordings of lecture for people who weren't there.

Could be useful, but not overwhelmingly necessary.

In favor

Yes, absolutely!

Yes! The current classrooms make it difficult to teach with AL.

Yes. I realize that in large lecure halls this is probably impossible. With our classrooms now being virtually all in use, it is probably a matter of the instructor requesting certain rooms whose configuration works!

Usually I can arrange to be in a good room -- OH 126, 218, 223.

A bad room is OH 109: desks immovable, very hard to circulate, very limited board space, screen covers most of the board

More good rooms would be better, although generally I get what I need.

Q 4. What do you want to see in an AL classroom?

Maximize furniture flexibility. Very, very important.

Whiteboard and blackboard space is useful.

Document cameras to show students work in class.

Screensharing technology could be useful, but needs good training. Natural light.

Long continuous tables (also helps during exams, especially with open note/open book), sound propogation devices, two projection systems separate from the board (can use screens along with board, as well as all students being able to see) Technology that automatically screenshots writing on board so it can be put on mWPI

Ability to configure seating in small U-shapes, trapezoidal shapes, creating privacy in between competing groups, no specific technologies needed for each team, document camera, screen sharing technology would be useful, necessary? SMARTboard technology, whiteboard space all over the walls. Use mobile whiteboards to create breakout rooms within the classroom

Movable everything, possible tiers so all groups could see the professor. Possibly move the good groups to the back and the groups that suck to the front so they can get more attention.

Rooms need plenty of space for materials/tools, desks need to be big enough to accomodate materials. projector at the side of the room, not the front, what features in a room could be used for video conferencing/distance learning? Live video in rooms, useful for snow days, can still hold class

Mobile tables, especially for the 60 person classes. Power outlets. Screensharing technology.

For big lecture halls, potentially the Purdue sort of layout.

The technology for the teachers is generally enough. Some sort of mobile technology so you can walk around and draw on an iPad or something? Security issues. One person he knows has tablets he can hand to students for them to write.

The Surface can push directly to TV's, maybe that would work?

Software available for all students (physiology) or develop software. Just a plain classroom with movable chairs, have students stand up around taller tables to get more involved, two screens on either side with board in middle

Technology, an IQP in copehagen, "Information in Computer Technology" last D term. Whiteboard paint all over the place is really useful. Easy to use, no learning curve, low support costs. Gives a more creative feeling, more fluidity, more expressive

Flat classrooms with mobile furniture

Technology isn't as useful, because it's really paper based and computer based. The technology can be useful (video, web, etc), but only if it works very well. Screens for the students group can be useful, could push her notes to their computers. Could also have them turn their chairs. Need to make sure everyone can see what's being done.

Studio classrooms are less convenient when students do need to be going back and forth to the board, more for the simulation classes

Maybe a studio classroom wouldn't work since it wouldn't have enough space, but a lecture hall set up so students could face each other and work togoher would be great. Studio classrooms can force certain group sizes, which can be bad. Be careful: AL classrooms could be constraining, too. Modular classrooms could be very useful, but could also cause logistics problems for fast changeover: engaging students in the process could be helpful. New technology isn't as useful unless there's really big benefits. Screensharing technology could be useful, though, some people think that's useful. Could be good to have the option. Probably more useful when it's been more developed and proven.

How could we do screensharing with non-fixed tables, not fixed group sizes?

Challenge: individual traditional exams need to still be suitable for the classroom. Indiviual assessment is still necessary, takehome exams have major academic integrity issues.

Mobile furniture, lots of board and projector space. Potentially trapezoidal furniture?

Break up the class into smaller groups.

Professor needs to be able to get around the classroom

Could be useful to have a classroom set up for chemistry experiments: fume hood, etc.

Re-derived studio classrooms. Concerned about class size, could be issues with still not enough faculty student interaction

Good to have a space with multiple things you can do in it

Modular furniture

Rooms should be flexible

Projector shouldn't dominate the board.

More space on the podium

White boards all the way around

Window shades to adjust glare

Good facilities maintenance to keep things working, wants them to look in and ensure everything's working

Low level of background noise (eg AC)

No need to set things up

More electrical outlets for computers

Thinks studio classrooms look really good for AL

More than one projector so you can have multiple things going on

would like to have students use whiteboards

smart boards

NO CHALK BOARDS

some way of capturing white board and lecture to get that info pushed up for everyone

wants to be able to capture audio from the students

distance learning synchronous

electric outlets, possibly have checkout for laptops or something

modular furniture could be nice, but concerned about everything being messed up when they come in

coat rack could be useful for rooms that are filled to capacity

more mobile podium, with a handle or something

Studio classrooms may be able to work, would be interested in trying

Wouldn't be interested in tiered at all

Potentially would like to be able to cut off the cellphone access.

Code of conduct. Not comfortable with students recording lecture

Maybe interested in recording classes , but currently its difficult. If it was very simple to do that'd be good

There's a technology for having a camera aut follow you, you wear a little tag that it tracks. That could be useful

Mobile chairs and tables

Sink in classroom to wash hands of chalk (apparently common in Germany)

Full tech, complete computer/DVD/projector

Lots of natural light with shades

Ideally nice nature view

Colors should be pleasant

boards with adjustable heights, slide up/down, prefer whiteboard

Comfortable chairs

Better HVAC control, quieter fans

Open top of windows for fresh air

Recording device on doc cam

wants to use clicker polls

wants to provide more in-class problems ahead of time

two screens, good AV equipment, mobile tables, AK233 most similar to ideal classroom, if floor was flat and tables were mobile

Larger screen so everyone can see it?

Screen sharing could be useful, especially if they had dual monitors for the software class

movable chairs, lots of board space, computer podium with projection and ability to write on the screen and a means to save what's been written, ease of circulation for instructor

I would like the layout to be

For smaller classes, a conference table would be nice, but with enough room for me to circulate around it. For larger classes, easily moveable desks or some other configuration (e.g., small tables) to support group work and again with enough room for me to circulate. It would be great if both would be set up for new technology (e.g., tablets at each group station).

Access to a media station for Internet access and an iPod cable is essential (ironically, these are NOT always available in small seminar rooms that DO often have good seating arrangements). Beyond that, moveable chairs and tables.

Q 5. What requirements do you have for your classrooms? seating and capacity, presentations, etc...

GPS is 60 (use 305), environmental studies is 48, IQP prep 16-28

Statics: 70 students/class, two sections. AC system pretty loud; distracting. Climate control is very uneven; only real climate control is to open/close windows. [Possible digital controls? The technology exists. Make somebody do it for an MQP]

150 or so seats. Group size of 4-5. Run once a year. This professor doesn't always teach it. Hoping to start teaching it twice a year.
44 students this term
40-60 students, occasionally powerpoints, more control over lighting
40-50 is usually the maximum size. The fewer the easier it is because they have more space to move. Gov1320 is only 50 students once per year, could grow in the future
Lots of seats since there are so many students Power? How would that work? Could be very expensive.
35-60 person sections
Has 4 classes per year. 24 for two of them, pretty much all lab 150 for a general chem B term, 120 in C term Boards, doesn't use powerpoint visibility so that everyone can see whats happening and be engaged
Lin alg is 175 students (lecture)

40-50 students for calc
Small classes, 10-25 students. Every student needs a computer Groups of three Needs a projector, whiteboard
I need to get to my students. Most classroom as so crowded with chairs and often students (with their luggage) that I cannot reach individual desks to help people working in groups or on exams.
I would like the layout to be changes so that the computer screens are against the walls facing the middle of the room, so that students must turn away from their screens when the instructor or other students are talking. I would like a synchronized cloud storage folder on every computer so that files can easily be shared by the each student and any file can be instantly opened on the podium computer. I would also like a way for the podium computer to override the displays on the student computers when necessary for demonstrations.
I always need a computer, projector, and screen. I also use clickers, USB pointer/remote device, a wireless microphone for large classes. A lot of the rooms where I teach seem overrun by professors who prefer to use chalk. The chalk dust ruins the tech equipment I use and people actually leave pieces of chalk and chalky fingerprints all over the computer station. This creates a lot of problems for people who use tech (ask ATC or helpdesk about the effects of chalk on

the equipment). In larger rooms, people very often don't clean up after themselves and leave food (!), drinks, etc. on the computer station.

I would prefer to have high-tech, AL rooms reserved for those who know how to use the equipment (no chalk, no food/drink, people must clean up after themselves, people with the requisite knowledge to use the equipment, etc.). As it is now, people do things they shouldn't do with the tech in the classrooms, which makes things more difficult for people like me who rely on it (e.g., they shut it down in the middle of the day).

I like to have a lectern--I don't usually lecture formally at great length, but I do like to have a handy place to put my notes. Some rooms lack lecterns, and some have very heavy ones that can be tough for older faculty like me (!), especially if I'm fighting a bug and feeling out of sorts (like so many students!).

I asked my students this term if they prefer my somewhat messy PDF notes from the podium, or if they would prefer me to use the chalkboard, where I could be neater and more organized, but the notes would not exactly match what we did. Overwhelmingly, they prefer projection from a podium and a PDF file thereof.

Appendix B: Administration

Interview Questions

Academic Technology Center

1. What parts of the classroom are your jurisdiction? Which parts are handled by other administration?
2. How do you support faculty that use AL?
3. What technology do you already have planned to implement?
4. In your experience, what are the most popular or useful systems used at WPI?
5. Office of the Registrar
6. What are the utilization requirements of WPI classrooms?
7. What is the minimum seating requirement for different types of classrooms?
8. How flexible must classrooms be in order to accommodate other styles of teaching?
9. Any other utilization requirements?
10. What is the process for assigning classes to rooms?
11. Do professors have a say in what room they get?
12. Would they if WPI built AL classrooms?

Information Gathered

Academic Technology Center

- All of the AV is handled by ATC as well as podium equipment and shades. Furniture, lighting, windows handled by Facilities. Computer image is managed by the hosting team. In overall structure ATC and Facilities both report to Financing.
- There are 800-900 unique students using clickers this term
- Provides support for flipped classrooms, clickers, 3D projection, lecture capture, computers used in labs, and online courses
- ATC is very involved in designing info commons and tech suites
- Probably going to need more dedicated support for classroom space and course design in an AL classroom
- Looking into expanding 3D projection
- Echo360 is rolling out AL technology to provide support with screen sharing and flipped classrooms. Potentially a problem working on our network.

- Survey among faculty showed little interest in SMART boards, but that was a while ago. A new study might show different results.
- When using modular furniture, consideration has to go into the American Disabilities Act, power, and data
- Mobile, wireless displays for professors would be very useful

Office of the Registrar

- We currently have: 41 classrooms from 25-225 seats, five lecture halls with over 100 seats, large cluster of medium sized (70-102 seats) classrooms and a couple classrooms that are about 25 seats with various layouts ranging from tablet arm-chairs to tiered tables
- Rely on building and fire code to determine capacity
- Use population limit on classes so the appropriate room can be assigned
- GPS classrooms are going to be implemented in the Alumni Gym renovations
- Faculty have historically requested rooms of different design
- Very little space available to be turned into new classroom space
- Probably won't be able to justify reducing space due to growth of the student body and programs
- Class size is increasing dramatically, creating difficulties
- We're okay with lecture halls but could use expansion of mid-size classrooms
- Ideal capacity is 67% of actual capacity to allow students room to sit, move, and take tests
- Tries to accommodate everyone, but there is too much overlap in terms of needs and desires

Office of Undergraduate Studies

- Lecture and AL work well as part of a system
- WPI Plan was created 40 years ago, maybe it's time for an update
- Peer mentoring and professional development currently informal; done mostly by department and based on faculty learning communities
- Students at WPI are used to lecture, a change in teaching style would be met with resistance at first

- Currently updating our strategic plan using a six pillar method. Three initiatives looking at the undergrad program. The most promising one is the "radicals" who are trying to elevate project work even more and assign competency based credits
- It'd be great to have course design and professional development (like Indiana) but we don't have anything like that, tough to get money for that.
- Students don't seem to like flipped classrooms in course evaluations
- Some data shows students learn better when they're a little uncomfortable

Appendix C: Other Schools

In our interviews with other schools, we came in with a few questions based on our previous information gathered from administration and faculty. However, other than these basic questions we left the interview as open as possible so they could provide input on what they thought was important. The following is a list of our questions.

- What is the average classroom utilization percentage for the AL classrooms at your school?
- How do you deal with decreased room capacity of AL classrooms? Do you build new classrooms?
- How beneficial would it be to have modular classrooms?
- What kind of support system for faculty did you implement when implementing AL classrooms?
- How do you deal with the noise in the classrooms
- What are some metrics for evaluating effectiveness of the classrooms?
- What technology and classroom features have been particularly effective?
- What technology and classroom features have been ineffective?
- What challenges did you face from administration while trying to get AL classrooms built?

North Carolina State University: Robert Beichner

- Studio classrooms are most effective at 100% capacity. There is no need to leave open space for students, and it would cause problems for group formation.
- There are a variety of different table designs that can be used for different purposes.
- 7 foot diameter round tables seating 9 students each are best.
- If those are too big for the space, 5' D shaped tables can be used with 6 students per table.
- Mobile trapezoidal tables are useful if the room needs to be used for lecture as well.
- UMN's split tables are not very useful. The round tables are more optimal, and they haven't needed to break them apart.
- Using thin-backed chairs allows for more room to walk around

- Different schools have different approaches for professional development.
- University of Iowa has a very in-depth formal program, requiring teachers to be certified to use their A
- NCSU allows anyone use their rooms. They support them with faculty learning communities.
- While NCSU's approach is effective, it only works if faculty are experienced with the rooms. Beichner recommends we bring in outside experts until we have experienced teachers.
- Having professors do sit-ins on successful AL classes is very helpful.
- A variety of different metrics are useful for judging and optimizing classroom and course effectiveness in the long term
- Reformed Teaching Observation Protocol (RTOP) is useful for evaluating the forms of activities that goes on in the classroom, useful for research.
- Standardized subject tests are good for judging learning objectives compared to traditional classrooms and approaches
- Surveys of the students and faculty who use the rooms can get good feedback on the impressions of the rooms
- It is important to have a single computer per table. NCSU does this with laptops
- Having more than one computer divides attention.
- It can also be done with fixed computers or having students bring their own.
- Screensharing for the students is very useful
- NCSU uses Apple Remote Desktop
- Classtaught
- Not necessary for small rooms, students can just look across the rooms
- The rooms do get quite loud
- Professor should have a microphone to get the attention of the students
- Students should have microphones in larger classrooms
- Acoustic tiles in the floor and ceiling help
- Whiteboards are very important
- glass whiteboards are the best for the walls
- Students can write on windows if necessary

- Smaller whiteboard tablets for the tables are very useful, can be made out of white bathwall
- Conflict with administration
- Admin insisted it had to be multipurpose as a computer lab, provided too many laptops.
- Design group needs very specific instructions. They once put light fixtures in the way of projectors.
- Smart boards are not very useful in his experience. Highschool classes like them, though.
- Classroom capture is not very useful.
- It's hard because the professor is moving around a lot.
- It's not useful because there's no lecture to record.
- Input from students is not useful during the design stage.
- They don't know enough about pedagogies to be useful.
- It can be useful once the classroom is running.

University of Indiana Bloomington

- Seat counts in AL classrooms do go down. It's important to fill those rooms first so they're utilized effectively.
- In training faculty, faculty learning communities are most effective.
- Good to bring in outside people until local faculty have the expertise to train each other
- It's important to define how much we're looking to transform the pedagogy.
- SCALE-UP classrooms fundamentally change the way they teach.
- Other classrooms (eg rectangular tables) are more flexible.
- There are a lot of different types, find the ones that work best.
- Evaluation of the types of rooms:
- Surveys and input from the students and faculty gets mostly at attitude, not learning
- Observation is very useful
- Classroom Observation for Undergraduate STEM (COPUS)
- Important to calibrate the observer
- It's helpful to have an automated tool for information gathering and analysis

- Evaluate the training systems: what training systems lead to more teachers adopting the techniques?
- They've standardized classroom support under their classroom technology group
- Support from administration is helpful
- Their driving force has come from IT and academic affairs
- The drive for AL aligns with their strategic plan. How well do AL classrooms tie in with other initiatives?
- It's good to have larger initiatives rather than just building rooms so it can be well supported.
- It's important to get students involved in research and professional opportunities.
- Training TA's for the larger AL classrooms is very useful.

Appendix D: General Design Guidelines for Studio Classrooms

Figure 20 shows a few examples of how studio classrooms can be made from any type of room shape. Dimension A indicates the distance between the wall and the table. Dimension B indicates the distance between tables. Dimension $\emptyset_t$ represents the table diameter. Since the tables are arranged in a simple grid formation, it is easy to generate layouts for any room size. The examples below are generated using A=3.5 ft, B=5 ft, and $\emptyset_t$=6 ft. After setting these parameters we calculated the minimum room dimensions for any given amount of tables. Room 'i' has 3 tables on the X-axis and 2 on the Y-axis (i.e. $n_t(x,y) = (3,2)$). The minimum length of sides X and Y of the room can be determined using simple math to add the stacked dimensions of the room.

$X = 2A + n_t(x)\emptyset_t + [n_t(x) - 1]B$
$Y = 2A + n_t(y)\emptyset_t + [n_t(y) - 1]B$

As $n_t(x)$ and $n_t(y)$ increase, the contribution of variable A become less and less significant. Therefore rooms with more of tables (and more square footage) are more space efficient than rooms with less. As you can see in the figure below, the ft^2 per student decreases as the room grows and tables are added (while maintaining constant values of A, B, and $\emptyset_t$).
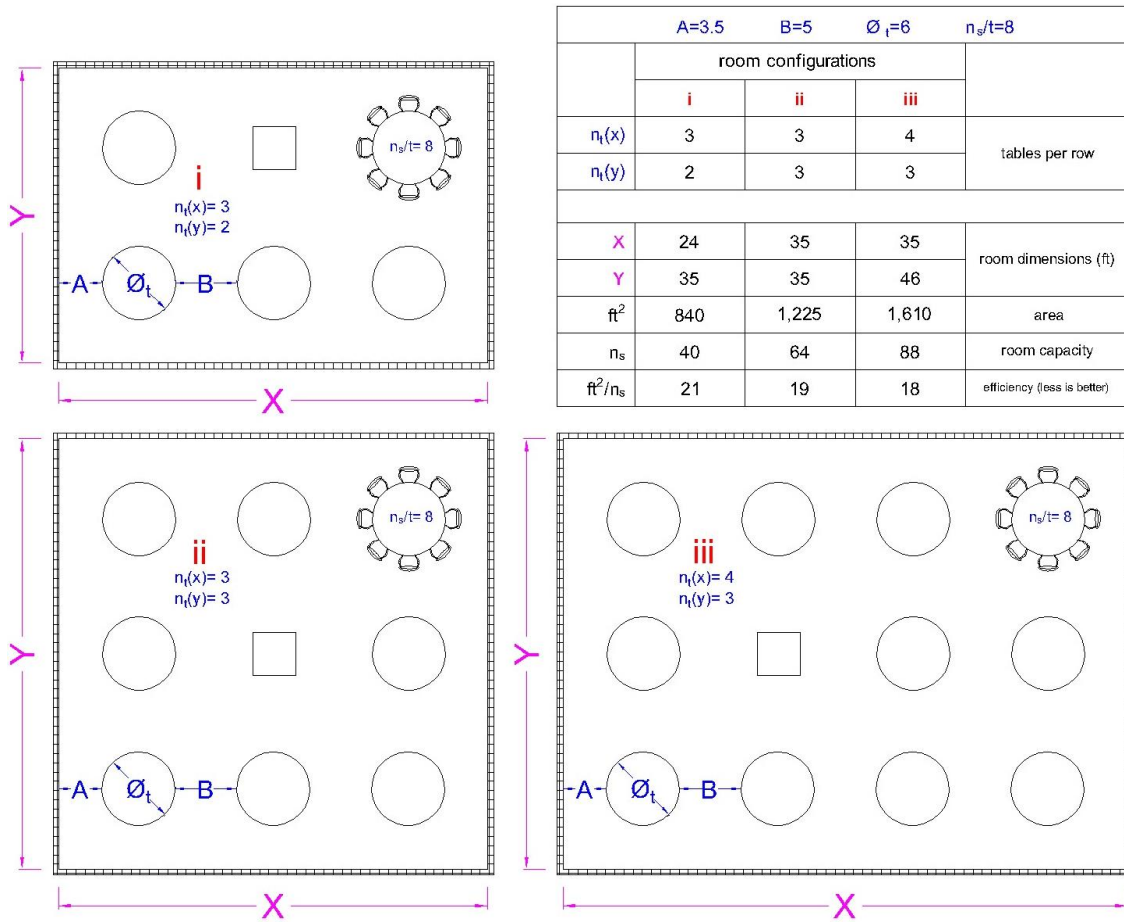
	A=3.5	B=5	Ø t=6	n s/t=8
	room configurations			
	i	ii	iii	
n_t(x)	3	3	4	tables per row
n_t(y)	2	3	3	
X	24	35	35	room dimensions (ft)
Y	35	35	46	
ft^2	840	1,225	1,610	area
n_s	40	64	88	room capacity
ft^2/n_s	21	19	18	efficiency (less is better)

Figure 19. General studio classroom design guidelines

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Appendix E: Cost References

Interchange Medium Round End Multimedia Table by Smith System. from http://www.worthingtondirect.com/computer-furniture/interchange-medium-multimedia-table-by-smith-system.htm

LG LB5550 49" 1080p 60Hz Class LED HDTV. from http://www.walmart.com/ip/LG-LB5550-49-1080p-60Hz-Class-LED-HDTV/39097418

NEC NP-PA500U - LCD projector - 3D Ready - 5000 ANSI lumens - WUXGA (1920 x 1200) - widescreen - High Definition 1080p - no lens. from http://www.amazon.com/NEC-NP-PA500U-projector-widescreen-Definition/dp/B004QOCKRW#