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Dissemination of Active Learning Tools for Software V&V Education and Their Pedagogical Assessment

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Dissemination of Active Learning Tools for Software V&V Education and Their Pedagogical Assessment

Abstract

Imparting real world experiences in the classroom for a software verification and validation (S/W V&V) course is typically a challenge due to lack of effective Active Learning Tools (ALTs). At Robert Morris University (RMU, the author's institution), this educational resource gap has been addressed by developing several ALTs in the form of class exercises, case studies, and case study videos that were created by collaborating with the academia and industrial professionals. Through this three-year work 20 delivery hours of case studies, 18 delivery hours of exercises and 6 delivery hours of role play videos totaling 44 delivery hours of Software V&V course materials have been developed. The developed tools have been disseminated through two hands-on summer workshops held at RMU in 2015 and 2016. In addition, several ASEE and other conference posters, papers, presentations, and journal papers have been published over the past three years. This NSF-funded project has been implemented and assessed and is now complete, however the author continues the disseminate the outcomes of this project

The basic objectives of developing the ALTs are to improve student engagement and interest in software education, and to make the education well aligned with academic research as well as industry best practices. The ALTs developed in this work are designed to impart knowledge of several important themes in S/W V&V education such as *requirements engineering, software reviews, configuration management,* and *software testing.* Four key skill areas sought after by employers, namely *communication skills, applied knowledge of methods, applied knowledge of tools, and research exposure* are also covered by the ALTs. These tools have been deployed in classrooms at several partnering institutions. Student feedback from RMU and partnering institutions have been collected and analyzed by the external evaluator to determine the pedagogical effectiveness of the ALTs. In addition, ABET outcomes assessment has also been performed by the course instructor at RMU.

Preliminary results support the hypothesis that ALTs constitute a better way to engage students in their learning process, and for enhancing their comprehension and interest in the S/W V&V topics being covered in the class. The student outcomes assessment data and pedagogical assessment data are presented and discussed in this paper. The class management strategies for delivering ALTs are presented in a separate accompanying paper in this conference.

1. Introduction and Rationale

Traditionally in engineering education, student-centered lectures have been the predominant model of teaching. However, it has been suggested [1] that this may not be the most effective method for imparting knowledge in all disciplines, as students may not be able to retain and apply knowledge they have gained to the extent that is required in their professional careers. Therefore the current push is towards flipped class rooms [2] and active learning tools [3, 4]. Active learning/teaching tools complement lectures and make class delivery more interesting to the learners. Active learning is defined as "a learning environment where the teachers and students are actively engaged with the content through discussions, problem-solving, critical thinking, debate or a host of other activities that promote interaction among learners, instructors and the material" [5]. Prince [6] defines active learning as a classroom activity that requires students to do something other than listen and take notes. Active learning is achievable by complementing lecture materials with case studies, class exercises and case study videos. Effective teaching requires effective teaching tools. More importantly such tools effectively assist the student in retaining knowledge. Active learning teaching tools such as case studies, class exercises, and case study videos have been utilized in a variety of teaching disciplines, including Biology, Medicine, Law, and Business. It is proposed in this work that these interactive pedagogical tools are especially important for software engineering education as well, specifically for software verification and validation courses, where graduates are expected to develop software that meets rigorous quality standards both in functional and application domains. The software V&V professionals must interact with other software professionals such as developers, and with customers for requirements elicitation. They must then contribute to develop a project proposal that can subsequently be turned into a legal binding contract. The accuracy and reliability of the software product are usually the technical performance measures in which customers are keenly interested. Therefore, case-study based education and videos of SW development scenarios are expected to enrich and enhance undergraduate education in software V&V.

1.1 Active Learning Tools: Case Studies

Case studies can serve as useful tools to teach applications of science and engineering principles. Raju and Sankar [7] define case study education as providing students with a record of a technical and/or business issue that actually has been faced by managers, together with surrounding facts, opinions, and prejudices upon which management decisions have to depend. Using case studies as a semester-long tool to teach neuroanatomy [8], in which students were actively engaged in the presentation and discussion of case studies throughout the semester, resulted in more understandable and enjoyable learning experience for the students. Biology was taught effectively [9]. Many other examples of the successful application of case study based methods in engineering have been given in a survey paper [10] where they observed increased learning and synthesis and analysis within the surveyed students. Case studies were applied [11] in six courses to help students (i) understand complex and complicated issues and describe interrelated processes; (ii) discuss policy- and decision-making ideologies that either are politically or socially charged; and (iii) engage in informative and focused classroom discussion. The results indicated that use of the case study method as an active learning tool provides students with a variety of important skills necessary for success both in and out of the classroom. Specifically, active learning helps students develop problem-solving, critical-reasoning, and analytical skills, all of which are valuable tools that prepare students to make better decisions and become better students and, ultimately, better employees.

Raju and Sankar [7] undertook a research to develop a teaching methodology to bring real-world issues into engineering classrooms. The results of their research led to recommendations to funding agencies and educators on the need to develop interdisciplinary technical case studies so that the innovations happening in the field of engineering can be communicated to students in the classroom.

1.2 Active Learning Tools: Class exercises

Class exercises provide class time to explicitly raise questions that invite student participation. When well designed for the context and presented in the right setting, class exercises raise questions for the students to exercise their thinking. Depending on the focus of the questions, the students may be more motivated to investigate the subject matter, may gain a deeper understanding of course concepts, or may improve their skills through hands-on experience using the knowledge in problem solving and design derived from the exercises.

There are many ways of using class exercises in the classroom setting. For a small class size, the teacher may simply use an exercise to engage students in discussion and hands-on practice. For larger classes, the students can be assigned to small groups using the class exercise as an instrument leading to group projects. Woods and Howard [12] effectively used class exercises for Information Technology students to study ethical issues. Day and Foley [13] used class time exclusively for exercises, having their students prepare for class with materials provided online. Bishop and Verleger [14] presented a comprehensive survey of the research that reviewed different ways of using class exercises in the classroom, often referred to as the "flipped classroom." Frydenberg [15] primarily used hands-on exercises to foster student understanding in data analytics. Well designed, class exercises become very effective learning tools and can be versatile in various classroom settings.

1.3 Active Learning Tools: Case Study Videos

One commonly used technique to enhance the classroom learning experience is the use of video. Videos are viewed as an effective method of presenting standard material while addressing students of different learning styles. A video engages visual learners with its images and motions, while auditory learners can listen carefully to the narration to gain an understanding of the topic.

Videos are an essential part of the flipped classroom model, in which the preponderance of lecture material is presented before class [16]. The class time is then spent on discussion and teamwork, reinforcing the material from the previous evening. Overall, the flipped classroom model has proven highly effective at increasing student engagement and enhancing the preparation of students for class sessions [2]. The flipped classroom also has been shown to allow the instructor to cover more material and results in higher student performance [17]. However, videos can also be used in a traditional classroom, and their use can be highly effective. There is extensive experience in using audio visual materials in the classroom, ranging from the usage of filmstrips during World War II to train solders [18] to modern digital video. Watching videos can reinforce reading and lecture material, help to develop common knowledge, enhance the quality of discussion and overall student comprehension; accommodate students of different learning styles, increase student motivation, and increase teacher effectiveness [19]. Videos can aid in showcasing highly complex concepts and ideas in a short period of time, provoking meaningful discussion and analysis.

Through a project funded by the National Science Foundation –Transforming Undergraduate Education in Science, Technology, Engineering and Mathematics (NSF-TUES) -- a required Software Engineering course at the author’s University, namely Software Verification

&Validation, is supplanting existing lecture modules with additional pedagogical tools that have many benefits. First, the improved courseware with the new tools are appropriate for delivery in undergraduate education programs, thereby improving the skill and knowledge level of graduates who will enter the software development profession. Second, the courseware is packaged in discrete modules so that the project results can be used for in-house training programs that will improve the skills and knowledge levels of current software practitioners. Finally, the courseware has been developed and tested through the efforts of a team of university and industry partners creating a V&V community that can champion and promote expanded institutionalization of V&V best practices.

2. Active Learning Tools Developed in this Work

This project is developing the following: twenty (20) delivery hours of case studies, eighteen (18) delivery hours of exercises, and six (6) delivery hours of case study videos. The twenty (20) delivery hours of lecture slides used in the author's institute have also been enhanced. In total, sixty-four (64) delivery hours of Software V&V active learning teaching tools and lecture slides in the form of course modules are created/enhanced.

2.1 Case Studies

At the time of writing this paper, eleven case studies as listed in Table 1 have been created. They have been reviewed and delivered multiple times. The case studies have three sections: *case study details*, *exercise*, and *instruction notes*. The case study details provide information on the focus area, case module name, prerequisite knowledge, ABET learning outcomes, keywords, expected delivery duration, and an explanation of the scenario. The exercise section describes what the students need to do. The instruction notes section provides details on how the instructor should deliver the case study. Some case studies can be completed entirely in 50-minute sessions, whereas other case studies are broken down by homework and classwork and require multiple sessions. All case studies require teamwork and communication in addition to subject matter knowledge. At the end of the case study delivery, students will be assessed on teamwork, communication, and content knowledge.

Table 1: Case Studies

V&V Focus Area	Case Study Modules	Mins.
Requirements Management	Understanding User Requirements	50
	Requirements from a Customer's Perspective	250
Software Configuration Management	Continuous Integration	100
	Version Control Management System	100
Software Peer Reviews	Importance of Reviews	100
	Peer Review Tools	100
Testing	Test Case Development	50
	Performance Testing/ Load Testing	50
	Software Test Plan (STP)	100
Additional Topics	Liability for Bad Software and Support	50
	Software Legal Issues	50
	TOTAL	1000
	Contact hours (50 minute periods)	20

2.2 Class Exercises

At the time of writing this paper, sixteen class exercises as listed in Table 2 have been created. They have been reviewed and delivered multiple times.

Table 2: Class Exercises

V&V Focus Area	Class Exercise Modules	Mins.
Requirements Management	Ambiguous Questions	25
	Business Requirements and Functional Requirements	50
	Clarifying User Requirements	50
	Needs Statement to SRS	50
	Needs Statements to User Requirements	50
	Requirement Ambiguity	50
	Stated and Implied Requirements	25
Software Configuration Management	Defect Lifecycle	50
Peer Reviews	Code Inspection	150
	Review a given SRS with Checklist	100
Testing	Cost Effective Testing Approach	50
	Test Cases for a Given Requirement	50
	Testing Tools	50
	Understanding Testing	50
Additional Topics	Deming's 14 Points on System of Profound Knowledge (SoPK)	50
	Understanding IEEE Standards	50
	TOTAL	900
	Contact hours (50 minute periods)	18

Each exercise is accompanied by an exercise description in MS Word format and an instructor slide in MS Power Point format. The class exercises also have three sections: *exercise details*, *exercise description*, and *instruction notes*. The exercise details provide information on the focus area, exercise module name, prerequisite knowledge, ABET learning outcomes, keywords, and expected delivery duration. The exercise description section describes what the students need to do. And the instruction notes section provides details on how the instructor should deliver the exercise in class. The exercise is also available on a separate page for easy printing. Some exercises can be completed entirely in 25- or 50-minute sessions, whereas other exercises are broken down by homework and classwork and require multiple sessions. All exercises are discussed in class. At the end of the exercises, students will be assessed on communication and content knowledge.

2.3 Case Study Videos

At the time of writing this paper, three case study videos as listed in Table 3 have been produced. All videos have appropriate narrations and pause points for class discussions. Pause points and discussion questions are provided in the videos for class discussions. At the end of the discussions, students will be assessed on communication and content knowledge.

Table 3: Case Study Videos Details

V&V Focus Area	Case Video Modules	Mins.	# of Scenes
Requirements Management	Requirements Elicitation	100	5
	V&V in Scrum	50	4
Peer Reviews	Code Inspection	100	7
Testing	Testing and Security	50	5
	TOTAL	300	21
	Contact hours (50 minute periods)	6	

3. Project Outcomes, Evaluation and Assessment

The expected outcomes from this project are grouped into three broad areas:

i. ***Improved knowledge and skills pertaining to V&V:*** The final outcome area is focused on improving the knowledge and skills of both undergraduate students and industry practitioners. The monitoring and measurement focus in this outcome area measures learning outcomes and user feedback. Student learning assessment and user feedback from students, academic instructors, and industry trainers on the active teaching learning modules have been systematically collected periodically and analyzed.

ii. ***Improved V&V teaching and learning opportunities:*** This project seeks to expand the availability of teaching and learning materials and increase their deployment in academic and industry training settings. Therefore the monitoring and measurement focus in this outcome area will be to quantify adoption of course materials in academia and industry. At this point, seven academic institutions and four industry partners have agreed to completely or partially deliver the learning modules developed through this project. It is expected that more institutions will join once the project matures.

iii. ***Development of Verification and Validation community spanning industry and academia:*** By proactively reaching out to several universities and industrial partners, the project has begun to establish a community interested in furthering the understanding and use of V&V practices. The project aims to strengthen and mature these new relationships into a sustainable community of educators and practitioners focused on V&V.

The project is using a team of two external evaluators from the author's institution to perform the following evaluation activities:

- **Develop Questionnaires and Instruments:** Evaluators are working closely with the PI and co-PIs to develop evaluation questionnaires and instruments. Various instruments in the following four skill areas will evaluate students' active learning:
    i. **Communication Skills (Ability to Communicate Effectively):** Active learning teaching tools will enhance students' communication skills. Sessions will begin with a class discussion on what was accomplished in prior sessions. Students will interactively participate in this collaborative review exercise. To have a better understanding of real work environments, students will participate in role plays, and case study videos will be used to facilitate understanding of what is expected

of these roles. Students will complete a project on testing that will include progress updates via emails and a mid-project progress presentation using Power Point. In each progress update, students will discuss the following: *what has been accomplished this week, what will be accomplished next week*, and *what were the issues and challenges and how they were resolved or not resolved if they were*. During the final-examination week, students will give a detailed final project presentation using Power Point. Students will be made aware of the importance of professional presentations and will be assessed on their content knowledge and their communication of that expertise.

ii. **Applied Knowledge of Methods (Applied Knowledge of V&V Principles):** Mini learning workshops (class sessions) will be used to translate theory to practice. Case-studies, class exercises, case study videos, and expert lecture sessions will enforce further understanding of V&V methods. Formal inspection meetings will be conducted, and students will be assigned to play different roles (*moderator, author, recorder, reader, and inspector*). The expert lecture sessions will focus on V&V processes and methods.

iii. **Applied Knowledge of Tools (Ability to Use Software V&V Tools):** Mini learning workshops (class sessions) will expose students to commonly used V&V tools. For example, students will make use of Sub-Version (an open source revision control system) for configuration management exercises, and Bugzilla (a server software) for defect management exercises.

iv. **Research Exposure (Ability to Engage in Life-Long Learning):** Research activities will be carried out in three ways. The first will involve discussions of case studies and case study videos. Students will read the case-studies, discuss them within their teams, and then discuss them with the class. Likewise, the students will view the case study videos and then discuss them in class. The second research activity involves the study of research papers. The students will analyze five research papers and answer questions related to the papers. The third activity will involve understanding of industry standards. SE standards for V&V will be analyzed and discussed.

- **Formative Evaluation:** From the evaluations performed, evaluators will assess the needs for the enhanced course modules and changes to the delivery strategy for the next planned delivery. As two delivery cycles are planned, formative evaluations will be critical for the success of the project.

- **Summative Evaluation:** From the evaluations, performed evaluators will assess the short- and long-term results of the project. The summative evaluation results will be used to understand, document, and share the project's short-term and long-term achievements.

4. Delivery Results

In the spring of 2014 and 2015, three case studies listed in Table 4 were successfully delivered within the Software Verification and Validation course at RMU. For each of these V&V areas, a pre/post survey instrument was used to assess student learning. In these instruments, two questions were related to case studies. The results for Spring 2014 term are shown in Table 4. As depicted in the table, the post-survey responses indicate that students' understanding of the subject matter has improved. The Software V&V course is being delivered at RMU.

Table 4: Case Study Survey Results

V&V Topic	Case Study Module		Pre Survey	Post Survey
Requirements Management	User Requirements	Do you think a case study exercise helps you understand the role of a Requirements engineer?	Yes (50%) No (50%) Not Sure (0%)	Yes (100%) No (0%) Not Sure (0%)
		Do you think a case study exercise helps you understand the skills required for Requirements elicitation?	Yes (50%) No (37.5%) Not Sure (12.5%)	Yes (100%) No (0%) Not Sure (0%)
Software Configuration Management	Continuous Integration	Do you think a case study exercise helps you understand the importance of configuration management?	Yes (50%) No (25%) Not Sure (25%)	Yes (90%) No (0%) Not Sure (10%)
		Do you think a case study exercise helps you understand the requirements of a configuration management tool?	Yes (12.5%) No (0%) Not Sure (87.5%)	Yes (100%) No (0%) Not Sure (0%)
Peer Reviews	Peer Reviews	Do you think a case study exercise helps you understand the roles of the participants in a formal inspection process?	Yes (87.5%) No (0%) Not Sure (12.5%)	Yes (100%) No (0%) Not Sure (0%)
		Do you think a case study exercise helps you understand the skills required to carry out a successful review meeting?	Yes (50%) No (12.5%) Not Sure (37.5%)	Yes (90%) No (0%) Not Sure (10%)

5. Educational Outcomes Assessment

The case study based approach to teaching and learning is broad in terms of its coverage of educational outcomes and it has been suggested that it can be used to deliver all eleven "***a***" through "***k***" criteria of ABET accreditation [20]. The flexibility of case studies coupled with the richness of data and information analysis, decision making education and conflict resolution results in strong links with ABET criteria. Kauffman et al. [21] have mapped case study outcomes to the ABET criteria for engineering economy case studies. Such analysis is adopted here for case studies in software engineering as shown in Table 5.

Table 5. Case study analysis in software engineering and its relation to ABET criteria

ABET Criterion	Software Engineering Case Study Analysis
(b) An ability to design and conduct experiments as well as to analyze and interpret data	Case studies requires students to find or develop the important information and ignore data that is not relevant
(c) an ability to design a system, component or a process to meet desired needs	Case studies requires students to confront complex issues such as trade off analysis along with time, resource and risk management decisions

(d) an ability to function on multi-disciplinary teams	Case studies requires students to solve case problems, they must also learn to negotiate and understand different viewpoints prior to their decision making
(e) An ability to identify, formulate, and solve engineering problems	Case studies requires students to identify important data and ignore irrelevant data, actively look for missing data or make appropriate assumption and use mathematical / computer simulation based tools to solve engineering problems
(g) an ability to communicate effectively	Case studies requires students to make presentation of case analysis results in both oral and written formats
(h) the broad education necessary to understand the impact of engineering solutions in a societal and global context	Critical thinking required by case study analysis promotes systems thinking related to larger impact of decision alternatives
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	Case studies requires students to learn and apply contemporary engineering tools to solve case problems

Pedagogical outcomes that are relevant for software verification and validation have been identified at RMU based on ABET Criterion 3 outcomes assessment. The relationships between the specified ABET outcomes for this course and their correspondence with the revised Bloom's taxonomy [22, 23] for STEM disciplines are shown in Table 6.

Table 6. Expected pedagogical outcomes for software V&V course at author's institution

Applicable ABET Criterion 3 Learning Outcomes for Software V&V course at author's institution	**Revised Bloom's Taxonomy for STEM Disciplines** [11]
b. An ability to design and conduct experiments, and analyze and interpret data	I & III
c. an ability to design a system, component or a process to meet desired needs	IV, V & VI
e. An ability to identify, formulate, and solve engineering problems	II, IV & V
f. An understanding of professional and ethical responsibilities	V & VII
g. An ability to communicate effectively	III, IV & V
h. Broad education necessary to understand the impact of engineering solutions in a global and societal context	VI
i. Recognition of the need for and an ability to engage in life-long learning.	VII
j. A knowledge of contemporary issues	V & VI
k. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice	VI & VII

Taxa I—Pre-knowledge Conceptual Experiences: hands-on laboratory experiences via demonstrations, physical models, practical applications to demonstrate, visualize and observe basic concepts.
Taxa II—Basic Conceptual Knowledge: learning, understanding, memorizing basic engineering concepts, definitions, terms, symbols, theories, laws and equations.
Taxa III—Applied Conceptual Knowledge: solving simple concept-based problems and conducting related laboratory experiments.

Taxa IV—Procedural Knowledge: working knowledge of solving multi-concept engineering problems.
Taxa V—Advanced Knowledge and Analytical Skills: inter-domain and open-ended problem solving skills.
Taxa VI—Project-based Knowledge: creative, conceptual, analytical, design, manufacturing and management skills.
Taxa VII—Professional Engineering Knowledge and Practices: life-long learning experiences, skills and practices.
It is clear from the information presented in Tables 5 and 6 that it is possible to evaluate student learning outcomes ***b***, ***c***, ***e***, ***f***, ***g***, ***h*** and ***k*** using the case study based educational tools.

6. Implementation of the Case Study Method

One of the authors has been delivering a S/W V&V course since 2005 and is required to perform an ABET Criterion 3 outcomes assessment. Figure 1 depicts a graphical display of the class assessment performed in Spring 2013 when the case study approach was not incorporated as a pedagogical approach. The Spring 2013 class had seven software engineering junior level students (all males) and all of them were considered for this study. This chart presents percentages of students scoring 80% or better on a variety of assessment tasks.

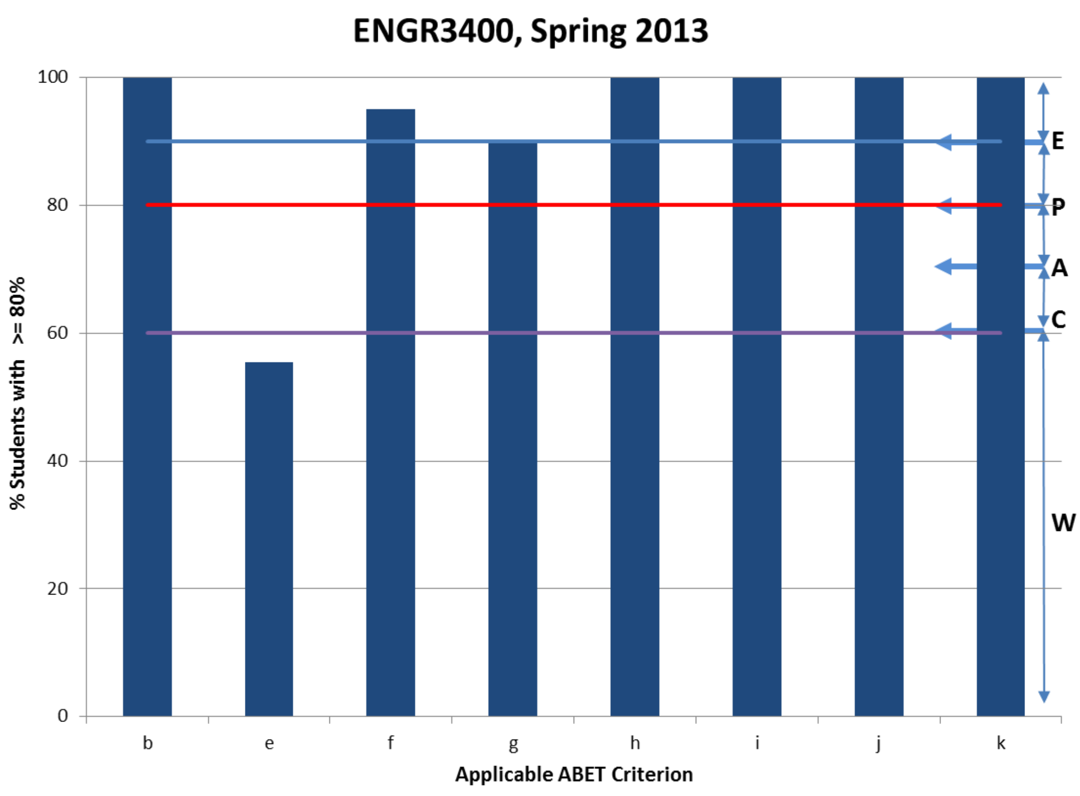

Figure 1. Student outcomes assessment with respect to the specified ABET criteria in Spring 13 term-case studies were not available for this class. (E-Excellent, P-Proficient, A-Adequate, C-Concern and W-Weakness)

The student performance in each assessment task was measured and regrouped in terms of ABET outcomes to calculate percentage of students that scored within certain levels of assessment vector as detailed in Table 7 given below.

Table 7. Descriptors of ABET outcomes assessment vector

% of students with at least 80% or better score in assessment tasks	Descriptor of the Resulting Proficiency Status
90%-100%	Excellent (E)
80%-89%	Proficient (P)
70%-79%	Adequate (A)
60%-69%	Concern (C)
< 60%	Weakness (W)

It is seen from Figure 1 that there was a weakness associated with learning outcome "***e***" (an ability to identify, formulate, and solve engineering problems), where less than 60% of the students scored better than 80% on the assessment tasks, causing ABET outcome "***e***" to be identified as a "weakness". One of the main reasons for the lower outcome percentage is because the student performance data was obtained through exams, which may not be the best suited tools for assessing outcome "***e***". It is shown in Table 1 that case study based education can be used to enhance outcome "***e***". From the 2013 ABET Outcome Assessment report this instructor realized a need for more applied, higher level learning tools. In the 2015 delivery of the S/W V&V course case study approach was incorporated as a pedagogical approach and relevant outcomes assessment was performed. The Spring 2015 class had twelve software engineering junior level students and all of them were considered for this study. This time the student performance data for outcome "***e***" was obtained assessing student performance in case study related tasks. The results of this evaluation are presented in Figure 2. The Spring 2017 class had twenty nine software engineering junior level students and all of them were included in this study. The student performance data for outcome "***e***" was obtained assessing student performance in case study related tasks. The results of this evaluation are presented in Figure 3.

It can be seen clearly that the student performance related to outcome "***e***" is now in the excellent range (>= 90%) as compared to being an area of concern (< 60%) in Spring 13. This presents clear evidence that the case study based teaching method is more effective in delivering an ability to identify, formulate, and solve engineering problems to the students. Therefore case study based educational tools will be progressively developed, adopted and delivered in several other aspects of the software V&V area such as legal issues in software, software consumer protection, and requirements from the customers' perspectives. The results of those implementations will be reported later as more data become available.

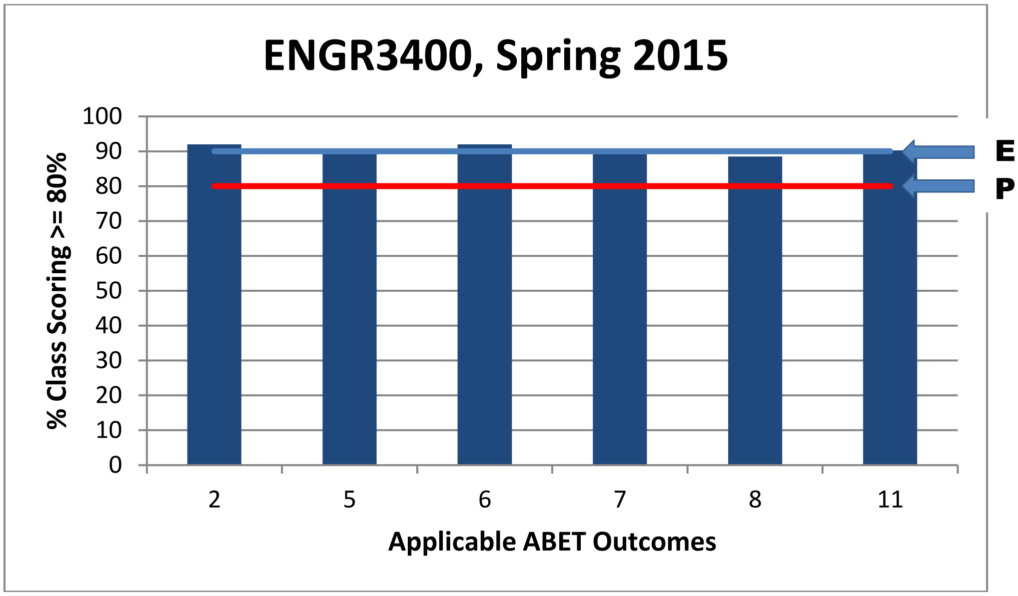

Figure 2. Student outcomes assessment with respect to the specified ABET criteria in Spring 2015 term – case studies were delivered in the class

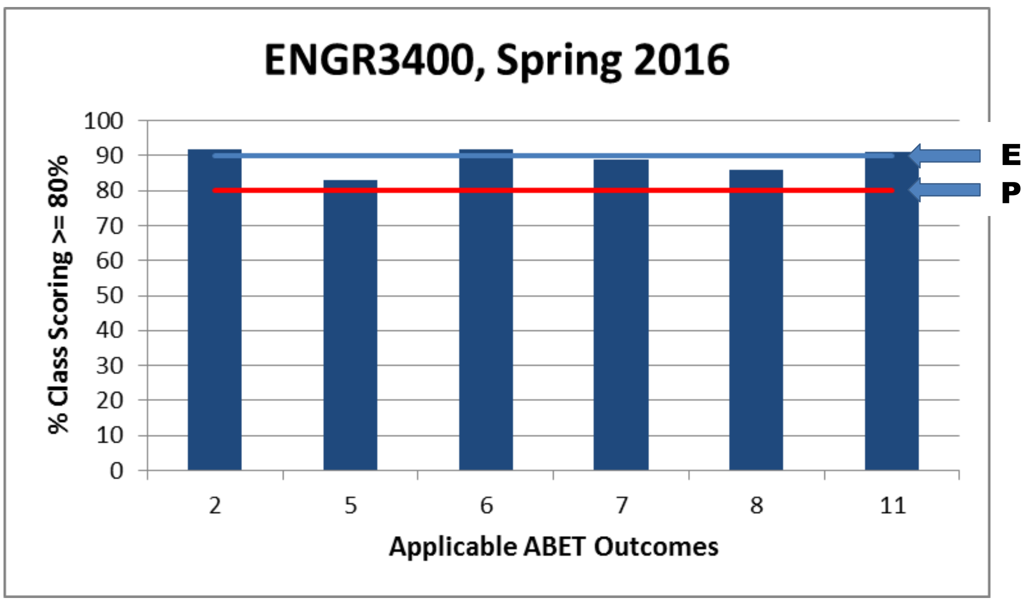

Figure 3. Student outcomes assessment with respect to the specified ABET criteria in Spring 2016 term – case studies were delivered in the class

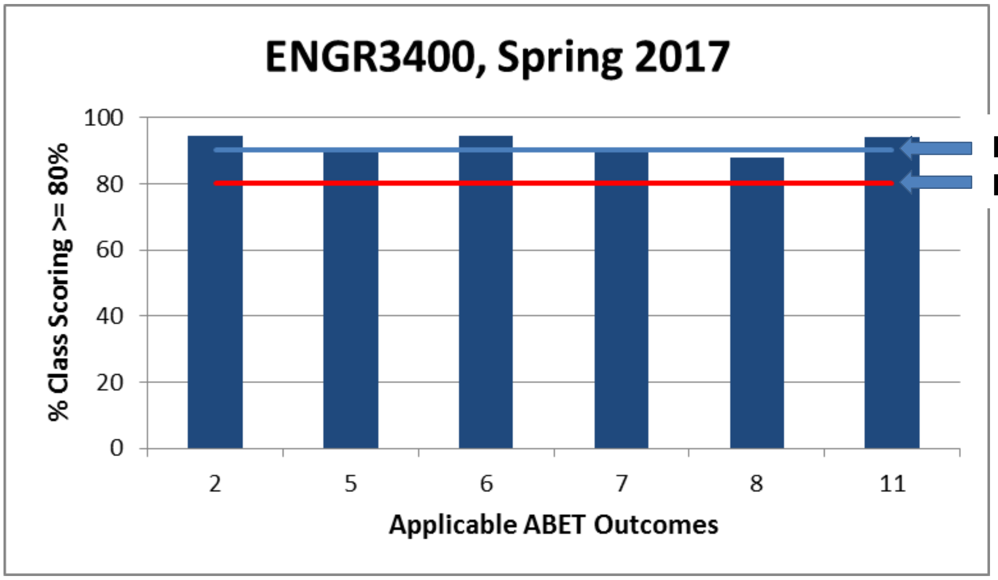

Figure 4: Class performance in Spring 2017 term as compared with respect to applicable ABET outcomes. All developed ALTs were delivered in the classes throughout the term. (ABET outcomes ***a –k*** are renamed ***1 to 11*** for convenience. The current RMU-designated benchmark for class performance is 80% or B-).

7. Student Evaluation of Active Learning Tools

A student survey tool was developed to assess the effectiveness of the active learning tools developed here and receive feedback for future improvement. Appropriate Institutional Review Board (IRB) clearance was obtained for the survey tools employed in this study. Ten software engineering junior level students participated in this study. The survey was carried out in-class on the last day of class using paper survey in the Spring 2015 term. Instructor was not present in the room and the survey was anonymous. The students were asked to rate the value of the in-class activities in enhancing their knowledge and learning process experience (Table 8). The feedback was given on a Likert scale of 0 (don't know), 1 (not useful), 2 (somewhat useful), 3 (moderately useful) and 4 (extremely useful). The results showed that 90% or more of the students who just completed the class found all of the active learning tools (case studies, exercises, videos) to be moderately or extremely useful. Related specifically to case studies, 100% of the students found the case studies to be moderately or extremely useful. On the other hand, the students found less utility in the written homework assignments and textbook readings.

Another question in the survey asked students about the types of activities they do in the class, including paying attention to lectures, engaging in small group or class discussions, completing real-world applications, thinking critically, reviewing research, or utilizing professional standards to some degree (Table 9). In this class that deployed active learning tools, the majority of the students (> 70%) responded that they completed real-world applications and felt accountable to classmates in full class discussions. Their communication skills were also utilized to a greater extent in these activities, thus increasing the educational value of active learning tools.

Table 8. Descriptive results from the general evaluation of course instructional activities

Rate the value of the assignments/activities completed in this class. Address the activities as a whole, rather than focusing on one single instance.

Activity	NA/ Don't Know (0)		Not Useful (1)		Somewhat Useful (2)		Moderately Useful (3)		Extremely Useful (4)		Descriptive Stats	
	n	%	n	%	n	%	n	%	n	%	M	SD
1. Lecture					3	30.0	6	60.0	1	10.0	2.8	0.63
2. Exercises							3	30.0	7	70.0	3.7	0.48
3. Case Studies							6	60.0	4	40.0	3.4	0.52
4. Video Case Study					1	10.0	2	20.0	7	70.0	3.6	0.70

Table 9. Descriptive results from the general evaluation of course instructional activities-Part 1

Address how often you do each of the following in a <u>TYPICAL DAY IN THIS CLASS:</u>

	NA / Don't Know (0)		Not at all (1)		To a small degree (2)		To a moderate degree (3)		To a large degree (4)		Descriptive Statistics	
Activity:	n	%	n	%	n	%	n	%	n	%	M	SD
1. Pay attention during at least 90% of the class session					1	10.0	4	40.0	5	50.0	3.4	0.70
2. Engage with classmates in small group discussion about course content			1	10.0	1	10.0	2	20.0	6	60.0	3.3	1.06
3. Complete real-world applications of course content					1	10.0	8	80.0	1	10.0	3.0	0.47
4. Think critically about course content					1	10.0	4	40.0	5	50.0	3.4	0.70
5. Engage with classmates in full class discussion about course content							2	20.0	8	80.0	3.8	0.42
6. Check texts or other communication via a handheld device			6	60.0	4	40.0					1.4	0.52
7. Feel accountable for my contribution to class.					1	10.0	8	80.0	1	10.0	3.0	0.47
8. Review research in the field.					5	50.0	3	30.0	2	20.0	2.7	0.82
9. Utilize/refer to professional standards.							4	40.0	6	60.0	3.6	0.52

Finally, the vast majority of the students (>= 90%) reported positive student behavior in this class as compared to other classes in their major in terms of the time spent in learning, subject interest, and understanding (Table 10).

Table 10. Descriptive results from the general evaluation of course instructional activities - Part 2

Answer each of the following regarding ENGR 3400 compared to other recent courses in your major:												
Question	**Much Less (1)**		**Slightly Less (2)**		**The Same (3)**		**Slightly More (4)**		**Much More (5)**		**Descriptive Statistics**	
How does:	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**M**	**SD**
1. the **amount of time** that you spent on this course OUTSIDE OF CLASS MEETINGS compare to the **amount of time** spent working on other undergraduate courses **IN YOUR MAJOR in the last 2 semesters**?			1	10.0	4	40.0	4	40.0	1	10.0	3.5	0.85
2. the **amount you learned** in this course compare to the **amount you learned** in other undergraduate courses **IN YOUR MAJOR in the last two semesters**?					1	10.0	5	50.0	4	40.0	4.3	0.67
3. your **interest in the types of instructional activities utilized in this course** compare to your interest in the types of instructional activities used in other undergraduate courses **IN YOUR MAJOR in the last 2 semesters**?					3	30.0	3	30.0	4	40.0	4.1	0.88
4. your **interest in content of this course** compare to your interest in the content of the other undergraduate courses **IN YOUR MAJOR in the last 2 semesters**?			1	10.0	3	30.0	4	40.0	2	20.0	3.7	0.95
5. your **understanding of content of this course** compare to your understanding of the content of the other undergraduate courses **IN YOUR MAJOR in the last 2 semesters**?					4	40.0	4	40.0	2	20.0	3.8	0.79
6. the **amount of real-world application problems in this course** compare to the amount of real-world applications of the other undergraduate courses **IN YOUR MAJOR in the last 2 semesters**?			1	10.0	1	10.0	3	30.0	5	50.0	4.2	1.03
7. the **amount of verbal communication required in this course** compare to the amount of verbal communication required in the other undergraduate courses **IN YOUR MAJOR in the last 2 semesters**?					1	10.0	1	10.0	8	80.0	4.7	0.67

8.	your **satisfaction of this course** compare to your satisfaction in the other undergraduate courses **IN YOUR MAJOR in the last 2 semesters**?			2	20.0	5	50.0	3	30.0	4.1	0.74
9.	the **amount of time** that you spent on this course OUTSIDE OF CLASS MEETINGS compare to the **amount of time** spent working on other undergraduate courses **IN YOUR MAJOR in the last 2 semesters**?	1	10.0	4	40.0	4	40.0	1	10.0	3.5	0.85

8. Summary

Several active learning tools (ALTs) such as case studies, videos, and class exercises have been developed over four years period of 2013 – 2017 and disseminated at RMU as well as many collaborating academic institutions over three years 2015-2017. The ALTs were deployed to teach four domains in software V&V education such as requirements engineering, configuration management, software reviews, and software testing. Pedagogical effectiveness of these ALTs in delivering the knowledge to the students was assessed using ABET student learning outcomes assessment as well as student pre- and post-surveys and student satisfaction survey for each of the tools. It was found that the vast majority of the students (>= 90%) reported positive student behavior in this class as compared to other classes in their major in terms of the time spent in learning, subject interest, and understanding. ABET outcomes of student's ability to identify, formulate, and solve engineering problems and communicate effectively was also seen to be improved when ALTs were developed for teaching. In summary the ALTS developed in this work improved software V&V education significantly and therefore these tools will be made available to any faculty interested in incorporating them in their own teaching.

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