Using Case Study Videos as an Effective Active Learning Tool to Teach Software Development Best Practices

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ABSTRACT

The fundamental challenge to a solution to improve software quality is in the people and processes that develop software products. Imparting real world experiences in software development best practices to undergraduate students is often a challenge due to the lack of effective learning tools. This pedagogical requirement is important because graduates are expected to develop software that meets rigorous quality standards. Certain best practices are difficult to comprehend by course lectures alone and are enhanced with supplemental learning tools. Realizing the necessity of such teaching tools, we designed and developed six (6) delivery hours of case study videos for use in courses that impart knowledge on Software Verification & Validation (SV&V) topics viz. *requirements engineering,* and *software reviews.* We see case study videos as an effective active learning tool in our flipped classroom approach. We present our design of the case study video in its generic components envisioning how it may be used in general. To evaluate our active learning tools we mapped the learning objectives of the case Study videos to the expected learning outcomes for ABET accreditation of an undergraduate engineering program. Our implementation has been disseminated to partner institutions. Results of delivery in a faculty workshop and in two different university courses are shared.

Keywords: Case Study Video. Active Learning Tools, Software Verification and Validation

1. INTRODUCTION & RATIONALE

Software quality suffers when practitioners lack skills in software development best practices. With mission critical and high-risk applications having human lives and resources dependent on software applications, it is imperative to aim for higher quality standards. However even after decades of development, the software industry continues to spend considerable time and effort to deal with the “quality” problem. Much of the improvement can be attributed to the implementation of standards and practices like software verification and validation (SV&V). Rakitin [1] states that SV&V is simply not adequately practiced in the software industry. Acharya et al [2] reason that firstly, there is not enough awareness of the SV&V benefits, and secondly, there is a lack of practitioners who adequately understand SV&V topics and processes.

The fundamental challenge to a solution to improve software quality is in the people and processes that develop and produce the software products. Imparting real world experiences in software development best practices to undergraduate students is often a challenge due to the lack of effective learning tools. Certain best practices are difficult to comprehend by course lectures alone and are enhanced with supplemental learning tools. 90% of what we say and do is retained by being there [3]. However it is not always possible for undergraduate students to be where software development practices takes place. In many cases students are not exposed to real world experiences until they are an intern or they are employed.

Funded by a NSF-TUES Grant (National Science Foundation: Transforming Undergraduate Education in STEM), our research project therefore aims at the root cause in the lack of SV&V courseware for effective undergraduate education in academia and on-the-job training in industry. The project is carried out through an academic-industry partnership. The entire team involves two academic development partners, five industry development partners, and twelve academic implementing partners. We created focus groups comprising of academic and software industry partners to critically review our existing course materials and to identify the gaps and inadequacies when checked against current methods and best practices. Then we refined the lecture materials and developed new active learning tools in the form of case studies, class exercises, and case study videos. We modularized the teaching materials and tools into small deliverables of 25 minutes sessions and in generic formats for adaptation to various settings. The developed modules are easily integrated into software courses and adapted by the industry for on-the-job training. To engage the students in active learning, we practiced a flipped or inverted classroom approach [4, 5, 6, 7]. In this approach we required students to review lecture and other reading materials prior to class and we used the class sessions to apply active learning tools to engage the students.

The basic objective of the project is to enhance the quality of software engineering education by increased student engagement in learning as well as bridging the gap between the theoretical knowledge discussed in the classroom and the complexity of real world problems. This endeavor will promote SV&V awareness and increase SV&V practitioners skilled in the practice. The goal is to improve product and process quality levels throughout the software development community.

In this paper we present case study videos, a category of our active learning tools, primarily for class discussion in concert with the other active learning tools. Our hypothesis is that case study videos will be effective learning tools for students since they facilitate student learning by seeing and subsequently applying what they learn to solve problems in the real world. These focused videos will enhance the understanding of the underlying theoretical concepts presented in class (and in preparatory reading) and provide a context for their application.

Section 2 describes the specific topic areas of focus in SV&V and the active learning tools we developed. In section 3 we discuss the case study video as an active learning tool. Section 4 describes the case study video development process. In Section 5 we present the components of a case study video tool. In section 6 we describe the pedagogical evaluation strategy of the case study video to facilitate support for our hypothesis that active, engaged learning will enhance student experience, interests and learning. In section 7 we present findings from a faculty workshop followed by a brief student performance and feedback in section 8. Finally in section 9 we present our conclusions.

2. SV&V TOPICS AND ACTIVE LEARNING TOOLS

The course enhancement effort is guided by four specific SV&V topic areas: *Requirements Engineering*, *Software Testing*, *Software Reviews*, and *Configuration Management*. We identified these as the critical areas in the software development process and also areas of importance in the industry. The course modules we developed in the form of active learning tools therefore focus on these topic areas and include the following:

- **Case Studies:** Case studies are drawn from industry SV&V practices. Students are presented industry standard documents for review to prepare for the tasks. These tasks may be resolution of review conflicts in the Software Requirements Specification (SRS) document, or compliance to security standards, or drafting of testing plans from use cases. A more extensive coverage of the study cases developed is being disseminated in another publication [8].

- **Class Exercises:** Based on the context of the class module, class exercises are designed for the class time to explicitly raise questions to invite student participation. It may be questions to think further into the concepts for a deeper understanding, or practice using their knowledge with hands-on practice for problem solving. There are many ways of using class exercises. For a small class, the teacher may simply use the exercise to engage the students in discussion and practice. For larger classes, the students can form small groups to use the class exercise as instrument leading to group projects. A more extensive coverage of the class exercises developed is being disseminated in another publication [9].

- **Case Study Videos:** Produced from the scripts first drafted by our industry partners and confirmed by the testimonies shared in focus group discussions, case study videos provide a realistic picture for the audience to appreciate many SV&V best processes in practice. These may show how peer code review is done, and how potential tension or conflict may arise, or the tedious detailed nature of requirements elicitation.

3. CASE STUDY VIDEO AS AN EFFECTIVE ACTIVE LEARNING TOOL

Active learning is “embodied in 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” [10]. Prince [11] defines active learning as a classroom activity that requires students to do something other than listen and take notes. Active learning tools complement lectures and make class delivery more interesting to the learners.

One commonly used technique to enhance the classroom learning experience is the use of videos that depict real world scenarios. 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 can aid in showcasing highly complex concepts and ideas in a short period of time, provoking meaningful discussion and analysis. Software development processes can be effectively taught using case study videos.

There is extensive experience in using audio visual materials in the classroom, ranging from the usage of filmstrips during World War II to train soldiers [12] 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 [13]. Videos can aid in showcasing highly complex concepts and ideas in a short period of time, provoking meaningful discussion and analysis.

Videos are an essential part of the flipped classroom model, in which the preponderance of lecture material is presented before class [14]. The class time is then spent on discussion and teamwork. Overall, the flipped classroom model has proven highly effective at increasing student engagement and enhancing the preparation of students for class sessions [5]. The flipped classroom also has been shown to allow the instructor to cover more material and results in higher student performance [15]. The videos developed through this project share real-life perspectives of actions and their consequences and are designed in sequences of scenes.

4. CASE STUDY VIDEO DEVELOPMENT

A generic iterative development methodology depicted in Figure 1 was used to ensure the active learning tools developed through this project reflected both academic research and industry best practices. The content development process began with a meeting of the focus groups at the authors' institution. The groups drafted a list of active learning content topics and delivery formats. The list was reviewed by the principal investigators and shared with the partners for further review. The finalized list was then used to guide the development process. In this methodology, an industry partner or academic partner led the development effort through a collaborative effort. Once the contents were ready for review, they were shared with focus group members and subsequently with all partners. The finalized contents were then transferred to a shareable media where they became available for delivery, further reviews, and dissemination. For ease of adaptation, the focus groups decided that each active learning tool will be of 25 minutes duration, with some active learning tools having multiple parts delivered in multiple sessions.

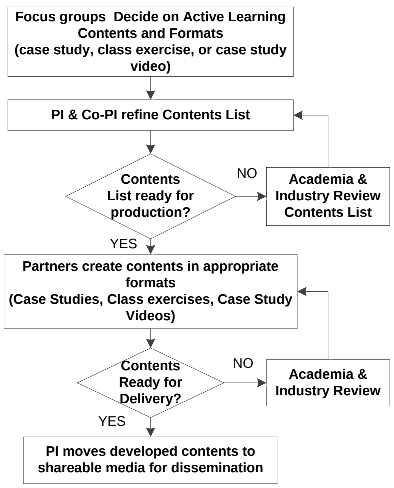

Figure 1: Generic Development Methodology

The focus groups identified that having case study videos would give students the closest feeling of "being there and doing that". The focus group followed the methodology described above to produce four case study videos in the areas of requirements elicitation, formal software inspection, software reviews, and SCRUM.

5. COMPONENTS OF A CASE STUDY VIDEO TOOL

Four case study videos listed in Table 1 have been produced and disseminated. These videos are available in YouTube, are in the project website www.rmu.edu/nsfvv, and in ENSEMBLE http://www.computingportal.org/. Each case study video consists of the following components:

Video

All four videos have appropriate narrations and pause points between scenes for incorporating class discussions.

Case Study Video Description

This document provides four categories of information. The first part provides general information about the video and includes details like the SV&V focus topic area, module name, prerequisite knowledge, learning outcomes, keywords, expected delivery duration, description of the scenes, and student exercise. The second part describes the instruction and assessment procedure. This section provides step by step instruction on how this exercise should be delivered. In addition this section may provide details of the documents that are required for delivery such as the slides for the discussion questions. This section may also serve as a check list. The third part has a list of possible discussion questions by scene. The final part of this document depicts the survey instrument. Figure 2 illustrates a sample "Instruction Procedure" of this document.

Table 1: Case Study Videos Details

V&V Focus Area	Case Video Modules	Duration (mins.)	Class Delivery (mins.)	# of Scenes
Requirements Management	*Requirements Analysis Scenes*	15	50	5
	Scenes from SCRUM	24	50	4
Peer Reviews	*Formal Inspection Scenes*	15	50	7
Testing	*Security Inspection Scenes*	16	50	5
	TOTAL		200	21
	Class contact hours (50 minute class sessions)		4	

Instruction and Assessment Procedure:

Instructional Notes:	This is to be delivered as a classroom activity. Class (50 minutes) 1. Before starting this exercise ask a few questions randomly to get a general feeling up student pre-requisite knowledge. Sample questions are: a. What is a software requirement? b. Who is responsible for providing the requirements for a software product c. What is the role of a customer in a requirements elicitation process d. What is the role of a practitioner in a requirements elicitation process 2. Play the video and stop after every scene to discuss the scene. Use the following questions or design your own questions for discussions. 3. Wrap up the exercises
Assessment: Procedure:	Ask the students to take the survey: ***VS Requirements_Analysis_Scenes_Survey***

Figure 2: Instruction Notes

Student Handout

This document includes information students need to participate in class discussion. This handout explains the scenes, objectives of the exercise, step-by-step instruction, and a set of sample question for Scene 1. Figure 3 illustrates a sample handout.

CCCCXXXX – Software Verification & Validation

Case Module Number: VS01

Video Case Study:
Requirements Analysis Scenes

The Scenes
The scenes in this video portray brief dramatizations in a requirements elicitation process. The scenes present industry best practices and problems that can occur during the process. The scenes also demonstrate appropriate and inappropriate conducts during Requirements Analysis process

The Business Analyst (BA), Mike, has a B.S. in Software Engineering and is working. Mike also has a year of experience in requirements elicitation. There are 5 scenes in this video.

- **Scene 1:** Mike is at ABC Inc. for a requirement elicitation meeting with Yang. Prior to the meeting Mike has studied the client's domain area and prepared a set of basic questions which he will ask Yang to elicit requirements. The meeting takes place in the client's meeting room and after a brief exchange of greetings Mike looks around the room and sits down for business. Mike pulls out his tablet pc and initiates the conversation.
- **Scene 2:** In this scene Mike and Yang work on the High Level Requirements.
- **Scene 3:** …

Exercise:
- Watch the video, remember the names of the players, notice their voice and their expressions.
- Take notes
- Be ready to discuss what went right and what went wrong in the scenes.

(Assume appropriate information when necessary!)

Figure 3: Student Handout

Discussion Questions

For each video, suggested discussion questions for each scene is available as a power point slide. Instructors are welcome to modify these questions to suit their class. Figure 4 depicts a sample scene description and discussion questions.

Scene #, Scene Discussion Questions
Scene 1: Scene 1: Mike is at ABC Inc. for a requirement elicitation meeting with Yang. Prior to the meeting Mike has studied the client's domain area and prepared a set of basic questions which he will ask Yang to elicit requirements. The meeting takes place in the client's meeting room and after a brief exchange of greetings Mike looks around the room and sits down for business. Mike pulls out his tablet pc and initiates the conversation. • What is happening in this scene? • Do you think Mike is asking the right questions? • Do you think Yang is giving the right answers? • In a software project would both of them be project stakeholders? • What is the next step for Mike?

Figure 4: Scene and Discussion Questions

Assessment Instrument

The assessment instrument is a simple survey primarily for indirect assessment of student learning outcome, and also for student feedback. This survey assesses students on communication and content knowledge. It is designed for generic use in every exercise, to be completed quickly at the conclusion of the class exercise. Figure 5 illustrates a sample instrument.

<University Name>
<Course Level>
<Course Number> – <Course Name>
Video Case Module: Requirements Analysis Scenes

Video Case Study Module: VS01

	Yes	No
My team and I understood the purpose of the activity.	☐	☐
My team and I could complete the activity with the directions that were provided.	☐	☐
At least one member of my team was uncertain of how to carry out the steps of the activity.	☐	☐
The activity used a real-world application.	☐	☐
I could imagine carrying out this activity as part of my job.	☐	☐
I communicated verbally in a <u>small group</u> while completing this activity.	☐	☐
I communicated verbally in a <u>large group</u> while completing this activity.	☐	☐
I / we provided written communication as part of this activity.	☐	☐
I / we made a formal presentation as part of this activity.	☐	☐
I thought critically about content while completing this assignment.	☐	☐
Provided your overall thoughts about this activity:		

Figure 5: Assessment Instrument

6. PEDAGOGICAL EVALUATION

Since the case study videos are designed with specific learning objectives, we mapped the objectives to the learning outcomes derived by ABET (Accreditation Board for Engineering and Technology, Inc.) for engineering program accreditation [16]. While experienced teachers may intuitively know that good class exercises presented in an interesting way will invite student engagement into active learning, we proceeded to analyze how the ABET outcomes correspond to the levels in Bloom's taxonomy of knowledge and learning [17], to present the case study videos as active learning tools, in our case, specifically for SV&V in the undergraduate curriculum. Table 2 lists the eleven pedagogical outcomes derived by ABET pertaining to the accreditation of undergraduate engineering curriculum. We examined the specific learning objectives of our case study videos. For each case study video, we identified the outcomes specifically addressed by the learning objectives. Table 3 presents our results: S indicates an outcome specifically addressed.

To make the case for these case study videos to be active learning tools, we adopted the revised Bloom's taxonomy for STEM (Science, Technology, Engineering and Mathematics) disciplines proposed by Girgis [18]. Table 4 below lists the seven levels derived from the revised Bloom's taxonomy. We adopted the term "taxa" for each level as proposed by Girgis, with the description wording specific for STEM education.

Table 2: ABET Learning Outcomes

Outcome	Description
1	ability to apply knowledge of mathematics, science, and engineering
2	ability to design and conduct experiments as well as to analyze and interpret data
3	ability to design a system, component or a process to meet desired needs
4	ability to function on multi-disciplinary teams
5	ability to identify, formulate, and solve engineering problems
6	understanding of professional and ethical responsibilities
7	ability to communicate effectively
8	broad education necessary to understand the impact of engineering solutions in a societal and global context
9	Recognition of the need for and an ability to engage in life-long learning.
10	knowledge of contemporary issues
11	ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Table 3: Case Study Videos mapped to learning outcomes

Case Study Video	1	2	3	4	5	6	7	8	9	10	11
Requirements Analysis Scenes	S				S	S	S				
Scenes from SCRUM	S				S	S	S				
Formal Inspection Scenes	S				S	S	S				
Security Inspection Scenes	S				S	S	S				

Table 4: Engineering Knowledge Taxonomy

Taxa	Description
I	**Pre-knowledge Conceptual Experiences:** hands-on laboratory experiences via demonstrations, physical models, practical applications to demonstrate, visualize and observe basic concepts.
II	**Basic Conceptual Knowledge:** learning, understanding, memorizing basic engineering concepts, definitions, terms, symbols, theories, laws and equations.
III	**Applied Conceptual Knowledge:** solving simple concept-based problems and conducting related laboratory experiments.
IV	**Procedural Knowledge:** working knowledge of solving multi-concept engineering problems.
V	**Advanced Knowledge and Analytical Skills:** inter-domain and open-ended problem solving skills.
VI	**Project-based Knowledge:** creative, conceptual, analytical, design, manufacturing and management skills.
VII	**Professional Engineering Knowledge and Practices:** life-long learning experiences, skills and practices.

We classified the ABET-EAC (Accreditation Board for Engineering & Technology – Engineering Accreditation Commission) learning outcomes by the proposed taxonomy to present the mapping in Table 5 below to indicate the expected "taxa" levels each outcome focuses on.

By the ABET-EAC learning outcomes each of the case study videos specifically addresses, we then determine the "taxa" levels each video focuses on. Table 6 is an extension of Table 3, to include the classification results, showing that the case study videos correspond to levels I to V in the knowledge taxonomy.

Table 5: ABET Outcomes classified in taxonomy

Taxa	Decsription	1	2	3	4	5	6	7	8	9	10	11
I	Pre-knowledge Conceptual Experience	X										
II	Basic Conceptual Knowledge	X				X						
III	Applied Conceptual Knowledge	X						X				
IV	Procedural Knowledge					X		X				
V	Advanced Knowledge and Analytical Skills					X	X	X				
VI	Project-based Knowledge											
VII	Professional Engineering Knowledge and Practices											

Table 6: Classed Exercises mapped to ABET-EAC outcomes and Knowledge Taxonomy

Case Study Video	ABET-EAC outcome by learning objectives	Knowledge Levels (Taxa's)
Requirements Analysis Scenes	1,5,6,7	I, II, III, IV, V
Scenes from SCRUM	1,5,6,7	I, II, III, IV, V
Formal Inspection Scenes	1,5,6,7	I, II, III, IV, V
Security Inspection Scenes	1,5,6,7	I, II, III, IV, V

7. Faculty Workshop: Video Case Study Results

In summer 2016, 15 faculty members from universities (offering SE and CS programs) and 3 industry partners participated in a two day “Software V&V Workshop” at RMU. The goal of the workshop was to make users familiar to the developed active learning tools which included Case study videos. A total of 14 attendees completed survey questions related to a case study video used in the workshop. The results are discussed below. When total counts do not sum to 14, data were missing for individual questions.

When asked whether they will or will not use the activities, nine respondents provided an answer. In general, comments indicated that instructors find the tools valuable and engaging, and would or will use them if they relate to their curriculum.

- ❖ I personally feel these activities are highly engaging and accessible to students. Can be used in many software departments and development courses.
- ❖ Will use because it is useful – will engage students to learn what is important. Will not use because the opportunity is not there (yet) (RMU respondent).
- ❖ I will likely use the video in my society and technology class to illustrate the kinds of things that can go wrong. This relates to the ethics portion of the class.
- ❖ I will probably use with some variation in my SE1 course. (Security is not the main topic in this course).
- ❖ I really liked the videos. I think they provide a good critical thinking activity.

When asked to provide a summary of any suggested changes they have regarding the instructions or materials, ten attendees responded with the following comments. In general, the comments were general and fairly generic, and indicated that the videos were helpful. Three suggestions were to improve depth, increase the amount of videos, and increase the video resolution.

- ❖ The depth is high, but the depth can be improved with future grant support. The PIs team is professional and passionate about improving teaching of V&V and software development knowledge in general.
- ❖ Viewers may be familiar with the technical background.
- ❖ It is clear the materials were developed using sound instructional design principles. I think you did a great job designing and developing the materials and they will fit into a variety of my classes.
- ❖ Good trigger for discussion importance of securing in the (?). Would be better if focus throughout was on software issues for server config.
- ❖ Add more videos and cases ☺
- ❖ Materials are very good. Would discuss standards as part of the case.

Tables 7 & 8 provide strategic partner summaries of video case studies similarity and quality.

Table 7: Strategic Partner Summary of Similarity and Likely Use of Video Case Studies

Question	Not at all	Somewhat	Moderately	Extremely
How <u>similar</u> are these materials to those utilized in your previous classes?	6	2	3	
How <u>likely</u> are you to utilize one or more of these materials in one or more of your classes during the Fall 2016 semester?	*1	2	2	7

Note: *Respondent indicated “Not at all” because he/she was teaching no relevant classes in fall

Table 8: Strategic Partner Summary of Quality of Video Case Studies

How would you <u>best</u> characterize the	Low Quality	Moderate Quality	High Quality
Overall quality of the materials		4	10
Academic relevance of the materials			13
Interactivity required by the materials		2	12
Instructions provided with the materials		1	13
Depth and breadth of materials	1	4	9

8. Student Performance and Feedback

Discussions after each scene were used to measure and understand student learning and perspective. The students felt that scenes and the dramatization of the software engineering process helped them relate to industry best practices. The questions asked, the responses from their classmates, and the thoughts of the professor helped them understand why certain things would happen at work. With the understanding of the “dos” and “don’ts” as depicted in the video students felt confident on being able to execute in the real world should situation arise. Some student comments on videos shown in class were:

- ❖ Insightful exercise for understanding the process.
- ❖ It did a good job at demonstrating requirement analysis while dealing with a client.
- ❖ The video was professional a real-life situation. Maybe include more group thinking.
- ❖ Gives you a good picture of the real-world. Work place is not always friendly. However you must be a professional.
- ❖ Was good to explain how V&V would be like in real world.
- ❖ Very helpful in understanding how to deal with customers.
- ❖ It was a descent representation of a how a real client interaction takes place.
- ❖ I thought it was an effective way to facilitate a discussion

9. CONCLUSIONS

Through a vibrant academia-industry partnership and academic research, and a project funded by a NSF-TUES grant we have developed, delivered, and disseminated 442 delivery hours of active learning tools which include Case Studies, Class Exercises, and Case Study Videos in specific SV&V topics viz. *requirements engineering, configuration management, software reviews,* and *software testing.* In this paper, we reported the details of the case study videos. The case study video instruction packet consists of the video, description of the video, student handout, discussion questions, and an assessment instrument. We described an example case study video on formal inspection. To evaluate our active learning tools we mapped the learning objectives of the case Study videos to the expected learning outcomes for ABET accreditation of an undergraduate engineering program. We also analyzed them based on the classification by Bloom's taxonomy of knowledge adapted to software engineering. The case study videos along with other active learning tools developed in the project are disseminated through YouTube and project website. Faculty and student feedback on case study video as an effective active learning tool is presented.

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