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Increasing student motivation and knowledge in mechanical engineering by using action cameras and video productions

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A B S T R A C T

Action cameras were used in a material science class laboratory setting for improving student motivation and understanding of material failure mechanisms. The design, implementation, and student perceptions were examined when using cameras. The students recorded video footage of destructive material testing using GoPro Hero action cameras in order to evaluate material failure and develop a video presentation. The use of action cameras allowed students to view and record their experiments without the risk of damage to a more expensive camera, view their experiments in slow motion, and improve technical communication skills. An assessment of the innovation was conducted through student feedback and existing performance measures related to continuous quality improvement. Students participated in developing a grading rubric for video laboratory presentations. Five criteria in order of importance were content, clarity, organization, format, and creativity. The students' surveys were positive regarding increased understanding of course material and improved technical communication skills. The students were satisfied with the variety of laboratory experiments. They perceived increases in their abilities to share technical information through a medium other than written reports. Implications included needing more training in camera usage, editing, and video production techniques in order to improve the learning process. This innovation could be extended to other engineering and management classes.

A R T I C L E I N F O

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1. Introduction

1.1 Technology and engineering education

In the past two decades, more and more attention has been devoted to the evaluation and appraisal of technology in the classroom. Likewise, studies have examined methods of instruction, student motivation, and improved learning. Such studies suggest that technology and hands-on experiences in the classroom may improve learning and motivation. The classroom innovation using technology described in this study is using GoPro Hero2 action cameras as an additional project for the required course, Materials Science and Manufacturing.

The mechanical engineering course has a significant laboratory portion which involves destructive material testing. Goals of this project in utilizing GoPro HD Hero2 action camera kits were to: (1) stimulate interest and enthusiasm in the laboratory material; (2) increase understanding of material failures; and (3) improve technical communication skills. This paper will discuss the design, implementation, and results of adding this technology to an engineering laboratory setting.

1.2 Background

Students had commented previously that performing repeated material tests had become monotonous. In addition, similar tests had to be run on different types of materials to understand how failure mechanisms differ among material types. Therefore, this initiative included both new and informative methods in conducting the experiments. A major premise of the study was not all laboratory reports in the industry are limited to paper. However, with the lower costs of digital cameras and videos plus available easy-to-use editing software, presenting results with video productions has become feasible.

This study focused on using the GoPro Hero action cameras to assess student learning, motivation, and teambuilding. GoPro Hero 2 cameras were purchased to enable 120 frames per second digital recording of destructive material tests, such as impact, tensile, and compression and bending tests. Students used the footage to further evaluate the damage mechanisms and obtain additional data. In addition, the project provided students both visual and traditional data to review and analyse.

A specific objective of this initiative was to prepare students to present scientific results in a format that goes beyond professors and classmates. To this end, students took the footage from the experiments and prepared video laboratory reports. These videos were uploaded to a dedicated YouTube channel. Also, students participated in developing a rubric to enhance an effective evaluation of their team projects.

Student surveys indicated that students generally did indeed benefit from the experience with some exceptions. Accordingly, implementation, findings, and evaluation of the camera project in a materials science laboratory setting are examined.

2. Using technology in a materials science laboratory setting

2.1 Literature review

Goodhew and Bullough [1] believed a goal in a materials science laboratory should not only be that the students correctly obtain a proper measurement but also encouraged to do something useful with their results. As new technology is made available to educators and students, it is possible to find new ways to encourage students to take a closer look at what they are studying, whether it is in the classroom or in the laboratory.

Davies and Ringer [2] examined a flexible learning studio with equipment for both studying and preparing presentations for materials science engineering students. He recognized that modern engineering students need skills not only to obtain results but present them to others as well.

Pinder-Grover et al. [3] used screencasts to overcome the difference in academic backgrounds and interests of students coming into a large materials science course. Likewise, Laoui and O'Donoghue [4] implemented a multimedia virtual learning environment to achieve a similar goal. Another web-based approach was developed by Kurt, Kubat, and Oztumel using a conceptual model of a virtual materials testing laboratory simulation for students [5].

The applications of GoPro cameras in research have been numerous in several areas over the past few years. For example, the action camera was used to capture the remote control monitoring of a robotic arm [6], and motion capture in microgravity [7]. Kindt used a head-mounted GoPro camera to gain a better understanding of the student's point of view during a class lecture [8].

Tugrul (2012) studied using a camera in the classroom The research conducted in a marketing course in a private university in Turkey found video-recorded presentations in the learning environment were highly effective in learning outcomes and enriching the education [9].

Schultz reported examples of using video productions in other disciplines including the use of student-produced videos in management classes. Interacting with the management content was believed to give students a greater chance of understanding and synthesizing the material [10].

Although video assignments have been used in the classroom in other disciplines, none have implemented the particular needs of mechanical engineering materials laboratories. Cochrane and O'Donoghue found that engineering students created video productions to present to their peers [11]. Armstrong, Tucker, and Massad investigated an innovative project where students developed and produced podcasts, giving students hands-on experience with modern tools [12].

A recent study hypothesized that in engineering classes, student learning is more effective with interactive activities than constructive, passive activities. The researchers measured student knowledge and understanding of materials science and engineering concepts. The results showed that students scored higher in all post-tests while participating in interactive activities [13].

2.2 Purpose of material science and manufacturing laboratory

Materials Science and Manufacturing, a required course in the mechanical engineering program, consists of two hours of lecture and one hour of laboratory per week. The course description is as follows: "Introduction to materials science including the structure of metals and polymers, the testing of mechanical properties of materials, the relationship between material properties, structure and processing techniques, and the capabilities and limitations of modern manufacturing methods."

The laboratory portion of the course allows students the opportunity to gain "hands-on" experience with materials testing, focusing on tensile, impact, hardness, and bending tests. Inherent within this type of experience is learning to create professional, high-quality reports. Three of the 12 course learning objectives related to the innovation are to:

1. Analyse the effect of heat treatment on metal alloys.
2. Perform standard hardness, tensile, and impact tests on metals and polymers.
3. Present experimental results in laboratory reports.

Traditional testing allowed students to perform numerous tests of material properties using only visual aids at normal camera speeds using cellular phone cameras. However, due to the destructive nature of some of the lab tests, the recording may contain risks for both students and camera.

3. The action camera experiment

3.1 The action camera GoPro Hero2

This pilot study implemented a high definition GoPro HD Hero2 action camera kit in order to capture more than just numbers in the materials testing lab session. According to CNET editors, the GoPro HD Hero2 has a glass lens, a mini-USB port for charging, a 2.5 mm microphone input, a full-size SD card slot, an HDMI video output, and a 1,100 mAh lithium ion battery [14]. In addition, it ships with a clear polycarbonate waterproof housing with spring-loaded waterproof buttons giving the user access to all buttons needed for recording and modifying settings [14]. The camera kit used contained housings to facilitate its secure attachment to almost anything from a helmet to a piece of swinging lab equipment (see Fig. 1).

Fig. 1 GoPro HD Hero2 action camera (Source: GoPro website)

The innovative aspects of this approach consisted of using a lower cost, more student-friendly medium to capture relatively high-speed videos. While the video quality may not be as excellent as a 1000 fps, multi-thousand dollar camera, it seemed sufficient to perform experiments in material failure and to capture exciting visual results.

3.2 Usage in the laboratory

The action cameras captured 120 fps footage of material failure in impact tests, tensile tests, and tensile tests of metal and plastic specimens (including heat treated metal specimens). Cameras were set up to record the failure of the material for all three types of tests and placed in a position which allowed ease in switching off and on during the test. Yet, because of its small size, its position was assured a safe area from the equipment. Two similar setup recorded impact tests were: (1) camera faces the specimen as it comes out of the impact tester; and (2) camera records the trajectory of the specimen as it leaves the impact tester. For example, its usage is described in connection with a Charpy V-notch impact test, using a pendulum testing.

Students were tasked with not only recording the impact strength indicated by the impact tester, but to (1) estimate the speed of the specimen as it left the tester and (2) comment on the breakage of the specimen as it left the tester. This data was then supplemented with digital photos of the before and after specimen.

To maintain a smooth operation of the laboratory sessions, the teams took turns performing and recording their experiments. To achieve the simultaneous recording of the experiment from multiple angles, a WiFi BacPac + ComboKit allowed the recordings to begin at the same time while removing the students from hazardous moving equipment (e.g., the impact tester pendulum arm) as recording begins.

4. Creating video productions

4.1 Student teamwork

In order to increase student interest in video production, a dedicated YouTube channel was created [15]. This channel included videos of the impact test of a metal specimen from two different views and recorded at 120 fps, in lieu of the 30 fps that is typical of a standard digital video camera.

An in-class demonstration on editing footage in Windows MovieMaker was given [16]. In addition, students were provided information on downloading the free trial of Camtasia Studio from TechSmith, which supports integration of PowerPoint slides with video and imaging [17]. Each laboratory team chose a team name and was assigned a Blackboard team page for sharing and editing files. Their team names were used with the laboratory videos posted on YouTube to protect privacy.

After the experiment was performed, the video files were uploaded to the team page on Blackboard. If issues arose with the file exchange on Blackboard, the file was posted to another online file sharing system. Next, the student teams completed the video lab editing and then submitted their video productions for grading.

4.2 Student expectations and evaluation

Students were given the opportunity to assist in developing the rubric for effective grading of the video productions. They agreed that the most important weights for the evaluation should be content (45 %), clarity (30 %), organization (10 %), format (9 %), and creativity (5 %). The video production grade was assigned as a team grade. Also, this same rubric was used during the second year of using the cameras and is shown in Table 1.

Table 1 Rubric for video laboratory reports

Criteria	Novice	Competent	Proficient
Content	*0–10 points* Missing over ½ the required content	*11–30 points* Includes at least half of the required content	*31–45 points* Contains all the required content
Clarity	*0–5 points* Excessive use of technical jargon without explanation, or incorrect explanation	*6–20 points* Use of technical terms fully explained with correct explanation, but requires a strong background in science to understand	*20–30 points* Technical terms fully explained with correct explanation understandable to someone without a physics background
Organization	*0–1 point* Poorly organized	*2–6 points* Organization is present, but flow is not logical	*7–10 points* Shows evidence of careful organization with logical flow
Format	*0–2 points* Unprofessional formatting	*3–7 points* Professional formatting, but minimal effort put into appearance	*8–9 points* Professional formatting with considerable effort put into appearance
Creativity	*0–1 points* Minimal creativity exhibited	*2–4 points* Some level of creativity, but showing little evidence of thought or skill	*5 points* High level of creativity, showing evidence of thought and skill

(Source: Developed by instructor and students in the Materials Science and Manufacturing class)

4.3 Impact testing and video production

The first video laboratory covered impact testing and required students to use the video footage to estimate the speed of the specimen as it flew out of the impact testing machine. This requirement assisted the students in viewing video footage as part of the actual experimental data, rather than as a visual supplement to data.

Next, students recorded video footage for an experiment of their own choosing. The following tests were performed:

- impact testing of a polymer specimen,
- tensile testing of a polymer specimen,
- tensile testing of an aircraft bolt,
- bending tests of steel,
- compression tests of tests of steel,
- bending test of heat treated Damascus steel.

Each team video submitted for the second video laboratory was shown in class. Students commented on all team videos and were shared via the Blackboard team page and used in final grading.

4.4 Videos on YouTube

When the submitted videos were posted on YouTube, keywords were impact testing, material testing, bending testing, and Hero GoPro. Accordingly, the videos became more useful to a wide variety of audiences. A screenshot of the videos posted on the dedicated YouTube channel is shown in Fig. 2.

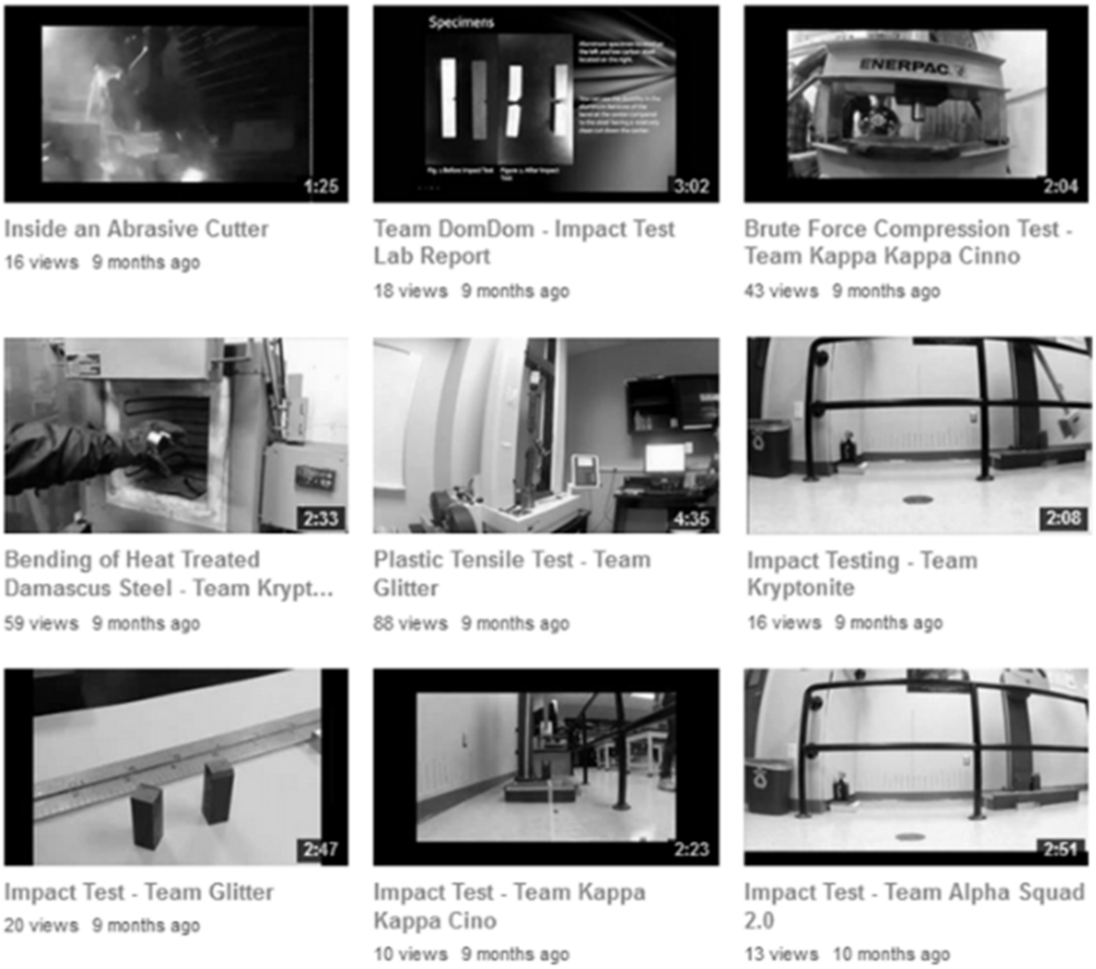

Fig. 2 Video team production presentations on YouTube

5. Assessment of the action camera experiment

Three types of assessment were used to determine the effectiveness of this innovation. They were (1) student surveys from laboratory; (2) departmental surveys on student perception of understanding of course learning objectives; and (3) mechanical engineering faculty ratings according to student performance and accreditation standards.

The last two methods are an inherent part of the accreditation process of the Department of Mechanical Engineering by the Accreditation Board for Engineering and Technology (ABET) and are related directly to an existing continuous quality improvement process implemented within the department. The faculty reviews student achievement on course objectives on a regular basis and using student data related to their understanding of the course learning objectives and performance on embedded indicators within graded course assignments.

5.1 Student perceptions of the camera project

Students completed a short, anonymous survey regarding their experiences with the camera project. Using a 7-point scale, student understanding, satisfaction, and improvement of technical communication skills were examined. Also, open-ended comments were obtained on the effectiveness of the experiment and methods to improve the camera project. For this pilot project, 11 completed surveys were analysed with a response rate of 31 %.

A majority of the respondents (73 %) indicated that they were satisfied with the variety of lab experiments (see Fig. 3). The mean score on satisfaction was 4.9, with 7 being very satisfied.

A majority (55 %) of students reported they were satisfied with the understanding of course material, while 45 % indicated no change.

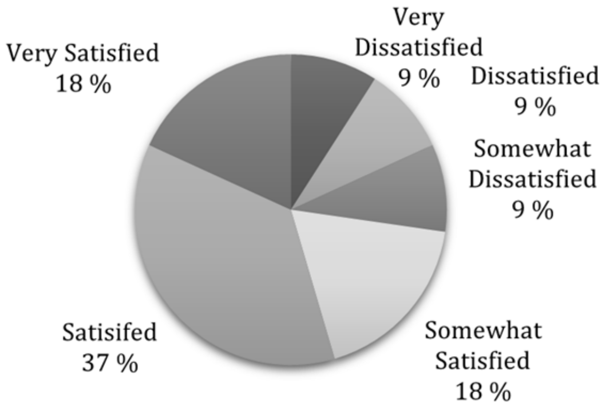

Fig. 3 Degree of satisfaction with the variety of laboratory experiments

When asked if their technical communication skills had improved as a result of the videos in lieu of a written report, 55 %, indicated a perceived improvement as shown in Fig. 4. In addition, a wide majority of the respondents (75 %) reported a perceived increase in their ability to share technical information through a medium other than written reports.

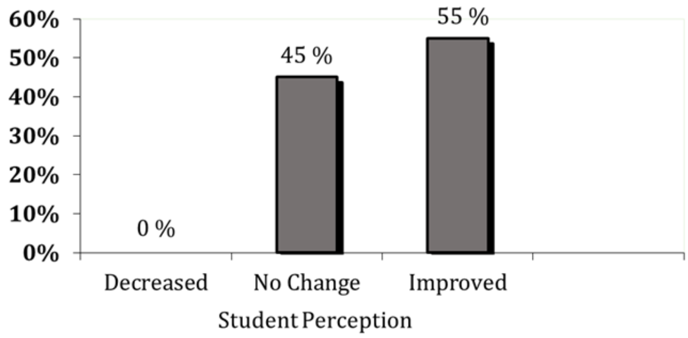

Fig. 4 Perception of technical communication skills after the experiment

Students offered the following comments during the assessment process.

- The cameras showed great resolution and helped with all of our projects
- When we had to turn in lab reports, I didn't prefer the videos. You won't necessarily do that in the future, whether it is in another class or in your job, and I would like to see the lab reports help prepare you for the future more or even better represent what you would be doing in future classes or your job. Other than that, I loved the lab!
- I loved them!
- They were great – more would improve the lab.
- The video quality wasn't as great as I had hoped for, but it got the job done.
- I enjoyed using them; however, there is a need to learn some form of digital editing software beforehand. Until some familiarity with the software was gained, the video reports were somewhat more time consuming. Using the footage to analyse failure tests, however, was quite useful in watching for fine detail.
- I enjoyed using them; however, there is a need to learn some form of digital editing software beforehand. Until some familiarity with the software was gained, the video reports were somewhat more time consuming. Using the footage to analyse failure tests, however, was quite useful in watching for fine detail.
- I would enjoy some hands-on experience with the GoPro cameras. I did enjoy the last couple of experiments where we were able to choose our own material, test, and present it. I also wish the GoPros were capable of better high-speed capture. The impact testing, in particular, was hard to document and analyse because of blurry shots.

5.2 Mechanical engineering faculty reviews

The Department of Mechanical Engineering faculty reviews course objectives and student performance as part of the continuous quality improvement process. Table 2 summarizes mean scores of faculty ratings before the cameras were introduced (spring 2012) and the following two years when cameras were used. A substantial improvement in learning objectives accomplished on treatment on metal alloys and a smaller improvement were recorded for the course objectives 2 and 3. This data is directly based on embedded indicators within graded assignments by taking the average over the entire class for that assignment/embedded indicator. The scale was A = 5, B = 4, C = 3, etc. with the average of these scaled grades taken over the entire class for the embedded indicators.

Table 2 Faculty ratings of course learning outcomes

Learning Objectives	Spring 2012	Spring 2013	Spring 2014
1. Analyse the effect of heat treatment on metal alloys.	3.7	4.5	4.7
2. Perform standard hardness, tensile, and impact tests on metals and polymers.	3.4	3.4	3.5
3. Present experimental results in laboratory reports.	3.4	3.5	3.5

As part of ABET continuous quality improvement, students rate their level of knowledge related to course objectives on a scale of 0 to 3. After the cameras were used, ratings were very high in the three learning objectives as shown in Table 3. Students had a high average score of 2.87 in in performing hardness, tensile, and impact tests. These mean score were quite encouraging and support other student perceptions and faculty reviews.

Table 3 Student perceptions of achievement from first semester of camera usage (scale is 0-3, n is 15)

Course Learning Objective	MIN	AVG	MAX	σ
Analyse the effect of heat treatment on metal alloys	1.0	2.47	3.0	0.64
Perform standard hardness, tensile, and impact tests on metals and polymer	2.0	2.87	3.0	0.35
Present experimental results in laboratory reports	2.0	2.67	3.0	0.49

6. Conclusion, limitations, and future research

6.1 Conclusion and discussion

Results from using the action camera and video productions are very encouraging regarding student learning and motivation. Students perceived their technical communication skills had increased as a result of the action camera experiment. Use of these cameras and associated video editing helped prepare these students for future coursework. Video reports are becoming an integral part of undergraduate courses, including the capstone Senior Design class for mechanical and electrical engineering majors.

Students seemed to be enthusiastic and asked permission to use the cameras for other classes where they needed to use the 120 fps video to determine how high an object bounced after being dropped from the walk through between buildings on campus. A graduate student also used the cameras to record the deformation of an aluminium honeycomb nosecone material during a simulated impact study. Also, these cameras seem ideal for other purposes, since they are all break-resistant, water-resistant, and student-resistant.

The use of the GoPro cameras in the materials science laboratory was a success, marred only by the first effort. Students indicated an improved understanding of material failure by visualizing the breakage and replaying the video. The video provided an opportunity to see a metal specimen undergo ductile or brittle failure over a span of seconds as opposed to the blink of an eye.

This technology may be used in other classes, such as business and technology, i.e. Operations Management. Likewise, while this innovative technique was used in a materials management class, the process may be expanded to other courses such as Entrepreneurship. For instance, a business plan may show a new product with only a picture, but students could implement this technique in their presentations. In addition, this video would bring the project to life and allow demonstration of the manufacturing process, testing, and being used by consumers. Presentations of strengths and features of many new ventures and products could be improved by using this technology.

6.2 Limitations and directions for future research

Since the research was designed to be exploratory in nature and thus was broad based in scope, only one laboratory experiment was conducted. The validity of the projects were measured by student perceptions, faculty ratings, and course evaluations. However, assessment of using cameras and video production should be measured in other classes with larger sample sizes.

Though the research provides interesting insights into student learning, limitations do exist. Although this innovation proposed in this study may have extended applications, the empirical tests rely on data collected from one mechanical engineering class. While no research has identified that this project in this class is fundamentally different, differences may exist in other classes. Future research would do well to integrate lessons learned in this experiment to other classroom settings and other disciplines. Specific examples are:

- *Computer Integrated Manufacturing* – Study the application of computer-aided design, computer-aided manufacturing, computer numeric control, robotics, programmable logic controllers and communication networks to achieve automated manufacturing.
- *Lean Production* – Explore applications of metal materials processing with an emphasis on lean manufacturing tools for reducing waste and streamlining production.
- *Advanced Manufacturing Processes* – Complete a survey of the latest manufacturing processes that are used in order to produce products that cannot be created with conventional manufacturing processes. Processes covered will include non-traditional machining methods, abrasive machining, advanced casting methods, specialized welding methods, and other high-end processes used in manufacturing industries.
- *Total Quality Management* – A study of the principles and practices of TQM to include leadership in quality, customer satisfaction, employee involvement, and continuous process improvement. Such TQM tools and techniques as quality function deployment and experimental design are studied.

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