Enhancing Course Learning Outcomes Through Partnerships with Field Experts

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Abstract

To achieve the course learning objectives in a professional degree program, field experience and real life problem solving are usually necessary. The objective of this work is to demonstrate a methodology to create a learning environment where theories come to life through real problems, real data, and taught by the faculty partnered with industrial experts. This approach is intended to make the course current, engaging, and motivating to the students, as well as to spark curiosity in students and demonstrate usefulness of the theory they study. To ease the development of this type of experiential learning, a methodology for such collaboration is needed. This paper provides a template for a course taught by a team in which university professors partner with the field experts. The methodology includes guidelines, activities, and best practices which can be used by faculty to more easily integrate field practice into their classroom. To illustrate the use of the developed methodology, a case study of a team taught course with field experts is provided. To measure the effectiveness of the approach, a course assessment is used in the case study.

Keywords

Course learning outcomes, team teaching, field experts, assessment, pedagogical interventions

Introduction

The team teaching approach has been around for years and is a strategy used at many different levels in many schools. A strong team includes a variety of different teaching styles. Team chemistry between the team members is arguably one of the most important indicators of success. Team teaching is "a method of coordinated classroom instruction involving a team of teachers working together with a single group of students" [1]. Lindauer[2] formalized faculty interaction by employing a discussant format, wherein each of the faculty was assured of ten minutes at the end of the other's lecture. The advantages of the discussant format have proved to be numerous and have addressed matters of both form and substance. Relative to more ad hoc team teaching approaches, the discussant format disciplines faculty by encouraging them to prioritize comments and limit the pursuit of tangential issues. The format also proves valuable in reviving student interest toward the end of class sessions. Changing faculty members an hour into the lecture revitalizes the class, enabling key points to be conveyed more effectively. Because discussant comments are prepared during the lecture instead of beforehand, they possess a dynamic quality. Robinson and Schaible[3] suggested that the optimum team size is two members. The complexity of a team size beyond this inhibits good collaboration. The teammates should agree from the start that the first time teaching together is a trial run and there should be no hard feelings if the chemistry isn't right.

A case study where three professors decided to integrate their teaching and the content of three separate courses into one period of time is documented by Bakken et al[4]. This work provided an example of integrated curricula for teacher education and the team members came from different disciplines. They used several collaborative or cooperative teaching approaches. First, each of them taught in their specific discipline, in traditional team teaching. Two or three teachers led discussions and presented information together. Sometimes, when one of them was teaching, another would join in to clarify or add another view. Gray and Halbert proposed an approach called teaching with a student[5]. This model is less expensive, involves less conflict, conserves faculty time, and leads to a more student centered classroom. The professor in charge of course design shares the daily delivery and delegates most of the administrative duties to the "student teacher". The team teaching methodology used can determine the effectiveness of the instruction. El-Sayed[6] rates the effect of several different team teaching models on course delivery, including interactive course dialogue, transitions/integration, and efficient use of faculty time. From the literature, the advantages of team teaching include:

1. Courses can reflect real-life engineering challenges.
2. Courses can be interdisciplinary by engaging professors with unique expertise.
3. Students are able to see the professors interact in the classroom. Such an interaction constantly leads to new insights about the disciplines involved because each professor models the behavior of an individual from his discipline.
4. During the problem solving process, it is beneficial for students to see the professors as learners as well as teachers, and demonstrate that learning is a lifelong endeavor.
5. The level of classroom discussion and interaction is improved. This interaction is beneficial for students who might have trouble articulating their questions or may lack the confidence to question the professor who is the expert.
6. Students have the opportunity to see that faculty members from different disciplinary areas and departments really do have consistent educational and intellectual goals.
7. It is beneficial and refreshing for students to see different teaching styles in the same classroom, and helps them develop their own methods for their reports and presentations.
8. Students have good models of team work when they see professors working together through collaborative teaching.
9. Working with new people and learning more about another discipline is very stimulating for both the faculty members and students and their enthusiasm makes the classes more interesting.
10. Team teaching gets faculty members into other places to get better acquainted with colleagues they often have little contact with.
11. It is beneficial for companies to have many different solutions to their engineering problems at very low or even no cost. Very often the students look at the projects from very fresh perspectives and might lead to innovative solutions.
12. Companies can find future recruits by this kind of interaction with students, and students also have the opportunity to see if the companies and products fit their interests in the future.
13. Interacting with academia is a chance for the industrial experts to have a respite from the normal day to day work pattern.
14. Industrial experts are provided with the philanthropic opportunity to leave a legacy to the next generation.

Certainly there are a lot of challenges in the team teaching model:

1. The class schedules of the universities may be very different from that of the current product development/launch in the companies. Therefore the conflict of priorities in educational institutes and industrial companies will have to be resolved and agreed upon.
2. Students might be confused when they do not know which professor to ask specific questions.
3. It is expensive to pay more than one professors to teach one class.
4. It would be difficult for all parties involved if the professors were not compatible, and faculty should never be forced into something like team teaching.
5. Class projects will be more "on the fly" instead of thoroughly prefabricated.

The Need to Team up with Industrial Experts

Kettering University offers one of the largest co-operative educational programs in the United States. Our students rotate their academic and work terms every three months. They conduct research through their co-op projects leading to graduation thesis. It is very important to bring the real life projects and industrial experts to the classroom in order to stimulate the students' skills of creative thinking, problem solving, and therefore achieve the educational outcomes. It is a common practice and easy to do to invite guest speakers to the classrooms for certain topics. Yet it involves much more work to have a true team teaching approach. The main theme of this paper is to develop an understanding of team teaching with industrial experts and provide practical recommendations that other faculty can use to build upon for use in their own courses.

The process for team teaching involves the following steps:

1. Define course learning outcomes (CLOs)
2. Choose topic/theme
3. Choose teaching team
4. Choose industrial partners
5. Outline activities matching and mapped to CLOs
6. Choose project with input from industrial partners
7. Choose guest lecturers
8. Provide field trip for immersion learning at industrial sites
9. Design assessments
10. Timeline for development

Table 1 shows the template of the team teaching course outline, where the weekly topics are tabulated. This template can be modified based upon the instructor's course and type of project. It is best geared for use in courses beyond the freshman year when the students have enough background for more sophisticated team projects.

Table 1 Template of Team Teaching Course Outline

Week	First class period	Second class period
1	Introduction to class with prof(s) /Selection of project teams	Overview of industrial process with expert(s)/presentation of project
2	Lecture 1, assignment 1	Lecture 2, assignment 2
3	Guest lecture- topic 1	Progress report/pres. on projects
4	Lecture 3, assignment 3	Lecture 4, assignment 4
5	Lecture 5, assignment 5	Assessment/exam 1
6	Guest lecture- topic 2	Lecture 6, assignment 6
7	Lecture 7, assignment 7	Lecture 8, assignment 8
8	Lecture 9, assignment 9	Progress report/pres. on projects
9	Field trip to industrial site, written reflection	Lecture 10, assignment 10, continue to work on project
10	Lecture 8, assignment 8	Assessment/exam 2
11-14	Lecture 9, assignment 9, project	Lecture 10, assignment 10, project
Final week	Final presentation with experts	Final exam

Best Practices

In order to provide some of the wisdom that comes from experience, the following recommendations are provided. Working with projects that are based in industry creates challenges; however the rewards in student learning are worth the extra effort. Having clear mutual expectations and communication are keys to success.

1. Keep open communication, when in doubt ask for approval.
2. Remember that the frustrations that the students encounter is not unlike situations that they will encounter in industry - do not underestimate the value of this learning.
3. Remain positive and do your best, some things will work and some will not.
4. Make the development of the team a top priority. Do not just assume the team will work well together without any issues.
5. Set clear goals for the team that all members agree upon, and then ensure its activities lead to those goals.
6. Communicate clearly and honestly to survive and grow stronger from conflict.
7. Honor individual and team success through administrative support.
8. Assume responsibility for assigned roles.
9. Be prepared for team discussions and work.

Guidelines for Guest Lectures

Guest lecturers from industry are largely unfamiliar with academia and the mindset of students. In this case the professor is the expert and must be the facilitator. The professor must communicate how to best interact with students and the level of content needed for each class period. Most individuals from industry will greatly appreciate this guidance as they wish to make a positive contribution. Often the industrial experts have limited time but greatly look forward to the opportunity to contribute.

1. Provide time estimate and orientation for guest lecturers - be a coach.
2. Attend all class sessions with guest lecturers.
3. Help the experts to understand how your students learn best.
4. Be approachable and seek regular feedback from students.
5. Communicate the background and experience of the students

Suggested Additional Active Learning Activities

In addition to the activities outlined in the template, several active learning techniques can contribute to student learning and are synergistic. Activities can be planned where the students can participate in the preparation, presentation, or grading work well due to the spontaneous nature of these types of courses. Students can take ownership of their learning and often have ideas that provide superior knowledge construction. Following is a list of possible additional activities.

1. Written briefs on topics or pre reading.
2. Presentations on research papers.
3. Ask students to write quiz questions based upon guest lecturers topics.
4. Have students set the performance criteria and expectations for grading.
5. Present projects.

Check List for Team Teaching with Industrial Experts

The following is a recommended check list of discussion items. These issues should be discussed before beginning to teach together in order to make the team more efficient right from the start. Some of these decisions are straight forward and others will take some time for instructors new to this methodology to build sufficient experience.

1. Scope of topics
2. Approval timeline
3. Confidentiality
4. Materials, books, supplies
5. Role assignments
6. Who provide what, how to get it
7. Who should teach what
8. What content should be taught separately
9. What content should be taught jointly
10. How we grade the students' work
11. Who grades which papers
12. What grading system

Case Study - Redesign Engine Cam Cover

An automotive powertrain application is chosen as a case study example to illustrate the team teaching approach discussed in this work. The design process of a typical powertrain component will be presented by the industrial expert, including the engineering specifications and goals for mass and cost reduction. Supervised jointly by the faculty members and engineers from industry, different project teams will perform their own designs approved by the teaching team.

Step 1. Define students' learning outcomes

Hanson[7] provided a great guide for defining, designing, and aligning the activities with the students' learning outcomes. For this course the students' learning outcomes include the following:

1. Improve problem-solving skills in real-life projects;
2. Apply knowledge learned on engineering mechanics;
3. Reduce cost in materials and manufacturing;
4. Reduce mass of products;
5. Apply skills in computer-aided engineering (CAE);
6. Develop environmentally friendly products.

Step2. Project Orientation

Automotive powertrain systems include engines and transmissions, and auto makers have been making constant efforts to improve the powertrain systems for higher fuel efficiency, increased temperature resistance, mass and cost reduction, etc. For this work, we teamed up with the powertrain expert to transition powertrain components from metallic to plastic materials.

The motivations for transitioning powertrain components from metallic to plastic materials[8]:

- Manufacturing and materials cost reductions
    - Lean manufacturing principles
    - More efficient material usages by thinning wall sections and integrating components
    - Mass reduction
- Laser welding
    - Potential high volume production with complex design at low cost
    - Replace vibration welding allowing thinner reinforcing ribs and reduced weight
- Enhanced Material and Property Characteristics
    - Material NVH Characteristics
    - Consolidation of Components
    - Appearance
    - Colorable
    - Improved Structural Performance
    - Increased Temperature Resistance
    - Replaces higher cost composites such as reinforced nylon
- Recyclable / Environmentally Friendly Products

- Thermoplastics are more desirable than Thermosets
- Bio plastics
- Natural Fiber Reinforcements

Plastics can assist engineers functionally and esthetically. The underhood (as shown in Figure 1) looks neat, orderly, uncluttered, integrated and well-engineered by taking the following measures:

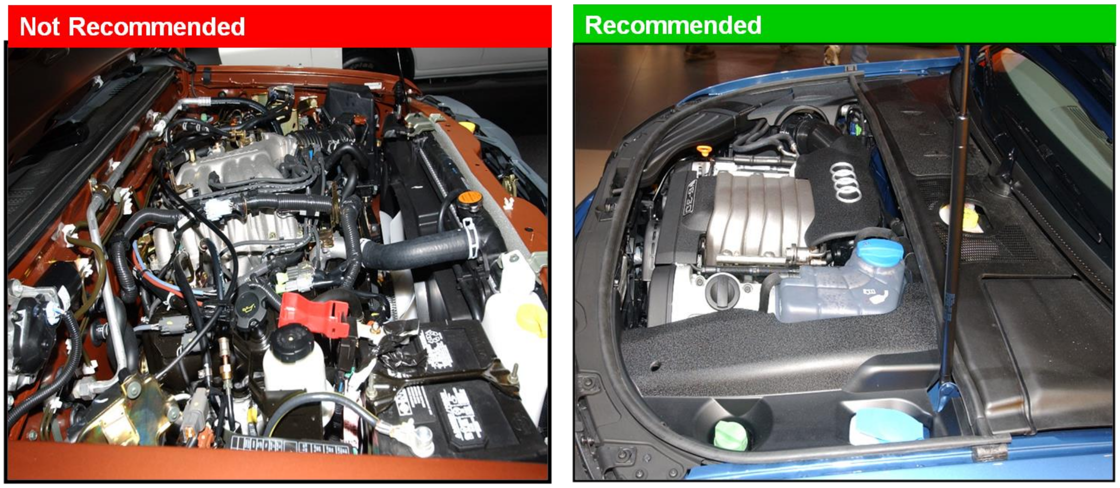

Figure 1 – the underhood Engine compartment

- Hidden when possible or integrated to components
- Routing of wires and hoses are neat and orderly, generally orthogonal in layout or aligned with components/body
- All exposed wires and hoses are black unless they are intended to be character enhancing
- All hoses, wires and connectors are black, tubing black, natural when not possible
- All connectors to be booted or sealed
- The bends of routed wires and hoses are executed to a level complimentary to the under-hood appearance

Step 3. Demonstration Project

The powertrain specialist was invited to the class and gave a lecture on the cam cover design introduction. The purpose of cam covers is to cover the engine cam that open/close the exhaust and intake valves, keep oil in the engine using elastomer gaskets, and reduce engine noise, as shown in Figure 2. The objectives of the design analysis are:

- Determine deformation, at the gasket groove (see arrow), under gasket pressures
- Change the material to for mass reduction
- Compare the deformation of each cam cover
- The best cam cover design for sealing should deform as less as possible when gasket pressures are applied.
- Determine if cover stresses are acceptable

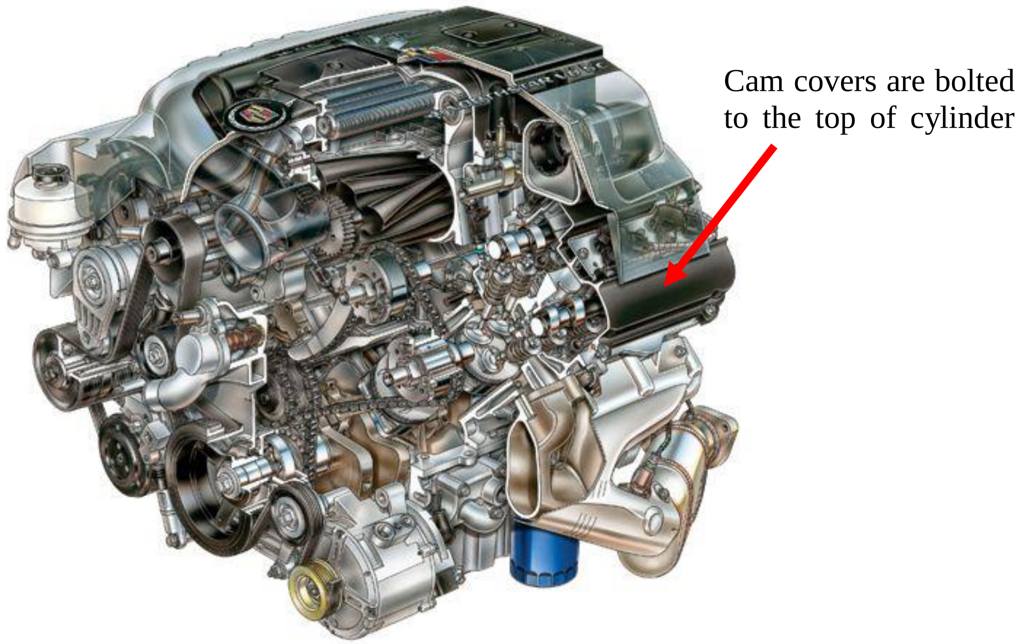

Figure 2 – Engine cam cover

There are several typical engineering materials that are used for cam covers with strengths and weaknesses (Table 2). A sealing pressure of 1.0 MPa was applied for this analysis along the cam cover grooves where the gaskets are mounted in order to keep splash oil from leaking. In the finite element analysis (FEA), the translation constrains are applied at the bolt holes where all rotations are set free (Figure 3).

After the lecture of the powertrain specialist, some material suppliers and the university's plastics industrial advisory board members were also invited to teach the material engineering and applications. Then the faculty and the students toured the powertrain facility to better understand the products engineering.

Table 2 – Typical cam cover materials and comparison

Cam Cover Materials	Strengths	Weaknesses	Comments
Magnesium	Weight	Cost Galvanic cell reaction Creep resistance	There is a concerted effor to reduce weight for fuel economy gains and all components are continually being evaluated. Can cast 2.0mm wall thickness. New magnesium alloys have been improving creep and strengths
Thermoset glass reinforced plastic	Cost Weight	Strength Stiffness	Thermosets cannot be recycled and made into other components
Glass reinforced Thermo-plastic	Cost Weight	Strength Stiffness Creep resistance	The recyclability and cost of the material make an attractive alternative but the strenght and creep resistance make this material a concern for long term reliability.
Aluminum	Stiffness Creep resistance Corrosion resistance	Weight	Aluminum has been a traditinal material for covers, but requires at least 4mm wall thickness for casting.

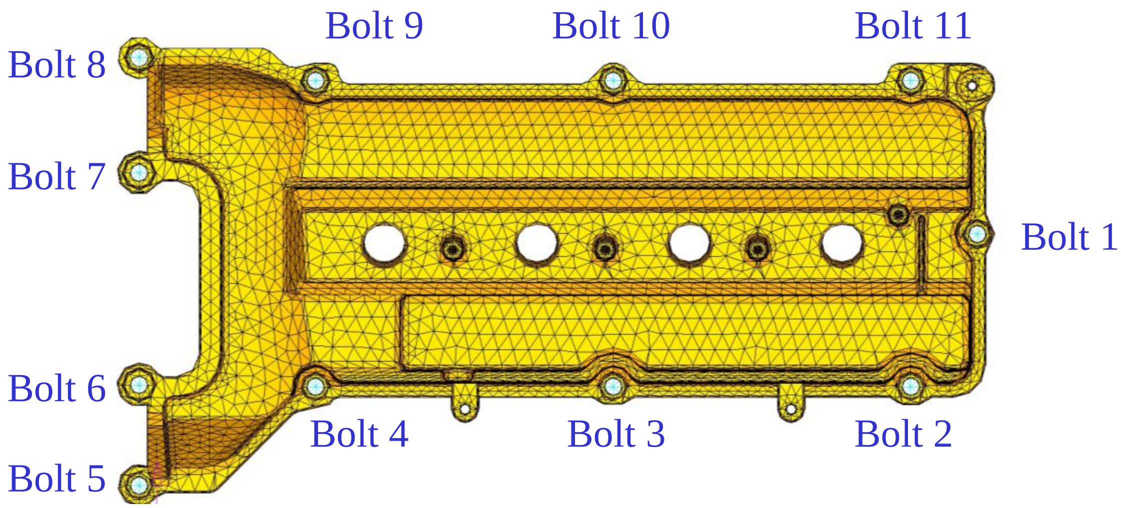

Figure 3 – the cam cover FEA model

***Step 4. Finite Element Analysis of an Engine Cam Cover* – Faculty and Industrial Expert**

In the next phase, the students were divided into project teams and began the design and analysis. The following sessions represented the students' work in the project.

Material Selection

Through research on common plastics used in automotive applications, three materials, in addition to the magnesium, where selected for analysis. These three materials are 30% glass filled nylon 66, Akulon®K224-G3 (PA6-GF15), and Stanyl®46HF4130 (PA46-GF30).
The 30% glass filled nylon 66 is typically used for textile and industrial fibers, but is also used for injection mold resins. This injection mold resins include automotive parts, electrical parts, and consumer articles. Also, Nylon resins belong to a group of high-performance plastics often referred to as engineering thermoplastics. These materials are noted for their outstanding properties, including high tensile strength; excellent abrasion, chemical and heat resistance; and low coefficient of friction. The current price is approximately $1.40 per pound, compared to magnesium which is at about $2.20 and still rising.

Akulon®K224-G3 is a 15% glass filled polyamide 6. Some common applications include film, automotive, industrial, and consumer. Akulon polyamide resins represent a great value in all-purpose engineering materials. For molded parts, they offer an excellent balance of easy design and processing with outstanding mechanical properties over a wide temperature range and in diverse operating environments. The PA6 was chosen because compared to PA66, PA6 offers a better price to performance balance for most applications where polyamides are used. Although there are differences in melting temperature, moisture uptake and ductility between PA6 and 66, actual performance is virtually identical and the products are interchangeable in about 90% of applications.

Stanyl®46HF4130 is a 30% glass filled polyamide 46. This material has thousands of applications in automotive engines and transmissions, lighting, computers, phones, power distribution equipment and appliances. Also, Stanyl has a high stiffness in combination with excellent wear resistance even at high temperatures (capable to more than 200ºC and for short term peak temperatures to 250ºC). The strength and stiffness allow it to survive dynamic and static loading. Also, it has high creep resistance especially at high temperatures and for design flexibility and ease of molding it has high flow. The solution is very durable and has a outstanding toughness in addition to excellent oil resistance.

Analysis

Finite Element Analysis (FEA) will be performed on the cam cover with each material, including the magnesium and the alternatives. The material will be selected based on the comparison of the stresses and deflection of the cover for the four materials. Table 3 below lists the important material properties used in the FEA of the materials.

Table 3 – Material properties used in the FEA

	Magnesium	**GF30 Nylon 66**	**Akulon**	**Stanyl**
Young's Modulus (MPa)	40000	10000	1060	9030
Ultimate Tensile Strength (MPa)	260	180	125	210
Density (g/cm3)	1.81	1.8	1.23	1.41

To perform the FEA a couple of assumptions had to be made. First that the holes left for the injection sites can be neglected and second that all radii under 5 mm can be neglected. These assumptions allowed the part to be idealized making the model less complex. Figures 4 and 5 show the results of the FEA on the magnesium part.

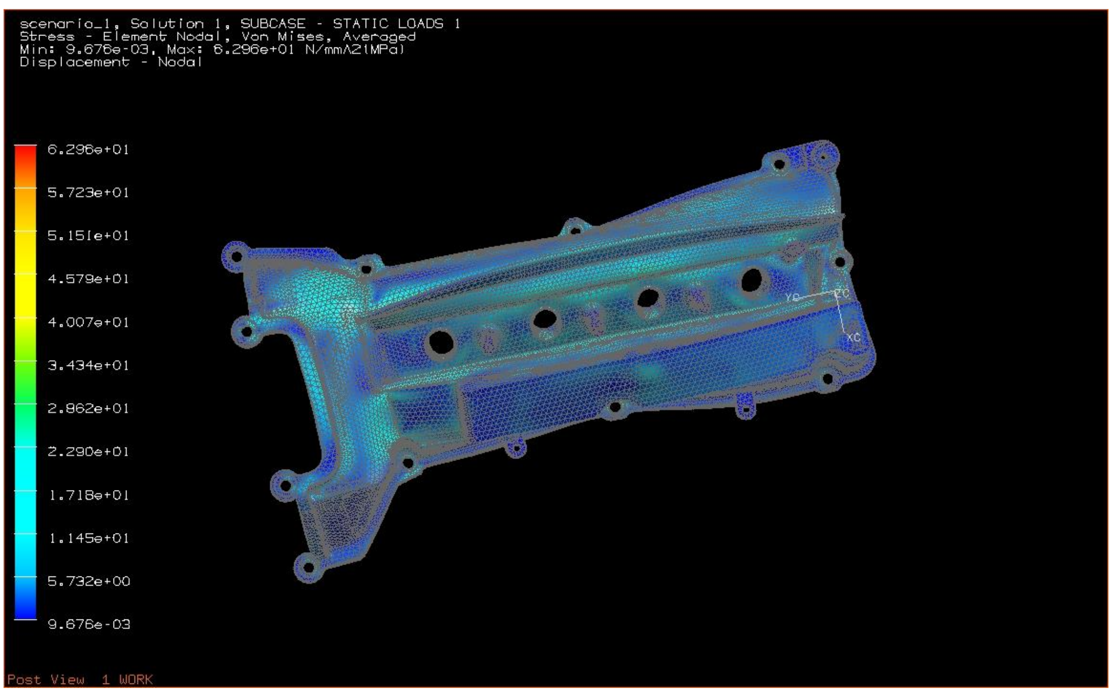

Figure 4 – Engine CAM cover stress distribution (magnesium)

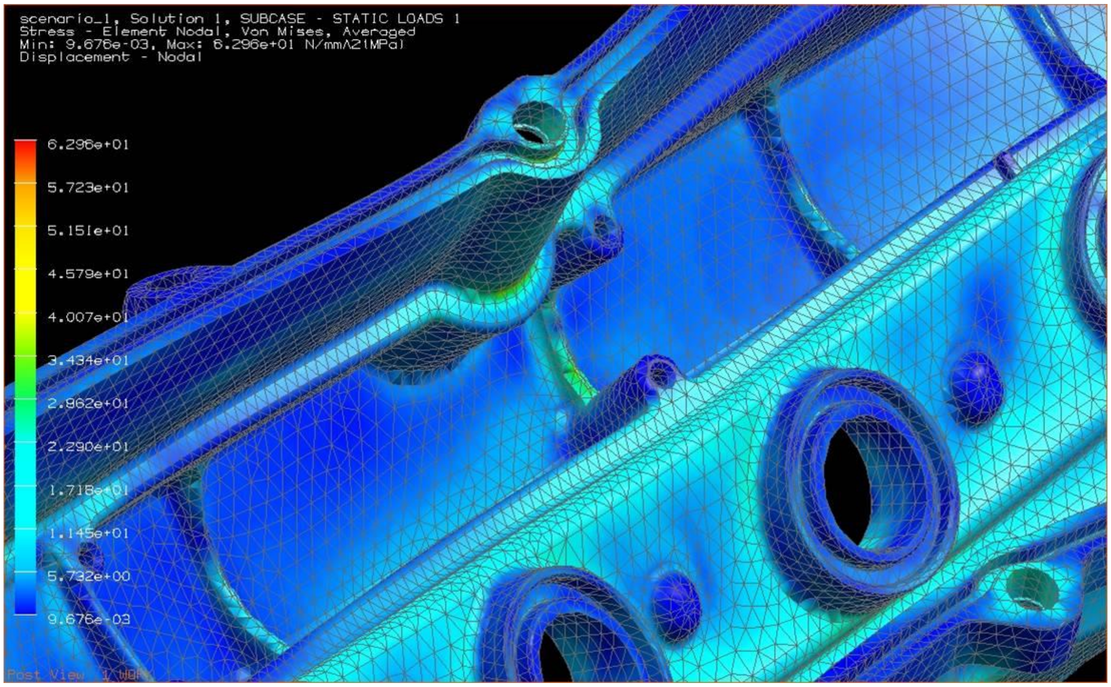

Figure 5 – Engine CAM cover stress distribution zoomed in (magnesium)

Student Project summary

Using the maximum stress found in the FEA and the ultimate tensile strengths the safety factors for the cam cover with the four various materials were determined, as shown in Table 4.

	Magnesium	GF30 Nylon 66	Akulon	Stanyl
Safety Factor	4.1	2.9	1.7	2.8

Based on the FEA of the four materials Stanyl®46HF4130 and 30% glass filled nylon 66 would both be suitable for the cam cover. Other properties of the material must be considered to further narrow the selection. Some other properties include the materials resistance to chemicals and materials behavior at higher temperatures. The FEA analysis was ran assuming the parts were at room temperature, but the cam cover will be exposed to temperature up to 150ºC. This temperature is around that of the glass transition temperature for nylon 66, so this material will not be appropriate for this application. On the other hand, according to DSM, Stanyl is able to maintain stiffness and wear resistance at temperatures more than 200ºC and for short term peak temperatures to 250ºC. For this reason, Stanyl is the material of choice for this application to replace magnesium.

Assessment

To measure the technical role of “collaborator”, the assessment method of direct observation was used [9]. Three key performance indicators were selected from the list of attributes in this literature. These attributes were: (1) respectingnindividuals with diverse backgrounds, perspectives, and skills important to the efforts; (2) valuing roles, accepting role assignments, and supporting others in their roles; and (3) contributing to the effective cooperation of the team in its development of consensus goals and procedures. These attributes were mapped to corresponding rows in an analytical teamwork rubric[10]. The adapted modified rubric is shown in Table 5.

Table 5 – Key performance indicator rubric

		Beginning	Developing	Accomplished	Exemplary
Key Performance Indicator	Listens to other teammates	Always talking - never allows anyone else to speak	Usually doing most of the talking - rarely allows others to speak	Listens but sometimes talks too much	Listens and speaks a fair amount
	Fulfils team roles/duties	Does not perform any duties of assigned team role	Perform very few duties	Perform nearly all duties	Performs all duties of assigned team role
	Cooperate with teammates	Usually argues with teammates	Sometimes argues	Rarely argues	Never argues with teammates

Based on direct assessment of the students, over 75% of the class measured “Exemplary” in all three key performance indicators selected for the technical role of “Collaborator”. The other 25% of the class measured “Exemplary” in two key performance indicators, and “Accomplished” in one key performance indicator. Comparing this to the program target of all graduating students measuring “Accomplished” , this signifies that pedagogical interventions such as team teaching field experts can indeed enhance movement toward achieving educational objectives and outcomesThe comments of the students on the course evaluations suggest that such innovative classroom techniques may also increase students’ enthusiasm and engagement.

Conclusions

A team teaching strategy to bring industrial experts into the classroom is proposed. To facilitate the development of this type of collaborative learning, a template for such team teaching is provided. Using this template, a methodology that includes best practices, guidelines, and activities is developed which can be used by faculty to more easily integrate practice into their classroom. A checklist for selecting appropriate industrial projects with the collaborating partners is also included. To illustrate the usage of this methodology, a case study of a course partnership between industrial experts and Kettering University Mechanical Engineering faculty is provided. This case study involves an automotive engine cam cover design. Four different materials were chosen in the FEA and Stanyl is the material of choice for this application to replace magnesium to reduce the mass and cost. A collaborative course teaching approach stimulates the critical thinking and team work between faculty, field engineers, and students and can lead to optimized designs.

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