

Using Literature Reviews as a Learning Tool for Solid Freeform Fabrication

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Over the past six years, students involved in the “Non-Traditional & Additive Manufacturing” course at Utah State University have been assigned an in-depth literature review as one their course projects. This literature review, done in groups of 2 or 3 students, involves becoming an expert on a topic of interest to the students and then presenting this material to the class as an in-depth, oral presentation in addition to writing a journal-like review article on the topic. This project has proved to be a consistently effective method for enhancing learning of SFF technologies and their applications, and has been consistently noted by students in their course evaluations as a highly effective teaching tool. The methodology used for assigning and assessing these projects will be explored, in addition to a discussion of the benefits of this project toward meeting ABET criteria for accreditation of engineering programs.

Introduction

Due to the relatively recent advent of solid freeform fabrication (SFF) technologies and the fact that these technologies have rapidly evolved over the past two decades, no up-to-date comprehensive engineering textbooks exist. Although a number of excellent books do exist that describe most SFF processes, they are relatively short compared to traditional engineering textbooks and are typically more suited to training technicians and businessmen than engineers. These books do not provide sufficient mathematical and scientific depth of material to satisfy the requirements of a semester-long engineering course dedicated to SFF.

When considering the books that have been written about SFF in combination with other “secondary” sources (journals, conference proceedings, trade publications and websites) there exists a sufficient body of knowledge to fill several semesters on SFF technologies. As a result, faculty who desire to teach engineering students about SFF must utilize these secondary sources. In order to make use of these secondary sources, to provide students with up-to-date information on new technologies and applications, and to ease the faculty workload necessary for class preparation in the absence of a comprehensive textbook, student literature review projects have been a key component of engineering coursework at Utah State University for the past 6 years in the Non-Traditional & Additive Manufacturing (MAE 5650) course taught within the Mechanical & Aerospace Engineering department. This course has been taught to approximately 30 students each time it has been offered, and the literature review component has consistently been mentioned during student evaluations as the portion of the course which resulted in the best learning.

Course Overview

MAE 5650 is a three-credit course taught as a technical elective for upper-level undergraduates and graduate engineering students. MAE 5650 meets for one hour and 15 minutes, twice a week. It has also been taught using traditional 50 minute lectures 3 times a week, but the presentations

involved as part of the literature review project fit better within a longer class period. Thus the course is now taught exclusively using 75 minute lectures twice per week.

The first four weeks of the course are utilized to teach the fundamentals of SFF technologies, including a basic understanding of the benefits and drawbacks of SFF technologies compared to traditional manufacturing technologies, using mostly PowerPoint presentations and videos. As part of teaching the fundamentals, I have utilized several different rapid prototyping books over the years as required course textbooks. Recently, I have distributed a draft textbook I am co-authoring for use by my students rather than having them purchase a published textbook.

During the first week of the course, I hand out the basic literature review project details and by the second week of the course, the students have chosen a project topic and team, in order to begin working on their literature review.

My lectures for these first four weeks are designed to introduce the various types of SFF technologies using the same classification schemes as those used in whichever book the course is utilizing at the time. I do not focus on specific brand names for technologies, but instead overview the various additive manufacturing methods and approaches to SFF technologies which have been developed over the years. I typically follow this set of lectures with an exam during the fifth week of class to make sure students have sufficiently studied the lecture materials to understand the difference between common SFF technologies, to understand general benefits and drawbacks of each technology with respect to other SFF technologies and with respect to traditional manufacturing techniques, and to make sure they understand why SFF technologies were developed for and work well as prototyping technologies.

Project Assignment

A copy of the most recent assignment, handed out during the first or second week of classes, is shown in Table 1. The dates noted in this specific assignment were relevant to the 2008 spring semester, where the first week of class began the week of January 7th with a Spring Break during the week of March 17th.

To summarize the assignment, the project contains two major parts. These are the preparation of a review article using the author guidelines for the *Rapid Prototyping Journal* and the preparation of a 30 minute lecture (where the presentation is shared equally between team members). Students typically have only one week to choose a teammate and select a topic. On a first-come-first-choice basis, I put out a sign-up sheet at the beginning of class. Students usually show up early this day and form a line. Students then sign up for a topic and presentation date, and I am there to help clarify topics and make sure all students find a suitable topic and partner. Thus, their topics are usually selected with little foreknowledge of the details (only a general understanding of SFF and the course, based on only 1 week of lectures, and whatever minimal literature review the students have done to select a topic).

In addition to the assignment, I always distribute a list of suggested topics. These are topics where I know there is sufficient information to merit a review paper and 30 minute lecture. Some example topics are:

Table 1. Project Assignment

Project Guidelines

This project is made up of 2 parts. These two parts are: (1) the preparation of a journal-quality article, and (2) a 30 minute professional presentation to the class about the topic of your project. The class will be divided into groups of 2 students each. I will not assign groups, so you will need to organize your own groups. You can begin signing up for a topic at the beginning of class January 17th on a first-come-first-served basis.

Part A:

The first part of the project is the preparation of a journal-quality paper (using the journal standards of the *Rapid Prototyping Journal*) that overviews the topic of your project. This necessitates a complete literature search related to your topic and completion of an overview manuscript that uses appropriate and complete bibliography citations for your topic. **A Draft of Part A is Due February 21st and will count as 10% of your Part A Project grade.** I will give you a more detailed list of requirements for the paper at a later date.

I will perform a review of your papers (as a journal editor would) and give you feedback. You must edit your paper, taking into consideration my feedback, and **submit the final version March 20th**. Late submissions will be docked 10%/day.

Your manuscripts will be distributed to the class in order to aid in preparation for the exam. Thus, **you must supply me with an electronic version of your paper.**

Part B:

A 30 minute lecture/presentation must be prepared. This presentation must be a multi-media PowerPoint presentation given utilizing the classroom projector system. You must evenly share the presentation responsibilities with your teammate (the presentation will be jointly given and each individual should talk for 15 minutes). You are encouraged to include hands-on demonstrations, videos, or other teaching aids as appropriate.

These presentations will be considered class lectures and everyone will be tested on an exam for knowledge of the materials presented. You must prepare handouts for the class as part of your lecture and bring them to class on the day of your presentation.

These presentations will be scheduled during February and March. There will typically be 2 presentations per class. You can sign up for a presentation time next week.

You ***must meet with me 1 week prior to your presentation*** to go over your presentation materials. Thus, your presentation materials must be in a final draft form at least one week before the presentation (giving you a week to correct or add information to the presentation after meeting with me).

You will receive 2 grades for this project. One project grade will be based on your paper and a separate project grade will be based on your presentation/lecture. I will give you more details concerning how your presentation will be graded at a later date.

- Medical uses of RP
- Rapid Tooling
- Use of RP techniques for producing end-products (rapid mfg./direct digital mfg.)
- Software Issues in RP
- Nano, micro and meso-scale additive manufacturing (including direct write)
- RP as a Concurrent Engineering / Design Aid

- RP as a Repair Methodology
- Finishing of RP Parts
- Reverse Engineering & 3D Scanning combined with RP
- Embedded structures (sensors, electronics, etc.) in RP
- Multi-material & Gradient Material Structures using RP

In addition to this list of potential topics, I make it clear that if they find a topic that they want to research that is not on the list, they can also come to me and I will either approve it or disapprove it, based on whether it is sufficiently different from other projects or whether or not it has sufficient literature of sufficient importance to merit a lecture and review paper. These student-initiated topics are usually related to either something of interest to a particular graduate student (who may be doing a thesis on a related topic) or a topic of interest to a student for personal interest reasons (such as automotive or aerospace applications of SFF technologies).

Several topics are sufficient in depth to merit multiple projects. Every semester there are several groups interested in medical applications, and we have subdivided that topic into multiple topics. One way to subdivide this topic is between surgical planning, implants, and prosthetic applications of SFF. Other topics can also be subdivided (such as rapid tooling divided into hard and soft tooling) depending upon the number of groups and the interests of that particular student group.

In semesters where the class has been particularly large, I have had the students form groups of 3. However, I believe this project is more effective in groups of 2, and I believe the learning outcomes merit the dedication of a large portion of class lecture time to these group presentations

In approximately the 3rd week of class, I hand out additional details concerning the oral portion of the project. These are included in Tables 2 and 3. I go over the information in these tables in great detail during class, emphasizing my expectations and the importance of each of these items as part of an effective, professional presentation.

In order to help motivate the students to do well on this project, I remind them that beginning engineers are often tasked with investigating new commercial opportunities or state-of-the-art technologies for their employers – to help them make important decisions about their applicability to their business strategies. These tasks typically involve oral and written reports of their findings. Thus, this project is designed to give them the literature search skills they need to perform such a role well, and the communication skills to effectively disseminate their findings.

Early in their projects, I also demonstrate the use of a number of common literature resources to help them find information for their project. The main ones I typically show them how to use or make available to them are:

- Internet
 - Google & Google Scholar
 - Castleisland website – this is a key resource as it includes all SFF abstracts
 - Rapid Prototyping Journal
- Library
 - Ei compendex, Web of Science, etc.

- Conference Proceedings and Trade Magazines
 - I make available my entire collection (complete SFF proceedings)
 - They must identify the article before I give them a copy
 - Students can take proceedings for a short time to copy an article

In approximately the 4th week of the course, I hand out greater detail regarding the written portion of the project. These details are shown in Table 4.

When I distribute the written project details, I emphasize the importance of proper attribution of materials and the necessity to avoid plagiarism. As their projects constitute a literature review and not results of their own research, I require them to properly reference every major claim. In addition, I strongly emphasize the need to minimize and properly reference every quotation. Almost every semester, one or more students directly copies a portion of someone else’s work and pastes it into their review without attribution. Whenever there is a significant change in writing style within a paper that they submit, I will type key phrases into Google to see if it is plagiarized. If there is plagiarism, I significantly dock their grades, taking into account the severity of the plagiarism.

Evaluation Methods

Tables 3 and 4 show the relative weighting of each grading metric that I use. Students perceive grading of oral and written presentations as “subjective” and I have found that a detailed grading rubric helps in three key ways. First, it helps the students think about their presentation style and content more fully, thus resulting in higher quality presentations. Second, it speeds up the grading process and helps me quickly assign grades in a more objective manner. Third, it helps minimize the number of student complaints about grading (as I can refer back to specific issues which negatively impacted their grades).

Table 2. Oral Project Details

| RAPID PROTOTYPING ORAL PRESENTATION DETAILS |
|---|
| <p>A lecture/presentation will be prepared for your group’s topic using the following guidelines:</p> <ul style="list-style-type: none"> • This presentation must be a multi-media PowerPoint presentation given utilizing the classroom projector system. • Each member of your team must speak between 14 and 18 minutes. Any more or less will result in a docking of your presentation grade. • You are encouraged to include hands-on demonstrations, samples parts, or other teaching aids as appropriate. • Videos should be edited so that they present only the most relevant information (30 seconds or less in length is a good rule of thumb). • Prepare PowerPoint handouts for the class as part of your lecture and bring them to class on the day of your presentation. • <i>Meet with me 1 week prior to your presentation</i> to go over your presentation materials • Use appropriate citations for the materials on your slides. • Try to find at least one visual for each slide you make. • Use approximately 1 slide per minute of speaking time. (Some people speak more rapidly or more slowly, so adjust to fit your presentation style.) • Do not use long sections of text on slides. Use bulleted summaries of ideas and expand upon them verbally. |

Table 3. Oral Grading Rubric

| | |
|---|--------------------|
| Topic: _____ | Name: _____ |
| Individual Grade (60%) | |
| Organization and Content (20%): | |
| • Individual Presentation Organization/Flow (Good intro, transition, flow) | 1 2 3 4 5 |
| • Use of Visual Aids (Demonstrations, graphics, etc.) | 1 2 3 4 5 |
| • Use of Time (Fit naturally within 14-17 min) | 2 4 6 8 10 |
| Presence (15%): | |
| • Physical Appearance (Dress a cut above your audience) | 1 2 3 4 5 |
| • Posture, Gestures, Movement, Eye Contact (Move around, look at audience, etc.) | 1 2 3 4 5 |
| • Enthusiasm, Enunciation, Clarity (Smile, no monotone, not too quiet) | 1 2 3 4 5 |
| Delivery and Grammar (25%): | |
| • Knowledge of Material & Terminology (Evidence of depth of knowledge) | 2 4 6 8 10 |
| • Overall Effectiveness of Delivery Method (Ability to Connect w/ Audience) | 2 4 6 8 10 |
| • Freedom from Distracting "Uh"s, etc. (No nervous words or motions) | 1 2 3 4 5 |
| Group Grade (40%) | |
| • Clear Thesis Statement & Purpose (What is your main point?) | 1 2 3 4 5 |
| • Adequate Support for Thesis (Did your back up your main point?) | 1 2 3 4 5 |
| • Overall Flow & Organization (Easy to follow, logical, smooth transitions) | 2 4 6 8 10 |
| • Definite Conclusion (Summarize main points) | 1 2 3 4 5 |
| • Overall Completeness of Topic Coverage (Any gaps in coverage?) | 2 4 6 8 10 |
| • Q & A Session-Knowledge of Topic | 1 2 3 4 5 |
| Comments: | |

I have found that it is important to write down the beginning and ending time for each student and to take detailed notes during each student presentation in order to give adequate feedback to the students. This detailed feedback is a key component for helping students improve their oral presentation skills.

Table 4. Written Project Details

RAPID PROTOTYPING WRITTEN PROJECT DETAILS

As a group, you must prepare a journal-quality paper on your topic, using the following guidelines:

- You must write the paper according to the journal submission requirements of the *Rapid Prototyping Journal*.
 - **ONE EXCEPTION:** Format the article to look like it is published in the RPJ (two columns with figures inserted) rather than the double-spaced version recommended for article review.
- You must perform a complete literature search related to your topic
 - At a minimum your references must include 5 or more journal articles, 5 or more trade/conference articles and 5 or more websites.
- Do not use extensive quotes unless they are critical!!
 - All quotes must be properly attributed within quotations, or if they are long then within smaller margins
- The reference style for the RPJ must be used properly, and all material must be properly referenced.
- A Draft of your paper is Due February 21st and will count as 10% of your written project grade.
- The final version of your paper is due by March 20th.
 - Late submissions will be docked 10%/day.

Your manuscripts will be distributed to the class in order to aid in preparation for the second exam. Thus, **you must supply me with an electronic version of your paper.**

Your paper will be graded using the following rubric:

- | | |
|--|-----|
| • Draft paper complete and on-time | 10% |
| • Good Abstract and Keywords | 5% |
| • Followed Formatting Rules/Looks Good | 5% |
| • Appropriate Use of References | 5% |
| • Appropriate Use of Figures | 5% |
| • Grammar & Spelling | 10% |
| • Effective Use of Case Studies/Examples | 10% |
| • Effective Thesis/Support/Conclusions | 10% |
| • Flow of Paper/Organization | 15% |
| • Completeness of Content | 25% |

Discussion

Based on the details described above, there is time for 2 groups to do their oral presentations per class period. Thus 4 different students will present during each class period. Typically there are a few minutes left after the last group presentation, and during that time I will discuss class logistics and go over general questions on the projects. I will also clarify any questions about the student presentation topics that the students themselves were unable to answer. As the content of these presentations is considered testable course material, I will emphasize or clarify, if necessary, the key concepts after the students are completely finished. Unless I am asked a specific question by one of the presenting students, I will never interrupt to correct information during a presentation, but instead wait until the end.

I find that student attendance and attentiveness during these project presentations is very high. As the content is considered course material for testing purposes, non-presenting students make it a high priority to attend. In addition, the fact that they get to see 4 different speakers during one class period helps break up the longer lecture timeframe, and holds the attention of the students more effectively than a single speaker can for a 75 minute lecture period.

Oral presentations usually consume 4 weeks of the course (usually weeks 6-9). The draft written paper is due early in the oral presentation schedule, and the final papers are due the week after oral presentations are completed. I will then distribute the written papers to the class and schedule another exam one or two weeks after their distribution to test student knowledge of the project material.

One area of common difficulty for both the oral and written presentations is the ability to write a good “thesis statement” and to create a logical flow within their presentations. I work with the students during my meetings with them prior to their oral presentation to help them figure out what are the main points of their presentation and to help them distill that down into a couple of sentences or bullet points. This becomes their thesis. Then I help them try to find a way to describe their material in a logical manner (building upon previous topics and ideas) to help deliver their content and convince the listeners of the importance of their thesis. Without proper instruction, student oral and written presentations default to a collection of random facts about their topic, rather than a well-thought-out presentation of the topic with a clear set of objectives and goals for what they are trying to communicate.

The rest of the semester is then left for other activities. Some of the activities I do for the remainder of the semester have included:

- Additional lectures on topics not covered in the projects
- Overviews of current research trends and future directions for SFF
- Design competitions (SME’s annual DDM Student Design Competition works particularly well in this context)
- An overview of other non-traditional manufacturing technologies
- Projects related to mathematical modeling and analysis of SFF processes

In addition to being a good learning tool, this literature review project directly links (in a very obvious way) to several ABET criteria. These include:

- d) an ability to function on multi-disciplinary teams

- g) an ability to communicate effectively
- h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
- i) a recognition of the need for, and an ability to engage in life-long learning
- j) a knowledge of contemporary issues
- k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Conclusions

After teaching aspects of SFF technologies to engineering students for 11 years, I have found that the literature review project described above (which I have used for 6 years) is a very effective teaching tool for giving students an in-depth overview of SFF technologies and their applications. In order to maximize learning of good presentation skills, it is important to communicate very clear expectations to students, and to provide a detailed grading scheme to them prior to their presentations. By meeting with students prior to their oral presentations and reviewing a draft of their written paper, the quality of their final presentations and papers are vastly improved, resulting in a higher-quality end-product. Overall, this literature review project, when properly implemented, is the best teaching tool I have found for improving learning of SFF technologies.

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