TO: Professor Benjamin Cohen

FROM: Trevor Quiel, Ari Langman, and Jake Hyatt

DATE: December 5, 2013

SUBJECT: Updated Capstone Project

INTRO:

Lafayette describes engineering studies as a major that "provides students with a platform to develop engineering habits of mind, such as problem-solving skills, analytical thinking, and an understanding of the design process. The coursework empowers students to meet the world's complex, interdisciplinary challenges and devise creative solutions and ideas for them." Over the past couple of years the engineering studies program has been reworked, remodeled, and reinvented to help adapt to a forever evolving technological world. With a constantly changing curriculum engineering studies (EGRS) students have been left with a false sense of identity. In order to recapture and truly define engineering studies we must find a way to successfully implement a new product to help current and incoming students gain a better understanding of EGRS. The best way to encompass engineering studies' technology and society, sustainability, and policy studies aspect is to integrate a hand on interactive study that will help students fully visualize the interdisciplinary challenges and creative solutions that go into Engineering Studies.

Our research question was: How can we use 3D printing as a case study in ES101 to introduce students to the study of technology and society? In order to successfully combine engineering and education we have developed a new entry-level (ES 101) course outline that will use the new pioneering technology of 3D printing/additive manufacturing to give students a life like interactive case study. With additive manufacturing on the forefront of engineering and technology, it pushes the limits of creativity, simplicity, and efficiency in all aspects of engineering contexts. Students will be learning about engineering, interacting with community manufactures, and developing prototypes with the intent to give students the ability to reflect and grow upon the courses experience.

BACKGROUND:

Before we could design a project we needed to understand the context that allowed additive manufacturing to develop and its role in society. The first source we used was Fabricated: the new world of 3D printing. This book is a great introduction into 3D printing. It discusses many aspects of the field beyond the basic function of the machines. Hod Lipson is a professor of engineering at Cornell University and Melba Kurman is a technology writer, analyst, and popular blogger. Together they have written a book that addresses many technical aspects of the field, but does so in a very accessible

and easy to understand way. This book is only an introduction into the realm of 3D printing and further resources were required to gain knowledge of details of the process and areas of concern. This book was very helpful in building a basis for the 3D printing aspect of the capstone project. Once we had a complete understanding of the basic concepts associated with additive manufacturing we need to research how to connect the technology and education.

We discovered and article called, Design to Manufacture by E.P. Flynn. His technical analysis of additive manufacturing is geared towards taking the educational theory learned in class about community and technology and applying it to a fully realizable product. He uses a in depth case study where they show how incorporating the technology of computation fluid dynamics simulation software to an internal combustion intake manifold system can improve the dynamics of a component. Flynn's case study of the combustion engine describes the product design process that goes into developing engineering products while simultaneously incorporating advanced manufacturing techniques. This source proved extremely useful to our project and goal because it relates to our main idea of developing an actual product with the use of additive manufacturing. Since Flynn uses an actual technological case study, students will be able to learn the proper techniques of integrating new manufacturing techniques into education. We found additional articles from Forbes magazine and an article written by Hod Lipson that confirmed the approach and conclusions of Flynn.

The last aspect of the project that needed research was the possible future applications of 3D printing and the policy implications of the use of the technology. We found a variety of sources from highly reputable authors and journals that talk to this point. The most interesting pieces explored the possibility of tissue printing and the societal implications when the technology takes off. There were also many pieces that spoke to the policy issues of the technology in its current state and on future applications. These were helpful for collecting different viewpoints about 3D printing.

APPROACH:

Once the initial research was underway the first step towards conceiving a final product was to look at the website of the previous year's capstone project on additive manufacturing. They created a website that highlights the basic functionality of 3D printers and has examples of applications of the technology. They also included some links to articles that discuss policy issues associated with 3D printers. We saw this as an area we could expand upon in our project. The policy aspect of the technology was already a piece we wished to incorporate into our final project as a way to connect the technology to education and society. Besides this aspect of divergence from the previous group's project is the creation and inclusion of a curriculum for an ES 101 module. We saw the module as an opportunity to improve the experience we had in the class our freshman year and more importantly, as an opportunity to expose freshman to the possibilities of engineering studies.

Engineering studies students thrive on the ability to see connections between technology and society. Because additive manufacturing is an emerging technology the implications of its use and the interaction with society are highly salient. This means that most students have some familiarity with the concept, but probably do not have a high level of knowledge about the technology and its contexts. As we began to see more and more similarities between the case studies in the capstone course and 3D printing it became clear how we should structure the course. It will begin with a discussion of technology and society, then move to information on additive manufacturing, then allow students to work on their own part to be printed offsite, then a discussion on policy about the technology, and finally a reflection on the process they went through and their perspective on 3D printing.

In order to ensure that our course design would be accepted by the faculty, we decided to contact professor and interim director of engineering at Lafayette, Scott Hummel. Beyond the basics of how the module should be constructed and what elements it needed to include, we also wished to learn about the history of ES 101 and the intended results of the course. By understanding the context that led up to the course in its current form we could show how our course design fit in the chronology of the introductory course. By understanding the intended goals of the course we could ensure that our curriculum would be accepted by the faculty and hopefully become an option for future Lafayette engineers.

Our group has been in contact with Jerry Lynch of Sigma design in Middlesex New Jersey. Jerry is the Chief Executive Officer of Sigma Design, which specializes in 3D prototyping and design. Mr. Lynch has been in the engineering and manufacturing business for over thirty years and has had experience with all the industries ground breaking technologies, but none of which have had the potential to change the landscape of manufacturing, engineering, and society. Mr. Lynch has a knowledgeable vision of where 3D printing is heading in the future and why it is so important to understand its capabilities as well as efficiencies. We will also be in contact with the engineers that interact with everyday clients in order to design the desired product. With the ability to gain both the engineers perspective on the evolution and importance of technological education with Mr. Lynch's social and economic implications, we can create a final product that includes all aspects of Engineering and Education.

CONCLUSION:

The final product of our project will be an interactive and educational website. The website will give information regarding 3D printing and show an interdisciplinary link between engineering and the rest of society. The website will give general information on the process of 3D printing. This includes how it works, its current uses and other information including diagrams for someone who has never heard of 3D printing. The website will also have a syllabus with information on the course instruction for ES 101, which will be the first course that will educate Lafayette College students on 3D printing. The website will also share how 3D printing goes beyond the classroom and is interdisciplinary. The website will describe the course schedule for ES 101, much of

which includes educating the students on the curriculum and focus of the Engineering Studies Program. This will include how technology has affected society and how society affects technology, an introduction to 3D printing, the policy behind technologies such as 3D printing, and a general reflection of the project. The website will be a general description of the weekly 3D printing course and will provide information beyond the technical scope of engineering. The 3D printing course will give students a better understanding of the type of work engineering studies students will do in the future. The website will also have a section on policy issues as they relate to the products created by 3D printers. Policy issues would include topics regarding 3D printed guns and the potential conflict with patent law. This will be integrated into the engineering studies curriculum of how engineers and society need to work together in order to obtain a technology that fits into a culture's needs. Lastly, the website will have a section on the future capabilities of 3D printing. This section will show how multi-faceted 3D printing can be beneficial for society. The section will cover technologies such as, live tissue printing, food printing, and other endless possibilities that 3D printing can provide.

RECOMMENDATIONS:

There has been concern about our final product in both the educational and physical website aspects. In terms of the curriculum individuals are concerned that 3D printing has either already reached its peak, or could become irrelevant in the future. Therefore we would have an educational curriculum focused on a technology that would not have enough social implications in order to fully educate students on technological societal impacts. The fact of the matter is society is just starting to witness the effects of 3D printing. Regardless of whether or it becomes the next revolution the technology itself for the sustainable future will act as a perfect case study for incorporating technology into education. Additive manufacturing is the ideal technology because it supplies students with insight on all contexts studied throughout EGRS. Additionally, our second concern is whether or not the website will have the ability to maintain relevance and stay up to date, not just over the course of a semester, but from year to year. In order to fulfill this requirement, our group decided to incorporate a related work section on the website where students submit their final projects. Allowing perspective students and individuals interested in the ES 101 module to view the progression of work done by student will give a better outlook of the course's progression.

Yet, even though we have somewhat answered the initial concerns raised with our project, we still have future recommendations that if implemented properly will allow our project to be maintained. Our first recommendation entails finding a way for future students to update the website on a frequent basis. This could be incorporated as a part of the curriculum in the sense of a final project or weekly assignment. Updates could range from adding new related news to including new and more relevant case studies. Solving this problem will remove doubts of whether the website will remain up to date and relevant to the module's curriculum. Our second recommendation is to in some way adapt the EGRS ES 101 module into a full semester course, which will serve as the Engineering Studies introductory course. We feel that using 3D printing technology as an educational case study provides enough contextual substance relating to Engineering

Studies, that professors will not find it hard to integrate the module into a full semester course. Our group feels that fulfilling these two recommendations will provide future students enough work to suffice as an Engineering Studies Capstone project.

Trevor Quiel	Ari Langman	Jake Hyatt

APPENDICES:

APPENDIX:

Work Cited

Berman, B. (2012). 3-D printing: The new industrial revolution. *Business Horizons*, *55*(2), 155-162.

Bradshaw, S., Bowyer, A., & Haufe, P. (2010). The intellectual property implications of low-cost 3D printing. *ScriptEd*, *7*(1), 5-31.

Dimitrov, D., Schreve, K., & De Beer, N. (2006). Advances in three dimensional printing–state of the art and future perspectives. *Rapid Prototyping Journal*, *12*(3), 136-147.

This paper written by Dimitrov, Schreve and De Beer breaks down the multitude of applications 3-D printing makes feasible, with a focus on uses within the medical field. It describes how 3-D printing can be used for a wide variety of situations, including being used in the medical field. The paper can be helpful because it defines the current applications of 3-D printing, and whether using it for production concentrated within medicine is plausible at this stage of technological advances. Challenges are made whether this revolutionary technology requires more research in the field. While this article is short, it adequately describes the uses and goals that are being set forth by researchers to utilize 3-D printing for use in the medical field; It gives a firmly grounded basis on where 3-D printers have applications beyond education, and explores the opportunities 3D printing can eventually present in various fields, but specifically regarding medicine. A major limitation is the date of the article, being that it was published seven years ago it could be dated and irrelevant at this time.

Flynn, E. P. (2012). Design to manufacture—Integrating STEM principles for advanced manufacturing education. 2nd *Integrated STEM Education Conference (ISEC)*. Ewing, NJ. Retrieved from: http://ieeexplore.ieee.org.

Flynn's technical analysis of Additive manufacturing is geared towards taking the educational theory learned in class about community and technology and applying it to a fully realizable product. He uses a in depth case study where they show how incorporating the technology of Computation fluid dynamics simulation software to an internal combustion intake manifold system can improve the dynamics of a component. Flynn's case study of the combustion engine describes the product design process that goes into developing engineering products while simultaneously incorporating advanced manufacturing techniques. This source could be extremely useful to our project and goal because it relates to our main idea of developing an actual product with the use of additive manufacturing. Since Flynn uses an actual technological case study, students will be able to learn the proper techniques of integrating new manufacturing techniques into education. The only draw backs might include the fact that the actual product they use is somewhat different than what a simplistic 3D prototyping printer can produce,

therefore creating an unrealistic product for our students. Therefore, some of the ideas derived from the case study might not properly assimilate to our project and product.

Gibson, I., Rosen, D. W., & Stucker, B. (2010). *Additive manufacturing technologies: rapid prototyping to direct digital manufacturing*. Boston, Ma, Springer. Retrieved from: http://www.spring.com/ebooks.

Gibson's technical analysis of Additive Manufacturing is an in depth literature about the whole process of AM from its basics principals to business opportunities. More importantly two sections add better understanding and connection to Engineering Studies and the goal behind our project. The Business Opportunities and Future Directions section gives great insight to taking an idea for a product and determining how it will fit into the context of community. It goes deep into the economic benefit of products and how they will be able to serve society, and whether they have a future existent of sustainable development. We feel that if students are able grasp and connect the concept of assimilating a product to society, it will give them a better outline and reasoning behind why they chose their product. This source will give them knowledge about the process behind selecting a product it terms of the process, its communal needs, and social impact of sustainability. This source will help the students answer these questions regarding social implications of manufactured products in a professional manner. At the same time we do feel this source is a little too in depth and advanced for what we are trying to accomplish. Students might get lost because it is a very creditable and professional source that isn't just tailored for students, but meant to help real life manufacturing employers evolve to a world with additive manufacturing.

Huang, S., Liu, P., Mokasdar, A., & Hou, L. (n.d). Additive manufacturing and its societal impact: a literature review. *International Journal Of Advanced Manufacturing Technology*, 67(5-8), 1191-1203.

Ladd, C., So, J. H., Muth, J., & Dickey, M. D. (2013). 3D printing of free standing liquid metal microstructures. *Advanced Materials*, *25*(36), 5081-5085.

Lipson, H. (2007). Printable 3D models for customized hands-on education.*Mass Customization and Personalization (MCPC) 2007*

Lipson, H., & Kurman, M. (2013). *Fabricated: the new world of 3D printing*. Indianapolis, IN: John Wiley and Sons Inc..

This book is a great introduction into 3D printing. It discusses many aspects of the field beyond the basic function of the machines. Hod Lipson is a professor of engineering at Cornell University and Melba Kurman is a technology writer, analyst, and popular blogger. Together they have written a book that addresses many technical aspects of the field, but does so in a very accessible and easy to understand way. This book is only an introduction into the realm of 3D printing and further resources will be required to gain knowledge of details of the process

and areas of concern. This book will be very helpful in building a basis for the 3D printing aspect of the capstone project.

Mellor, S., Hao, L., & Zhang, D. (2012). Additive Manufacturing: A Framework for Implementation*:*

Mironov, V., Boland, T., Trusk, T., Forgacs, G., & Markwald, R. R. (2003). Organ printing: computer-aided jet-based 3D tissue engineering. *TRENDS in Biotechnology*, *21*(4), 157-161.

This paper discusses the applications of 3-D printers regarding organ transplants via tissue engineering. While the authors, Mirnov, Boland, Trusk, Forgacs, and Markwald, discuss the potential 3-D printers possess, they state that the prospect of organ engineering 3-D printers have is promising, yet a difficult goal to attain at this point due to the organic nature of tissue. It discusses the steps necessary to print organs, and how single cells are easy to build with 3-D printers, but our technology is not advanced enough to manufacture whole organs. This source is very helpful in that it provides the blueprint for the manufacturing of organs by 3-D printers as well as graphs showing the process of organs being made in a 3-D printer. A limitation with this source is the inability to produce a final 3-D printed organ. While the article describes how it is theoretically supposed to be built; it conceptualizes something that is not yet feasible, which makes it hard to cite as it is off their assumption and understanding of how a 3-D printer ought to work. The published date is dated being 10 years since its publication. This could be a major issue since new technologies and studies could have been invented since it was published.

Mironov, V., Kasyanov, V., Drake, C., & Markwald, R. R. (2008). Organ printing: promises and challenges. *Future Medicine,* 3(1) 93-103.

This source written by Mironov, Kasyanov, Drake and Markwald, examines how organ printing is an emerging technology with promises to replace many medical procedures dealing with scaffold-based tissue engineering. It states that 3-D printing of organs provides an economic and timely solution to mass produced tissue engineered products. 3-D printed organs and tissue allow for each patient to be fitted with a custom-made tissue graft. It also solves the problem of vessels building up in tissue grafts, and can be done at any doctors office, skipping the need to ship the work elsewhere. The article gives many advantages why the technology for 3-D printed organs is necessary, economically, socially and medically. It describes recent developments, challenges and barriers that 3-D printed organs and tissue face, but also gives future applications that 3-D printers could have in the medical field.

Nieusma, D., & Riley, D. (2010). Designs on Development: engineering, globalization, and social justice. *Engineering Studies*, *2*(1), 29-59.

Designs on Development argues the ineffectiveness of past and current engineering for development projects. The authors, Dean Nieusma and Donna

Riley, use first-hand experience as evidence for their claims. They argue that some of the most simple assumptions can led to much larger problem. Only by increasing interaction with communities can development projects have a lasting impact and increase social justice. Nieusma, a professor of science and technology studies at Rensselaer Polytechnic Institute, uses insights from his participation in a renewable energy project in Sri Lanka as evidence in the article. Riley, a professor in the Picker engineering program at Smith College, highlights aspects of her involvement in a development collaboration between Nicaraguan and American universities as evidence. The article uses these example projects well to support the main arguments presented by the authors and supports the arguments of this project. From this argument the authors expand to highlight the importance of assumptions when assessing a situation and defining a problem. The article is not beyond reproach however. It uses several citations from the authors' previous works and the examples given include biases of the authors due to their close interactions with the projects. The source is still a useful a piece of evidence, but the details need to be analyzed to ensure they were not exaggerated for the authors' purpose.

Peltola, S. M., Melchels, F. P., Grijpma, D. W., & Kellomäki, M. (2008). A review of rapid prototyping techniques for tissue engineering purposes. *Annals of medicine*, *40*(4), 268-280.

Prados, J. W. (1998). Engineering in the United States: Past, Present, and Future. *International Network for Engineering Education and Research*, *1*. Retrieved October 7, 2013, from http://www.ineer.org/events/icee1998/icee/papers/255.pdf

The article by John W. Prados, a professor and vice president emeritus at the University of Tennessee, gives an overview of engineering education in the United States from the second half of the twentieth century to the present. He also touches on the possible future of engineering education by commenting on the optimal approach and possible limitations. The main focus of the article is the shortcomings of current engineering education. Prados highlights the differences between the highly technical instruction and the more holistic approaches and the differences in the engineers both systems produce. While it is fairly brief, six pages, the article makes concise and accurate points. It is logically structured and makes use of an extensive bibliography from a variety of perspectives. This article will be a useful basis for the discussion on engineering education as it gives a concise recent history and offers a suggestion for improvement.

Rosen, D. W., Schaefer, D., & Schrage, D. (2012). GT METOR: A High School Education Program in Systems Engineering and Additive Manufacturing. In *Proceedings of the 23rd Annual International Solid Freeform Fabrication Symposium–An Additive Manufacturing Symposium*.

The team of students at Georgia Tech Institute of Technology developed a collaborative design-manufacturing infrastructure that integrated into the educational high school curriculum. They did this by integrating CAE, CAD, design-for-manufacturing, and CAM software with 3D printers and other

manufacturing resources in order to incorporate technology and education. Their outline is to enable students to design and construct ground vehicle robots whose parts are generated with the 3D printer. The final goal is for the students to understand and learn about advanced manufacturing, collaborative design, and technology based careers. This project could be extremely beneficial for a reference because it is almost a branch off to what we are trying to accomplish with our project. It is a means to teach students by giving them an opportunity to design, build, and reflect using the incorporation of technology to develop a final project. We feel that the similarity of using software technologies and 3D printing will really help us gain a better understanding of the proper techniques of implementing these technologies as part of the educational curriculum. At the same time this source might not have such great credibility because it is trying to achieve the same aspirations of our project, therefore we would be drawing upon a study conducted by peers and not professionals. Additionally they are developing an educational curriculum for high school students, which is completely different that of the college level.

Shuman, L. J. (2002). The Future of Engineering Education. *Frontiers in Education*, *1*, T4A-1 - T4A-15. Retrieved October 6, 2013, from http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1157986

The paper is a construction of thirteen engineering educators and researchers who addressed different aspects of the future of engineering. Each of the authors contributed a short passage related to their topics that were edited into a narrative about the possible future outcomes of engineering. Topics covered in the article include the stimulating change, the changing university, teaching, learning, research, outcome assessment and technology as well as a look back at predictions for 2000. Not all of the opinions agree and it allows for a glimpse at the future from several mindsets. It is a very interesting and useful article as it covers a variety of issues concerning the education of engineers and gives perspectives from a variety of backgrounds. It will help to give a fuller understanding of the challenges to engineering education and the associated reform, which are important in understanding the capstone project in a larger context.

Wittbrodt, B. T., Glover, A. G., Laureto, J., Anzalone, G. C., Oppliger, D., Irwin, J. L., & Pearce, J. M. (2013). Life-cycle economic analysis of distributed manufacturing with open-source 3-D printers. *Mechatronics*, *23*(6), 713-726.

CONTACT SIGNATURES:

Hello Jake,

Yes we would be happy to participate in this program. Please tell me a bit more about the details, logistics etc...

In house here at Sigma Design Company we use a 3D FDM process to develop 3D rapid prototypes as well as working parts made in ABS plastic. These also become the base parts to further develop; thermal forming dies, and patent masters for silicone cast molding. These plus our 4 axis CNC milling and plastic welding provide a fairly complete "proof of concept" capability.

Our product designers and engineers can use these tools for rapid iterative design/review which helps our clients to physically see the fruit of their ideas in as soon as the next day after the idea was envisioned. This rapid iterative design process helps identify and resolve early design issues and certainly speeds the path to commercialization for our clients. i.e. "seeing is believing".

Today, as we enter what some are calling, the new "maker revolution" we see hobbyists and crafters getting into this as well. They can download free 3D models from "shareware sites" and print them on their own or on service providers like Sigma Design Company. In the past the ability to create 3D CAD models was only possible using engineering design software. Today the open use 3D Printing internet sites allow a much wider adaptation of 3D Printing Technology.

And lastly there are the issues of copyrights, patent infringement, counterfeiting, IP concerns, etc… that come with a free and open sharing of ideas.

Best regards.

Jerry Lynch

PS: Most of the above we can demonstrate here at our 200 Pond Middlesex NJ facility.
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