

Printed Electronics Applications for Publications

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Abstract

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The purpose of this research was to demonstrate that the printing industry can potentially benefit from the incorporation of printed electronics into the publications and packaging fields. Taking advantage of this technology would attract more consumers, especially younger generations who are immersed in the digital world and feel more engaged with products that offer user interactivity.

Experts in the field were interviewed to get information and feedback about the project. Also, a survey was conducted. Cal Poly students, from different areas and departments were included to see if they would be interested in subscribing or buying a magazine that incorporates printed electronics and then, determine if this project is possible considering the budget, plan, resources, information available, and the level of acceptance based on the survey results.

The analysis of the results indicated that the printing industry can potentially benefit by the incorporation of printed electronics in the publications and packaging fields. This project would involve more people who specialize in different majors rather than Graphic Communication like Physics, Business, Editorial, etc. Also, many students expressed that they would be willing to purchase or subscribe to a magazine that incorporates printed electronics if the content is relevant to them and the cost is not expensive.

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Chapter I: Introduction

Statement of the Problem: The Printing Industry is Struggling

The advancement of the digital technologies and mobile markets makes it difficult for the printing industry to compete. Without innovation and a strategy for the future, the industry is in a risky situation. It has been said that the printing industry is dying because of the digital revolution, and to continue the industry needs innovation. One area of innovation is “printed electronics”. What people like about digital technologies is their interactivity and user friendliness, so the printing industry should consider user interactivity as a relevant aspect to attract more customers. This technology can enhance the user experience and interactivity in the forms of packaging, intelligent labels, flexible materials, and publications. By using semi-conductive inks, a retail display can light up or track customer movements, a food package can indicate the temperature of the product, a publication can emit sounds when pressing a printed button, a medical label can indicate when a prescription has to be taken.

Significance of the Problem: Targeting a Young Audience

It has been said that the younger generations are immersed in the digital world. Therefore, it is important to focus on the people that are being targeted already by the companies and markets. The challenge will be to convince young people that printed products, like a magazine, can also be fun, interactive, and informative as a web page. By finding ways that enhance the finished product, through printed electronics, young customers can be attracted to and make decisions that will increase their use of printed products. With the help of something measurable, like a magazine that incorporates printed electronics, a young audience can be reached and the results can be analyzed for future projects.

Interest in the Problem: A New Field to be Explored in Graphic Communication

One of the reasons I am really interested in this topic is because printed electronics is a new field in Graphic Communication and the printing industry. I strongly believe that it can offer a lot of potential for publications, packaging, and other kinds of products and services that will help to recover this hurt industry in part by the emerging technologies in the digital arena, and by the crisis in the global economy. I am also interested because I am considering pursuing the Master's degree that Cal Poly will offer in Printed Electronics.

Chapter II: Literature Review

In the field of printing, there is a new area developing called “printed electronics”. This technology can enhance the user experience and interactivity in packaging, intelligent labels, flexible materials, and publications. With the advancement of the digital and the mobile technologies, the printing industry is struggling in the market place. Younger generations are immersed in the digital world and the printing industry is trying to survive and be competitive. Therefore, with the incorporation of new technologies like printed electronics in the publications and packaging markets, younger consumers could find in printed products a new interactive experience. This could impact the printing industry in a positive way.

First, it is important to define the term printed electronics. This term refers to the process of integrating semi-conductive inks made from chemicals like polymers with different kinds of substrates in order to get an interactive experience with printed products. According to Sridhar, Blaudeck, and Baumann (2014), printed electronics refers to the application of printing techniques, both conventional and digital, to fabricate electronic structures, devices and circuits, no matter which functional materials (ink) and substrates are used. “The only prerequisite is that

the functional material must be processable from the liquid phase.” These products go from smart packaging to interactive displays and publications. According to Scott (2006), the majority of the chemicals used in the printed electronics field are polymers. “They include the conductive polymers polyaniline, polyacetylene, and polythiophenes. Polymer films used as substrates for products such as printed circuits include pre-treated versions of polyester, polyethylene, and polyethylene terephthalate (PET).”

Moreover, it is also important to talk about the characteristics of printed electronics. Printed electronics is a new way of printing conductive materials that at the end can enhance the final product. By using semi-conductive inks, a retail display can light up or track customer movements, a food package can indicate the temperature of the product, a publication can emit sounds when pressing a printed button, a medical label can indicate when a prescription has to be taken.

Printed electronics offer many advantages to the printing industry. Among these advantages is the possibility of creating printed intelligent packaging, brand awareness, smart cards, and brand protection. It can also be applied in the medical field by telling the customer when a certain prescription has to be taken. Harrop (2007) states that Radio Frequency Identification (RFID) will replace 10 trillion barcodes yearly, mimicking the history of barcodes which were originally applied as labels - now 90% are directly printed. “Medical tablets will be supplied in packages that monitor which pill you took when, that prompt you by sound and vision - possibly even vibration - and show instructions in large scrolling fonts. There is even one experimental package that calls out ‘not now’ if you touch it at the wrong time of day.” Harrop also talks about smart packaging and indicates that signage and packaging in

supermarkets will be in moving color, the signage being changeable at the press of button in some remote office.

It is also important to talk about the historical aspect of printed electronics, in order to understand the factors that contributed to this field. The printed electronics industry started in the 1920s with the incorporation of graphite as one of the main components of conductive inks in order to transfer energy through the different manufactured circuits. Ken Gilleo declares in this article *The Real Printed Electronics the following:*

“In the 1920s, circuit pioneers printed conductive inks made with graphite and, later, powdered metals such as copper and silver. But a visionary dream of many who worked on printing conductors was in prim all of the electronics, including components. Primed passive devices, like resistors and capacitors, were relatively simple, and methods were developed during WWII. The idea of printing active devices was not even a consideration until the advent of solid-state electronics. Priming active electronics components would prove to be a greater challenge that would require special and complex materials, and never priming processes tor commercial viability” (Gilleo, 2007).

Even though this technology is still in development, there are many tangible applications that are giving positive results based on years of research and experimentation. Hariharan (2006) declares that printed electronics potential includes displays, backplanes, radio frequency identification (RFID) antennas and tags, computer memory, sensors, greeting cards, toys and smart cards. And this can offer many opportunities in the manufacturing side for companies

dedicated to produce inks, flexible substrates, chemicals, circuits, etc. “The growth of printable electronics should create new opportunities for chemical companies at the bottom of the supply chain such as those that can offer inks (metallic and organic), solvents, adhesives and plastic substrates. Some of the companies servicing the market are Cabot, Dow Corning, Ferro, DuPont, HC Starck, Merck KGaA and DuPont Teijin Films.”

One of the most utilized methods for printed electronics is inkjet printing. This is because of the lower cost, the high resolution in terms of graphics, and the capability of printing in a variety of substrates. According to Schroeter (2007), inkjet printing has many advantages, including high resolution (80- to 100- μm lines), flexibility, relatively low cost, and compatibility with almost any type of substrate. “Printed electronics is driving further equipment development, as the newest inkjet heads may be capable of 20- μm feature sizes, which would greatly expand the use of inkjet technology in electronics.”

Another printing method that has become popular for printed electronics is screen printing. Screen printing can be applied to many kinds of substrates and its flexibility is what makes this method unique for products that incorporate printed electronics.

“Screen printing can be used with a variety of substrates. It's also possible to deposit thick films in a single pass. On the other hand, it cannot be used to deposit extremely thin layers. It was once considered a very low-resolution technique, but state-of-the-art screens can achieve features as small as 40 μm , with sharper edges than ink-jet” (Schroeter, 2007).

The potential markets for printed electronics are in different fields like packaging, brand awareness, display screens, smart textiles, brand protection, smart cards, medical, solar cells, and

publications. This new technology also creates opportunities for traditional industries like printing. Nilsson (2012) declares that recent advances in printed electronics, radio frequency identification tag production, and standardization of communication protocols are factors that increase the design freedom for new applications. “As in all new fields, the first products are expected to appear in the high-cost segment attracting early adopters in the form of niche products.”

This new field of printed electronics has growth expectations because younger generations demand a more interactive experience. They are immersed in the digital world and printed electronics can satisfy those demands for more interactive printed products. Klaus G. Schroeter states the following:

“Next, just about everything can get smarter, as combinations of printed sensors, logic, memory, and communication appear in products that haven't included electronics. Applications include RFID tags for inventory control, interactive product packaging that talks or plays games, smart food packaging that changes the use-by date, drug packaging that monitors and communicates patient compliance, and clothing that monitors the wearer's vital signs and helps regulate body temperature. Printed electronics could provide power as well. Flexible, high-efficiency photovoltaics could power mobile devices and commercial/residential power, while lightweight photovoltaics and thin-film batteries could power printed electronic devices” (Schroeter, 2007).

The challenge for the printing industry is to integrate this new technology of printed electronics with effective marketing campaigns, quality designs and products, and new media platforms. According to Harrop (2007), if you put together a random selection of industries - electronics, chemicals, plastics land printing - a new technology emerges that is now seeing the first fruits of a long gestation period. "Printed electronics is without doubt the technology of the future, a technology that some pundits predict could even dwarf the success of the silicon chip." With the implementation of new technologies, the printing industry can be competitive in the market place.

Even though the printed electronics field has a long history of research and experimentation, it is still in development and can bring opportunities to the printing industry. By incorporating this new technology to printed products like packaging or publications, a new enhanced experience can be brought to younger generations who are definitely seeking for a more interactive visual experience. For this reason, it is important for the printing industry to consider this technology as the motor that could revitalize its permanence and competitiveness in the future.

Chapter III: Research Methods and Procedures

The purpose of this research was to demonstrate that the printing industry can potentially benefit from the incorporation of printed electronics into the publications and packaging fields. Taking advantage of this technology would attract more consumers, especially younger generations who are immersed in the digital world and feel more engaged with products that offer user interactivity. The objective of this research was to:

- Analyze the pros and cons of having a monthly magazine in Cal Poly, from a business perspective, that incorporates printed electronics and then test the results by analyzing student's response through a survey.
- Evaluate the effectiveness of using printed electronics for packaging and publications by interviewing experts in this field and analyzing the revenue of different companies that incorporate this technology in their products.

The targeted audience was Cal Poly students, male and female, with an age range between 18 and 34 years old. The plan was to work on an experiment to determine the effectiveness of the use of printed electronics in the publications field. This was accomplished by creating a fictitious prototype of a monthly magazine that incorporated printed electronics. This magazine contained information for Cal Poly students, like upcoming events on campus and the community, articles written by faculty members and students, a detailed directory of all the different colleges and departments, useful tips and information, suggestions for entertainment.

In addition, experts in the field were interviewed to get information and feedback about the project. Faculty members from the Graphic Communication department: Xiaoying Rong, Malcolm Keif, and Colleen Twomey were interviewed. Experts in the field who participated in the seminars during the International Printing Week, here at Cal Poly were contacted. Among them were Tim Luong, National Sales Engineer with Ceradrop MGI Group, and Philip Lazo, director of Innovation for RockTenn Merchandising Displays.

Questions related to printed electronics, packaging, and publications were asked. These questions were asked to find an effective way to incorporate printed electronics in a monthly publication. Another question was related to the possibility to run a test here at Cal Poly

considering the necessary equipment, materials, labor, and logistics behind this project. Moreover, the questions were intended to know the cost of working on a project like this, the possibility to generate some revenue based on other examples from companies that are already focusing in printed electronics, and the necessary implementations to create a prototype like this, run it, test it, and evaluate its effectiveness.

Finally, a survey was conducted. Cal Poly students, from different areas and departments were included to see if they would be interested in subscribing or buying a magazine that incorporates printed electronics and then, determine if this project is possible considering the budget, plan, resources, information available, and the level of acceptance based on the survey results.

Chapter IV: Results

First of all, some questions were asked to experts in the field to evaluate the effectiveness of using printed electronics for publications. The intent of these interviews was to analyze the pros and cons of having a Cal Poly monthly magazine that incorporates printed electronics, from the technical and business perspectives.

The same questions were asked to all the participants, but other questions were different during the process of these interviews. The first question was: What can be an effective way to incorporate printed electronics in a publication like a monthly magazine? Professor Xiaoying Rong emphasized the importance of having enough advertisement in the magazine that could offer some interactivity by using printed electronics. “Usually, very often there is advertisement in the magazine or could be a feature article and those are the ones that most reasonable that you can put some interactive in the magazine” (Rong, Appendix).

Also, Professor Rong explained that another consideration for an effective incorporation of printed electronics is the power supply. “You have to have power associated with that so every time you are doing something it has to be power related and figure out how you incorporate your power into the entire design” (Rong, Appendix). It is necessary to know if high power or low power is required and also the AC/DC difference is imperative for the success of its functionality.

Professor Malcolm Keif said that solving the power equation was crucial to find the effective way to incorporate printed electronics in a publication. He mentioned that he worked on a magazine that required low power and was called Canvas. “So the technology we used for Canvas magazine was electro chromic which is a very low power requirement technology so you can cause things to appear or to, you know, disappear” (Keif, Appendix). The term electro chromic is basically related to change the colors of a specific surface through the use of some sort of electric energy. In this case it is more difficult to come out with a magazine that would require high power, said professor Keif. “The one thing that is difficult is that a lot of the real luminescing technologies, the technologies that actually emit photons they usually require high power requirements” (Keif, Appendix).

Professor Colleen Twomey emphasized the importance of having a cool factor in order to attract younger generations and that can be done with printed electronics. “There is got to be a cool factor but research chose and you might be able to find this through your literature reviews at the library that if someone is viewing something that is interactive they are going to be staring at it longer therefore interacting with that brand” (Twomey, Appendix). Professor Twomey said that by adding printed electronics to a publication it would increase the duration of the readers looking at an advertisement or article to 11 times longer than a regular printed piece.

Philip Lazo, director of Innovation for RockTenn Merchandising Displays, suggested that the best way to accomplish an effective incorporation of printed electronics in a magazine was to integrate an NFC tag in the publication and then link it to a digital media experience. “NFC Tags are an application of RFID technology. Unlike most RFID, which makes an effort to give a long reading range, NFC deliberately limits this range to only a few inches or almost touching the phone to the Tag” (Wikipedia.com).

The second question was: Is there a possibility to run a test here at Cal Poly considering the necessary equipment, materials, labor, and logistics behind this project? Professor Rong mentioned that it basically depends on the type of material, the device, and the printing process used for this particular project. She also said that, in terms of knowledge in electronics, the Graphic Communication department is still limited to simple circuits, and not something more complex or ambitious. “I think that knowledge wise we are not in the position that we understand electronics really well” (Rong, Appendix).

Professor Keif said that it is possible to run a test of the prototype of a magazine, here at Cal Poly, considering static displays, things that appear and do not appear, electro luminescent displays like lighting up things, and simple things. On the other hand, it is more complicated to come out with a prototype that would include more sophisticated types of circuits in terms of logic. “If you are talking about things that have logic like gates and transistors, that’s a little bit more complicated but there might be hybrid approaches where you integrate conventional surface technologies all in some sort of a flex substrate” (Keif, Appendix).

Professor Twomey agreed about the possibility to run a test, but she emphasized that it all depends on the printing process used and it would require some modifications. “Most

publications if they are high volume are going to be printed sheet fed offset or offset printing and our printer has a coater on it and just recently Dr. Keif ran a test with the coater which is essentially a flexo plate and silver conductive ink. The other possibility is if you print digitally and then incorporating some sort of maybe screen printing but then you are doing two different steps so there is logistics, there is labor, those expenses because conductive inks are really expensive” (Twomey, Appendix). Philip Lazo mentioned that he thinks it is possible to run a test if the conductor is printed and a chip is mounted.

The third question was: What do you think would be the cost of working on this kind of project and if there is a possibility to generate some revenue based on other examples? Professor Rong answered that the run length is not a big factor in this situation. The most expensive part are the conductive materials used like silver inks for example. “If you have a five pound can of silver that’s 10,000 dollars, so your material used is not offset to your volume, so you can print 10,000 copies it is still going to be expensive because your material is in there” (Rong, Appendix). She also mentioned that cheaper materials can be used, but performance would be sacrificed in this case. One option as a conductive material that can be used is carbon based inks which are cheaper and environmental friendly. Another option is graphene which derives from carbon, but it is still on development. “You don’t really have to use graphene and it is easier with carbon. Carbon can be used for conductive material as well. It is a low cost and it is environmental friendly so you don’t have to worry about it because everything turns in to carbon by the end. There is a lot of development so far and I haven’t really seeing a very successful sort of commercialized products that can be used for graphene” (Rong, Appendix).

Professor Keif also agreed that the cost factor are the materials used for this kind of project. “Sometimes you don’t know going into it how expensive things are going to be but you

have to figure that the inks are going to be quite expensive and by quite expensive I would say maybe as much as a dollar per magazine for a couple of displays or maybe more than that” (Keif, Appendix). Also he mentioned that the best way to generate revenue in a project like this is to obtain enough advertisements and the generation of interest through the right marketing campaign and promotion. “So it can be quite expensive but there are maybe ways especially if you customize that meaning you are basically selling advertisement as well to generate every month money back in. So I think it is possible to generate revenue especially if it creates enough buzz” (Keif, Appendix).

Professor Twomey said that the possibility to generate revenue will be based on the readership response and advertisement as well. “I can see advertisers knowing that hey if I have somebody staring at my add 11 times longer than if they were just flipping through I can see advertisers very much interested in it. It depends on the readership and the magazine” (Twomey, Appendix). Philip Lazo mentioned that the cost of working on a project like this would be a few thousand dollars in terms of printing, mounting the electronic components, and working with the content management company.

The fourth question was: What do you think could be the necessary implementations in order to create a prototype like this, probably run in and test it, and evaluate its effectiveness? Professor Keif answered that some things have to be taken in consideration to achieve all these goals like the interactive communication, the technologies to be able to produce it in house, the materials, and the power supply for the different circuits used for this project. Philip Lazo mentioned that RockTenn, the company he works for, has not done a lot of implementations in the field of printed electronics for retail displays, but he offered five useful steps in terms of a new product introduction process:

- “1. Understand your target market and scope out opportunities to solve specific customer pain points.
2. Define the new product. What is the job to be done? Do the economics of the product make sense up front? Is there a financial return for the client? This is a model. Should use NPV and IRR as metrics. The model is often wrong but use as a sanity check before starting.
3. Develop a working demo and show it around to generate client interest.
4. Pitch a pilot to the client. Optimally client pays for part of the pilot. Get skin in the game early.
5. Analyze the result of the pilot. This is your best chance to develop the real value propositions based on financial and non-financial metrics. Sales lift is ultimate metric for retail but depending on product you could also use opex reductions.
6. Scale into high volume production” (Lazo, Appendix).

Tim Luong, National Sales Engineer with Ceradrop MGI Group, was not contacted since he never responded and did not answer the interview questions.

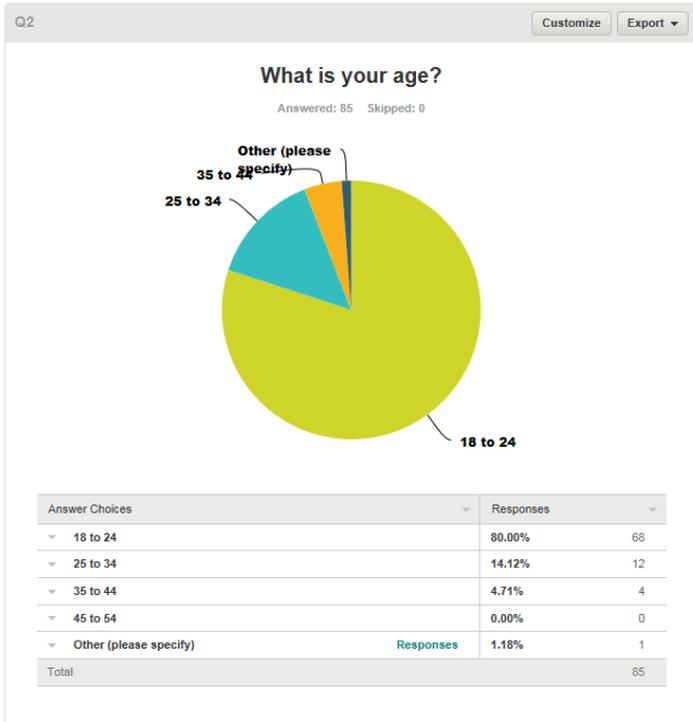
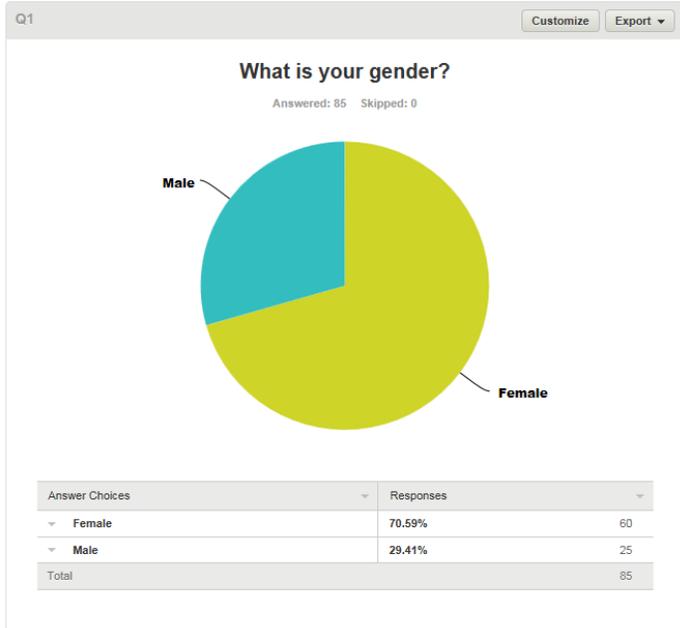
Moreover, a survey was conducted to students from the Graphic Communication Department. The purpose of this survey was to measure the level of interest in a monthly magazine that would incorporate printed electronics to make it more appealing and interactive. Also, a fictitious prototype of the cover was presented to students and the possible use of printed electronics applications was also mentioned in the survey.

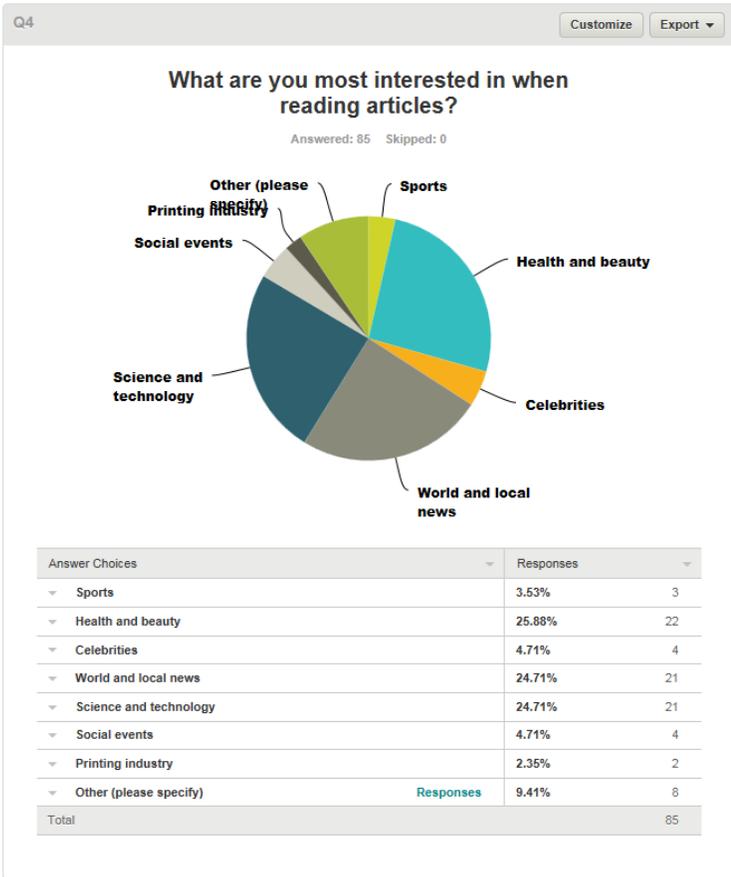
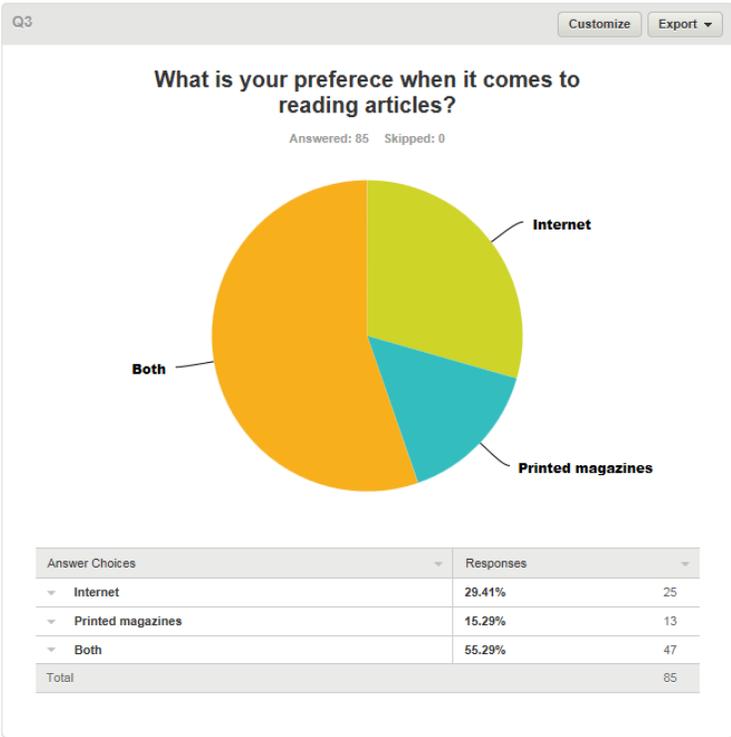
The survey was sent to all the students from the GrC department and from the approximate 300 students, only 85 answered the questions. These are the survey results:

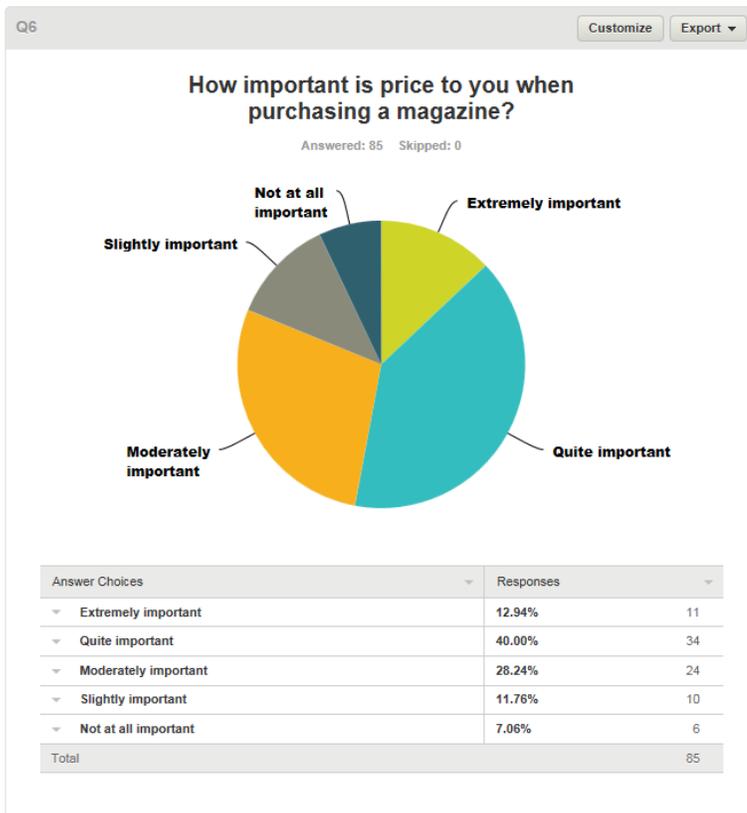
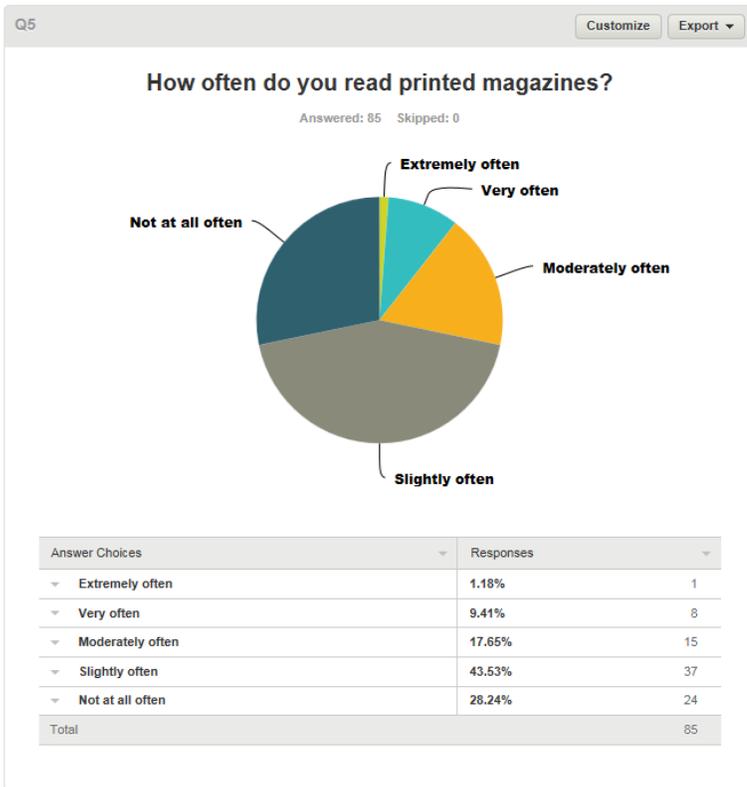
RESPONDENTS: 85 of 85 Export All Share All

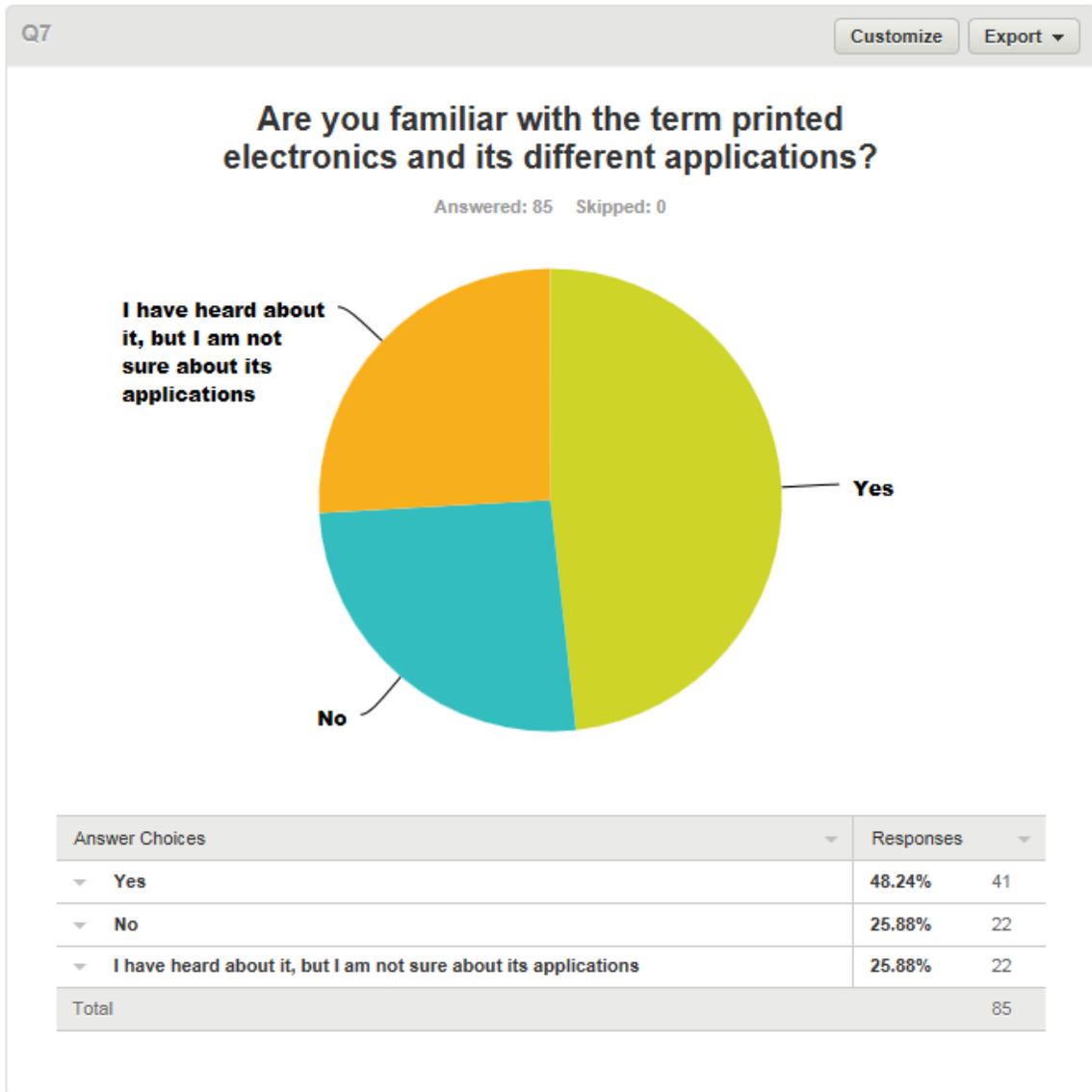
Question Summaries
Data Trends
Individual Responses

PAGE 1: The Inter-Active Magazine

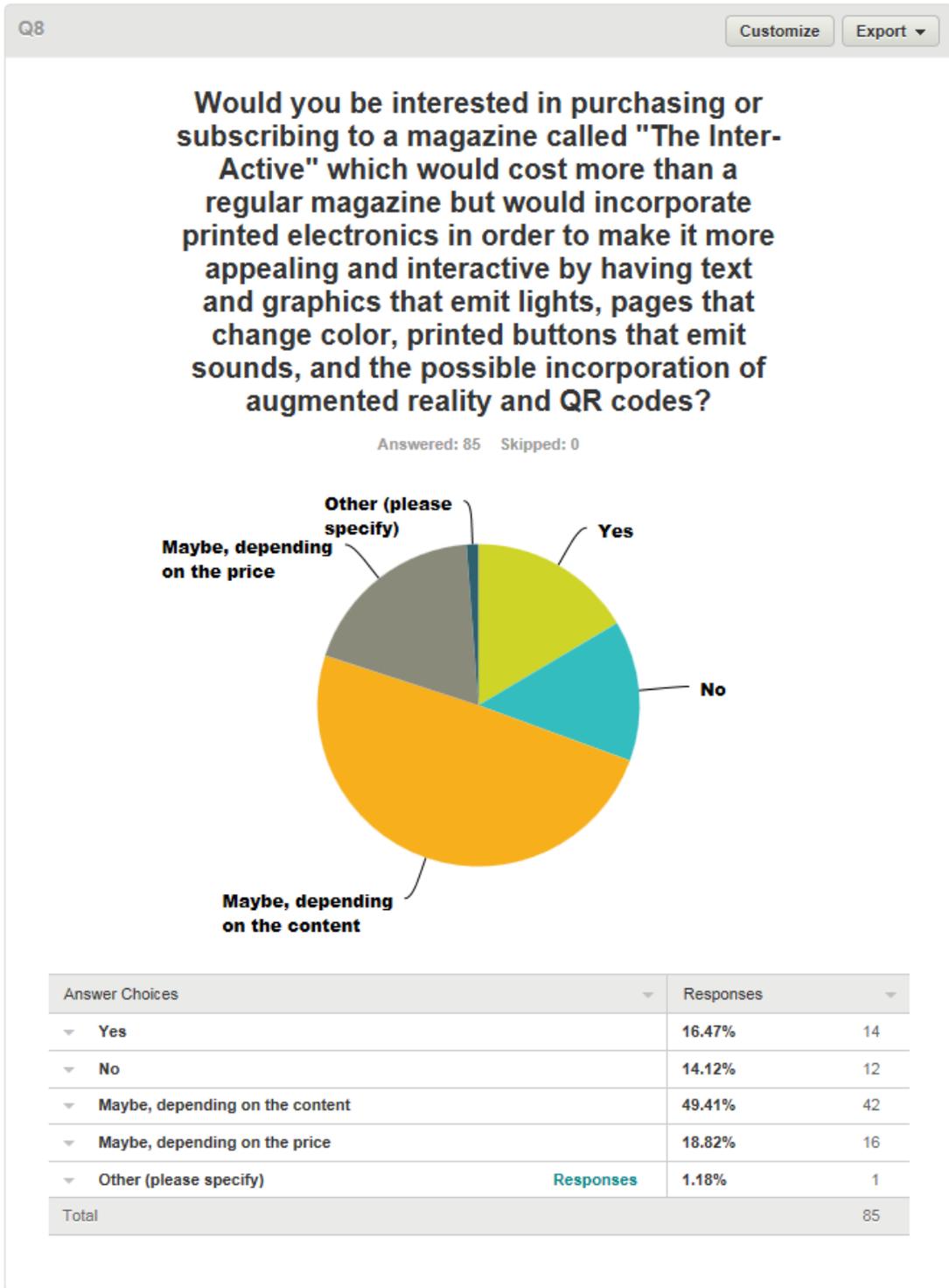








Finally, the hypothetical cover prototype was presented along a question more specific towards this new project called The Inter-Active magazine. The question was:



The cover of the prototype can be found in the appendix.

Chapter V: Conclusions

After the survey was conducted with students and the experts on the field responded to the questions during the interviews, the analysis of the results indicated that the printing industry can potentially benefit by the incorporation of printed electronics in the publications and packaging fields. On the other hand, the idea of coming up with a prototype for a monthly magazine requires a lot of investment in terms of materials, power supplies, printing processes, and labor hours. It is difficult to come out with a prototype, test it, and evaluate its results in one quarter or two. This project would involve more people who specialize in different majors rather than Graphic Communication like Physics, Business, Editorial, etc. Also, many students expressed that they would be willing to purchase or subscribe to a magazine that incorporates printed electronics if the content is relevant to them and the cost is not expensive.

In terms of cost, carbon based materials are ideal because they are not as expensive as using silver, which is a better semi conductive material, but would increase the cost substantially. A project like this would require sponsorship from advertisements, an effective marketing campaign, and interest in readership from a large number of subscriptions. Cal Poly is not in the position currently of coming out with an ambitious project like this as this technology is still developing, but some steps can be accomplished if effort and research is done in collaboration with other departments on campus, the local businesses, and the community of students and local people.

Until this moment, the packaging industry has demonstrated a lot of interest in printed electronics development and also, it has emphasized the importance of having interaction with the consumers through point of purchase displays in retail stores and small businesses. On the

publications side, developments in terms of interaction with the readers have been done through the use of smartphones, augmented reality, and QR codes. E-magazines, for example, have become popular because younger generations seem to prefer the digital world than the conventional printing world.

To become more competitive in the future, the printing industry should consider digital technologies as another vehicle to generate revenue and interest among the readers. That is the reason "The Inter-Active" magazine, a fictitious and ambitious prototype would incorporate printed electronics to make it more appealing and interactive by having text and graphics that emit lights, pages that change color, printed buttons that emit sounds, and the possible incorporation of augmented reality and QR codes.

This new technology, printed electronics, is the blue ocean that can offer a lot of potential to the printing industry if a lot of sailors are brave enough to take the challenge and devote themselves to the restoration of a hurt industry that it is evolving and requires innovative people from the Graphic Communication industry.

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Appendix

Interview with Professor Xiaoying Rong:

1. Question: What can be an effective way to incorporate printed electronics in a publication like a monthly magazine?

Answer: Usually, very often there is advertisement in the magazine or could be a feature article and those are the ones that most reasonable that you can put some interactive in the magazine. I think the model for having advertisement in the magazine has interactive features is probably the cost; you can share the cost to whoever wants the advertisement and place in there, it can be an insert; it can be a lot of easier ways to do instead of doing the entire magazine. With that you can be doing an insert and this piece can be taken out from the magazine in the feature that they want it to be played around it in a separate part of the magazine. To me it is an easier way to approach and it is an easier way for a manufacturing process. And one other thing for printed electronics is that you have to take a lot of things in consideration. You have to have power associated with that so every time you are doing something it has to be powered related and figure out how you incorporate your power into the entire design. Is it a high power, low power battery and some of the electronics may need a little bit higher and maybe an AC/DC difference in terms of power supply and all has to be taken in consideration. So that is just my thought. It is not a very easy way because sometimes magazines depends on what magazines you are looking for, if you have a large subscription and the magazines have a lot of print every issue and then the problem is how do you produce this in the same quantity as your magazine being used. You have Readers Digest and then, there is in compared to some local magazines maybe only 1000 copies and the readers probably go into 10,000 in the copies and it is very different in the volume when you pick a certain magazine which need to have that interactive feature then you have to figure out what title has to be the appropriate title to choose for the magazine to work with it that also attracts of course the reader to interact with it so I think it is a very hard choice into which one to do and the volume is a big thing because in printed electronics you can't run the same certain way of the magazine, so if you are having tens of thousands of copies of magazines, then you start to get in the bottle neck of your printed; the electronic part is a lot slower. You have to produce in different ways. A lot of magazines does have those sort of time sensitive so they have to come out at certain time of the month as their every issue so that is part of the things you have to consider if you put electronic product and electronic components to a magazine. And it is a little bit different as the packaging because packaging relatively sort of fixes the form so even your magazine has slightly different changes with the graphics and a lot of times there is a lot of things in common so there is still very similar so you can actually have your electronic components are very similar. They don't have to work with the timely manner like you have to be out in January and have to be out in a

certain time so it is a little different I think in packaging maybe more reasonable but magazine it is also an interesting area.

2. Question: Have you heard about any magazine that already incorporates printed electronics? Answer: This is a topic for long time and doesn't mean everybody has doing a lot of work on that. I think the last magazine that has used the E paper and that was the Esquire. It is actually on the very rigid boards so that is the magazine. It generated a lot of interest by then so it is a little bit flashy on the cover and once you put the battery on then you can see changes with the images and they are black and white but at least they are not static at the moment you have little changes on the image and of course the magazine that the art department produced a long time ago that's the electro chromic ink and then it changes de color, it is only showing or not showing so it is very simple, visibly show and disappear with the battery. And then the other one is, I haven't seeing a real magazine yet but it was a lot of video on the website. It was a color changing, I forgot the name of the magazine, you might want to look at it, and it was on a piece of paper. It changes the color by touching different buttons and changes the color. It was probably three or four years ago. Other than that I haven't really heard a lot and some of them use very simple like add a speaker and some of them you can actually print a speaker and then you can put a music on it. It is very simple because it comes with a memory. If you put a song you have to add the memory of that song. How do you attach the memory to it? And then you have to incorporate the speaker, you have to incorporate the battery issues and stuff; it is very complicated about doing that. Those are the things I see sort of related to paper based material. And of course add a little lighting that is very simple to add a little lighting but to how much it is going to be interactive when you have a lighting on it, so it is more complicated the feature than more interactive and there are simple features that are easy to achieve lower level of interaction, so these are the ways I have seen you can do on the paper but of course you can also do if you are doing an attachment to it, you can also do on plastic or some other format.

3. Question: I have seen that, for example, in some printing processes, the longer the runs are the cost tends to go down, but in this case with incorporating printed electronics since you mentioned that there is a cost related to the power, and the battery, and the supplies, do you think that would prevent from decreasing if the runs are long?

Answer: I don't think that the run length is the big problem. I think in the past, in the printing like graphic printing, the reason the run length is relevant to the cost is because your cost for your ink is relatively low and think about you are doing graphic ink and a five pound can is only like 20 dollars or something. But if you have a five pound can of silver that's 10,000 dollars, so your material used is not offset to your volume, so you can print 10,000 copies it is still going to be expensive because your material is in there and in the past days because you offset your volume by using a cheaper material your graphic

ink is cheaper, so when you are making your plates you think you make five dollar plates then you print 10,000 copies versus you might make 5 dollar plates and you only print 10 copies and that is the difference between the cost is the plate is very expensive but right now you look at it your expensive part is not your plate, it is not your substrate, it is your material. Once you put a certain material on your substrate that's a set off cost. It might go down a little bit but that's just too little to compare to the cost of the material. Of course you can choose cheaper material, than you sort of sacrifice your performance and especially for those products that have been used for magazines and packaging and you also have to consider your recyclability, how do you recycle them. If you do put a lot of expensive material on top and then your recyclability is an issue and how do we get things out of there and a lot of materials nonrenewable, so the silver used on it is less and less, so these are all the things you have to think about it. It is a good idea to say put this on paper and let it make a magazine but there are a lot of other things associated with that, so my feeling is use as a necessary when you are doing electronics.

4. Question: I also heard that graphene is another option of a semi conductive material that can be a lower cost. Do you think maybe that can be an option in this case for a magazine?

Answer: You don't really have to use graphene and it is easier with carbon. Carbon can be used for conductive material as well. It is a low cost and it is environmental friendly so you don't have to worry about it because everything turns in to carbon by the end. There is a lot of development so far and I haven't really seeing a very successful sort of commercialized products that can be used for graphene. It is just the process of the get the material, it is more like the material side of it, how do we get this graphene to actually make it work in the lower cost in manufacturing, so even sometimes of the material itself is not very expensive but the process to get the material is expensive. So now we are in the stage in that stage so we get the material as expensive it doesn't mean this material itself is expensive but going through the process is expensive. They make this material very expensive. And there is not a very good things that we are seeing that they have successful commercial available products now but carbon, I think carbon is, there are a lot of companies doing carbon ink, you can use carbon ink, but carbon ink has a relatively low conductivity which means you might have a problem in large area and in small area it is fine when you have a larger area and you are trying to cover the entire magazine whatever the size it is, it might be a little tricky because it is hard to actually deliver all these at the current all the way over and when it is really long. When you get longer of course the resistance is higher. So you have to consider the length of it and you have to consider the material you will be using and when you have really long lines and cover the entire magazine and you sort of have to consider silver or some other type of material be more conductive. So those are all the things, put it in there is and it is not just putting a concept in there and you have to start thinking about your production, your material

availability, your production environment, like for example our project for our 451 is going to do a project and then, the most of the material has to be in an oven and we just print one sheet and we put it in an oven for 15 minutes, and you can think about the speed of doing this production, how fast it is going to be versus you running in Goss to print newspaper constantly going, and now we can't do that because we have bottle neck for the drying and curing device so every time we do one sheet of printing we put in an oven, my oven only have five shelves, so that means we can only put five sheets in there at a time. So it is not the printing that lengths that actually the limits. You can't go fast. It is just there. You can't really go fast.

5. Question: Do you think if a prototype of a magazine is made, is there any possibility to run a test here in Cal Poly, considering the necessary equipment, the materials, the labor, and the logistics behind this project in terms of production?

Answer: It is hard to say. What is the device you are going to make? It depends on the device and it depends on what type of material you will be using and what printing process you choose. And then, of course, there is electronics behind it, and then, what if your electronic design about your material. There are a lot of trials and errors and it is really tricky about to make something that we know will be working long time, for example the projects that we work with, we know it is going to work because we had work before and we know it is going to work and for some other stuff that like if you have heard about last quarter and there is a professor Ulrich from Germany, and he came here for a project and they did for six month, and a group of 15 students from different disciplines worked in a project to make it work at the end. So it is tricky to have something printed in the very short period of time with efforts for yourself and without intensive or without knowing a lot of things behind it which is electronic part of it will be really hard. I think that knowledge wise we are not in the position that we understand electronics really well. We can do simple circuits, very simple circuits but we are not going to understand or coming out with the idea that very complicated circuits like if you were doing sort of inducting and changing the currents and by different forms and stuff that we are not into that so we don't know and your idea could be a very simple just putting a switch in the line. That is the simplest one right? You got a conductive line, you put light bulbs in there and you have a switch and that is the simplest one that you can do but when you get it more complicated can we wirelessly transfer data or transfer signal and can we use magnet or create a magnet field in to turn a switch on and off and so all the things that is very complicated. Making prototyping is more complicated that what we think in comparing to doing proofing test on the press do just to check it on the graphic it is very different. It depends on what you want to do. I would say you might get a 30% chance to maybe be able to make a successful sort of prototype and a 70% chance you just work on that and figure out it is not going to work. It depends on what you want to do and it is really what you want to do. There is a lot of commercial available products

like conductive inks and some other things commercial available and because printed electronics requires very special there is no unique material on the market that you can use. You can just say there is going to be CMYK, I want to have this, I want to have that, and it is not that way. You would have hundreds of different choices on materials depending on what you want to do because they all have different functions. So the point is what you wanted to do that you look for a specific material and then you come out with is this material possible to be printed by screen printing or flexo or somehow a lot of time people developing the material they don't understand the printing so they just develop the material. It might work, it might not work at all. You would think it should work in their way of deposition it work but in the printing world it is not going to work. So some of the material you can use by drop and what they usually do is they would do a swap. They put a drop of ink and swap it and then they check it. Oh it works. And then they say how did we do that? We are not going to have the uniformity we have with the swap. We are going to do screen printing, we are going to do flexo and then you start coming out with a lot of problems. I didn't get the performance that you look for. So these are the gap between the material development and the production. So, as I said, we have to figure out what you wanted to do. What is the electronic device you wanted to put on a magazine. And I think that your project so far is going to be big if you do that. So there are a couple of things you can do. I think that to me the project is a little too big if you want it to do. There are a couple of things. You want to break in chunks and you think the time wise. I think it is a little too big in size so this project can be in this way. So if you want to do the part of the sort of understanding interactive is that important or not and that could be one project. And the prototype you design something could be one project. And then to understand the interaction if that is important to the magazine or attract to the younger readers. And this can be easier when it is done in a one quarter period but the prototyping I would say two quarters. It is really hard. I had a student did the prototype in one quarter because I know the material; I know most of the part of it. I know most of the part of it will work and then we know it is just a matter of fact to put everything together and we do a few trials and something but it is not the point that I don't know this thing at all. For example right now you don't have an idea what you want to put it on. What kind of device do you wanted to do because you don't know yet. The time I had a student do it in one quarter for prototyping I know they are going to do a lighting device and I know that material. And I know the material I can get it from somewhere and I know someone is going to tell me if I am confused or if I get lost in the middle. I know someone is going to tell me what to do and about the circuits, about everything so this is very clear at the beginning if you want to do one quarter prototyping you have to get at this point that you know what you want to do. So in your case if you really want to do the prototyping I would ditch everything else and just to say I not going to do anything I am just going to focus on the actual project. If you really want to do a prototyping everything else is going away and I would it doubt you would be able to do all by yourself.

6. Question: In terms of this technology I think is more effective right now in the packaging arena right?

Answer: It can be used in the same way so it is not a problem if it is publication or the packaging it is just that how you purposely use it. You use electronics not just because it is electronics because it brings the function to actually enhance your products. That is the main purpose to add any function to your products is to enhance it and so attract the consumer whatever is a reader or is a consumer to buy a product. For the packaging or the publication the problem for them is it has to be very simple, it has to be very low cost and has to be simple. And you can't get a very expensive part of it because your magazine itself is only five dollars max. A lot of magazines are only four dollars and you put an electronic device it costs three dollars more. It is not the realistic type you would buy that. It is not going to help and the packaging is the same. Packaging looking for low cost, very low cost. And then you are adding electronic devices and you are going to add the cost and are you going to share this cost with your consumer. And unless they buy, you know they used to be the sales for 1,000 boxes and now when you add a device turns out 3,000 boxes and now you got the revenue by all the volume. Can you use that to actually bring that much of volume that is the point of having these things to be in there? So I think that, you know, when we talk a little bit more and I start popping out some ideas I think to actually understand if this will actually generate more interest or bring more sales I think it is a very interesting aspect to look at because people in now you are not the first one coming here, coming to my office and say hey I really wanted to put this on the magazine, I really wanted to put this one on the box without even thinking about why you want to put it on it, do you think it is going to work or do you think it is going to generate anything. And you are not the first one. I have people to come in I am excited about this. I think that the back of the mind is economy so it is efficient. In time wise and I think it is a good point if you are working with Cooper and he is an expert in that area in the business wise. I think it is a good point to understand that, I mean if you are working with me I am not totally in the business and area so I am in the more into like hey can we do this, we can built it, we can make and manufacture it because I am an engineer to me and I think I am going to build stuff but he is in a different point of view but if you work with him I think you wanted to sort of like having help you in going through some of the interesting topics that the industry always wanted to know and we add this as that is something reasonable. I think it is nice. You also could ask people if I add this, would you be interested in buying more. If I have something like this, would you be interested in buying more. Sometimes it is hard to show them, oh I don't have the exact prototype to show you but you can do a little animation, you can do a little something add in there to see if they are interested in.

7. Question: One of my ideas for this project is to come out with a survey conducted to students and just to come out with an idea of a prototype, the rage on the age, and see if they would be interested in purchasing and how much would they be willing to pay.

Answer: Eventually, maybe at the end you will find out they don't even care. What do I have to spend six dollars more to make this and they don't even care. I think that is important at this point and then you can come out with, of course you can come out with the ideas and these ideas could possibly, because I talked the same thing with Kayla. I said you can come out with some ideas. With your idea and say oh yeah there is something that we had a student came out two quarters ago and we proved and people is interested in doing this. Let's make this work and we can start prototyping and do some of the work. So it's a long process.

8. Question: What if it is offered to experts on this field, just to see results of what they are doing and investigating?

Answer: If you look at a research and right now everybody is doing, there is not one of the big problem, biggest problem I would say, there is no a lot of applications. We don't have a lot of applications, we don't have ideas what can do, what can be done, and what can be incorporated of course that is one of the things that we are interested in. We want to have our students being creative, and talented, and innovative and try to get these things to work. Idea is one point and how to make your idea work that is another part of the equation. So you get that idea and how is going through to make eventually make it work. I think that your project if you do prototyping it would be a little too big. I have people doing that all the time and doing their senior project and they change their direction as they realize that resource wise, realize the time wise that they can get it done and then they sort of modify their project along the way. Not very easy to do and especially in a short period of time. And you can tell your own time, you don't have a lot of time to do that either. We can actually do that if we have somebody do graduate student and come in two years in here and just things get started and towards the end you are going to give me a paper speaker and define all the things in there you need to do and use the printing technology and find the appropriate material and understand how this material would work in a specific way and by printing. So it could be a project for one year project I would say. And I don't say that your idea cannot be implemented or cannot be done. It can be done just timely wise it can't be done.

9. Question: Maybe that can be an interesting project if a group of students come together and work on it.

Answer: That is what happened with the 451 in the winter and spring, you know professor Ulrich was here. He did the project with 15 students from different disciplines for two quarters in period and they spent a lot of time doing the prototyping back and forth and trying this and that in different design and they had this inductive coil and the coil has been done for five different designs and they went back and forth just to try it. So it is a lot of work. You are not only doing the graphic part of it. You have to use a graphic incorporate with the electronic part of it. You have to make your electronic device work appropriately and you have to choose appropriate material, appropriate manufacturing process, and your design has to be probably not on work on the first time, maybe the lines

are not in the right way and maybe your circuit has to be redesign or somehow. I just one everybody sort like to talk in the class the same thing and I want everybody understand the difficulty but also excited about opportunities. So we are excited about there is things we can do but we also need to understand that the difficulty of it is not like switch.

10. Question: I think during this time probably it is harder to figure out things in this case for this technology but maybe in some years the future of maybe processes would be less complex and maybe the cost will decrease.

Answer: I think the idea is we have students interested in which is really nice, I think it is very good. And the problem in this short period of time you can do part of that work. Part of like figure out part of it, you might not be able to figure out the entire thing and that is the point. They have to understand the time limit that you can do. But we can do a very simple just say hey what if I print, I am going to have a speaker which is going to have a coil in the middle but what if I print the coil in different ways and what is the electronic sort of the action with the coil. And that is only the part of it is not coming to the speaker yet. I wanted the coil in here that's all. And what if I printed in different characteristic materials, combination materials, and then it is going to come out with a different property and that is a project for a senior project appropriate amount of work. And then you think about the coil is only one part of your speaker. You have some other things to test. So just by working on that particular part with real hands on experiments to do and that is appropriate for a senior project. The work load, time, and everything. So it is not like you can't do, it just takes time.

Interview with Professor Malcolm Keif:

1. Question: What can be an effective way to incorporate printed electronics in a publication like a monthly magazine?

Answer: I would say one of the keys to being able to implement printed electronics in a magazine is understanding and solving the power equation because some technologies require a lot of power of which means that you have to either send heavy and large electronic power, you know batteries or you have to rely in something people have at home. So when you are talking about the mobility of the magazine you normally are really focused on low power requirement technologies. So the technology we used for Canvas magazine was electro chromic which is a very low power requirement technology so you can cause things to appear or to, you know, disappear. The one thing that is difficult is that a lot of the real luminescing technologies, the technologies that actually emit photons they usually require high power requirements. So that would make that a little bit more tricky. Now that may be possible to use something like inductive power where you are actually getting power from a different source for example if you, if somebody had an inductive path

- you can put the magazine on this inductive path and that might generate the electric field you need for something like this but that is sort of, that has a different difficulty which is having this inductive path in all these peoples home. So that is I think one of the challenges. The most effective way is to really consider what the power requirements are. How you can accomplish that in a mobile product like a magazine.
2. Question: Do you think there is a possibility to run like a test here at Cal Poly considering the necessary equipment, the materials, the labor involved and the logistics behind this kind of project?
Answer: Yes. There are some printed electronics we don't have the equipment at the moment to be able to do especially required verifying features but if you are talking about static display kinds of technologies things that appear and don't appear, things that are more visual we probably can do that here at Cal Poly, all the capabilities to do that. If you are talking about things that have logic like gates and transistors, that's a little bit more complicated but there might be other approaches where you integrate conventional surface technologies all in some sort of a flex substrate.
 3. Question: What do you think would be the cost of working on this kind of project and if there is a possibility to generate some revenue based on other examples?
Answer: So the cost factor is interesting because some of these materials are very expensive and if you don't know, sometimes you don't know going into it how expensive things are going to be but you have to figure that the inks are going to be quite expensive and by quite expensive I would say maybe as much as a dollar per magazine for a couple of displays or maybe more than that. I think we spent 6 dollars per magazine on the electro chromic just for that cover. So it can be quite expensive but there are maybe ways especially if you customize that meaning you are basically selling advertisement as well to generate every month money back in. So I think it is possible to generate revenue especially if it creates enough buzz.
 4. Question: What do you think could be the necessary implementations in order to create a prototype like this, probably run in and test it, and evaluate its effectiveness?
Answer: Obviously the challenges of any sort of a prototype is you have to decide what is the interactive communication you are trying to achieve and then do we have the technologies to be able to produce it in house, do we have the materials to be able to produce it in house, do we have the power in the form of a battery or some other technology that the user is going to utilize, and then of course there is all the process control mechanisms to be able to print a reliability in a repeatable manner and those are all challenges. So in order to implement you have to have all those kinds of things in place.
 5. Question: Besides that example you showed me about the book, have you ever seen any other example of a publication incorporating printed electronics or this is kind of more oriented to packaging and things like that?

Answer: The only publications I know, there was the Canvas magazine cover that we worked on. Prior than that there was a magazine called the Esquire, there was the Esquire magazine sample, the Esquire had a display in there that I believe was an EE display so it shifted sort of colors based on a switch but it was a rigid display didn't bend I don't believe but that was back in about 2008 or 2009 I feel like. And that was one of the early ones, again not a printed product more like conventional but that was done on a magazine. And a couple of different things. But I also have seen one that had music integrated but it was sort of like, almost like one of those greeting cards where you have like a little speaker and some memory that started some music when you turned it up.

Interview with Professor Colleen Twomey:

1. Question: What can be an effective way to incorporate printed electronics in a publication for example like a monthly magazine?

Answer: One thing I think would be interesting is that the younger generation is so tied to the phone and they are used to get in stuff 24/7 so what's going to drag them to take the time to maybe download an app, pick up a printed piece of material and do something with it. There is got to be a cool factor but research shows and you might be able to find this through your literature reviews at the library that if someone is viewing something that is interactive they are going to be staring at it longer therefore interacting with that brand. So let's say it is for a car advertisement so it is the advertiser is where I am getting at that could be an advantage to printed electronics. So if there is something about the car, maybe the lights actually light up on the car, research indicates that people, I think it is something like 11 times longer than people normally flipping through. So the question it is going to be how can we get people to go from here to here and it is going to be the cool factor. There is got to be some kind of incentive and I think printed electronics kind of has a natural incentive because it is so interesting for publications.

2. Question: Do you think there could be like a possibility to run a test here at Cal Poly considering the necessary equipment, the materials, the labor involved, and the logistics behind a project like this, like a monthly magazine or maybe an annual magazine incorporating printed electronics?

Answer: Technically yes. Most publications if they are high volume are going to be printed sheet fed offset or offset printing and our printer has a coater on it and just recently Dr. Keif ran a test with the coater which is essentially a flexo plate and silver conductive ink. And he printed an RFID tag so that was very successful on the offset press so there theoretically you can combine graphics and printed electronics on our Heidelberg using the coating station. It is not offset but it is part of the offset press. Specifically the publications that might use a traditional press like offset using the coating station to print down a conductive ink. It is one layer of conductive ink. It is

- possible. The other possibility is if you print digitally and then incorporating some sort of maybe screen printing but then you are doing two different steps so there is logistics, there is labor, those expenses because conductive inks are really expensive. And then there is some post processing stuff so the conductive ink has to be dried in a certain way so there it doesn't oxidize. So can we test it here? Absolutely. Are we gear to do it regularly? It might need some modifications to the press.
3. Question: Do you think there is a possibility to generate some revenue if a project like this is offered to students here at Cal Poly or maybe coming more ambitiously with a local magazine that incorporates this printed electronics technology?
Answer: It depends on the readership. You know, would the readership respond? I think a little bit of research maybe has to go to the demographic of the particular publication. So what do the people who want to interact would read. So there is going to be an expense but people may be interested in paying for that novelty if it gives them something, entertainment or something along these lines and weather they are going to do that on a regular basis really remains to be seeing I think. Blinking lights and sensing and things like that to me are really cool. I probably would buy a magazine. I can see advertisers knowing that hey if I have somebody staring at my add 11 times longer than if they were just flipping through I can see advertisers very much interested in it. It depends on the readership and the magazine. So if you think about maybe higher end magazines that people pay a lot for anyway and maybe it is like a quarterly subscription and the advertisements that you see on that magazine tend to be higher luxury. Items like Rolex watches or something like that, that might be a possibility but I don't know how many young demographic people are reading this types of magazines.
 4. Question: Do you know any other example of publications that have incorporated this kind of technology before?
Answer: Really all I have seen are demonstrators so just small little prototypes that show capability of printed electronics. I am not aware of any publication.
 5. Question: I think it has been more successful recently with packaging right?
Answer: Yes, we have a point of purchase display and maybe some light up activities or maybe voice activated stuff.

Interview with Philip Lazo, director of Innovation for RockTenn Merchandising Displays:

1. Question: What could be an effective way to incorporate printed electronics in a monthly publication?
Answer: Probably best way is to integrate an NFC tag in the publication and link to digital media experience.
2. Question: Is there a possibility to run a test here at Cal Poly considering the necessary equipment, materials, labor, and logistics behind this project?
Answer: I would think so. You could print the conductor and mount the chip.

3. Question: What could be the cost of working on a project like this?
Answer: Probably a few thousand dollars for printing, mounting, and working with content management company.
4. Question: Is there any possibility to generate revenue based on other examples from companies that are already focusing in printed electronics?
Answer: You could link the tag to content from advertisers and they pay you.
5. Question: What are the necessary implementations to create a prototype like this, run it, test it, and evaluate its effectiveness?
Answer: Firstly, we've not done a lot of printed electronics implementation so can't go from actual case history. But I would offer this about the new product introduction process.
 1. Understand your target market and scope out opportunities to solve specific customer pain points.
 2. Define the new product. What is the job to be done? Do the economics of the product make sense up front? Is there a financial return for the client? This is a model. Should use NPV and IRR as metrics. The model is often wrong but use as a sanity check before starting.
 3. Develop a working demo and show it around to generate client interest.
 4. Pitch a pilot to the client. Optimally client pays for part of the pilot. Get skin in the game early.
 5. Analyze the result of the pilot. This is your best chance to develop the real value propositions based on financial and non-financial metrics. Sales lift is ultimate metric for retail but depending on product you could also use opex reductions.
 6. Scale into high volume production.

