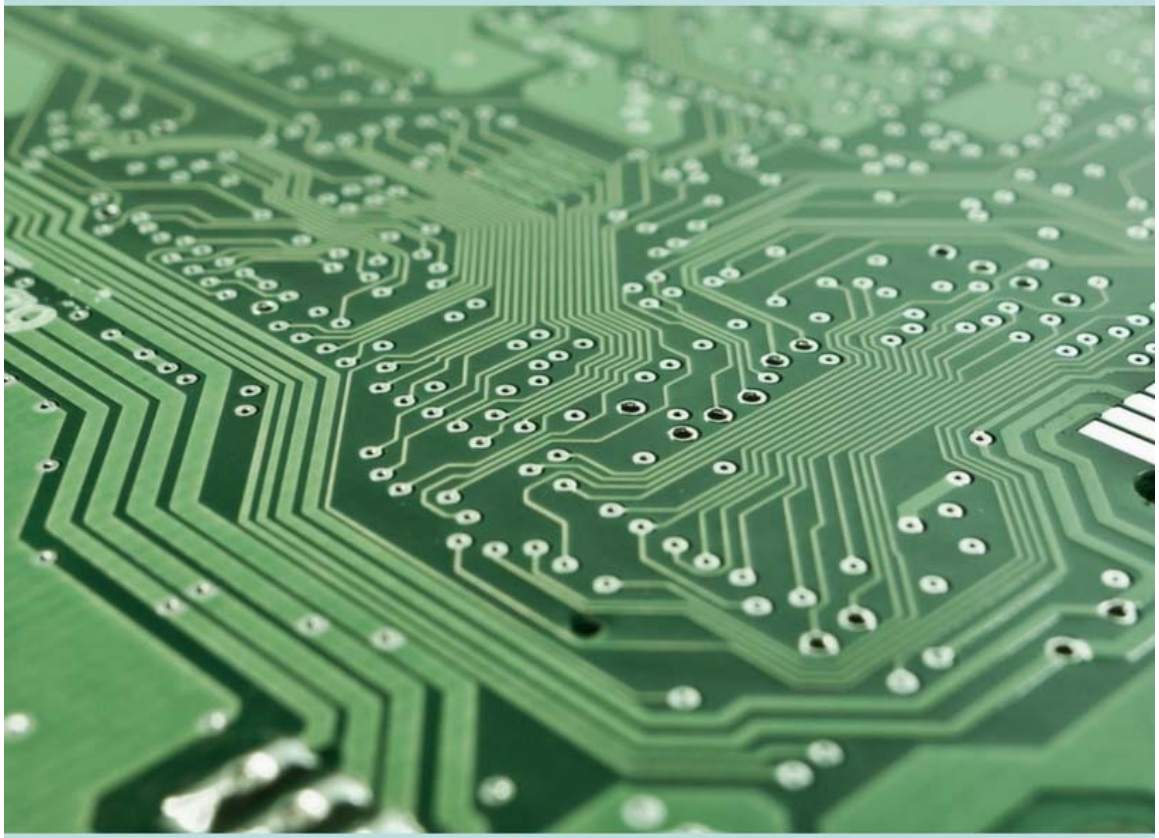
Project #3 - Research Paper



3-D PRINTERS: A LITERATURE REVIEW

PREPARED FOR: EDTC 803 PRINCIPLES OF EDUCATIONAL LEADERSHIP

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Abstract

3 D Printing is an emerging topic in educational technology. In this study, a scan of literature on 3 D printing in schools, business, and society is conducted. Primary data was collected from a small survey of teachers of students K-12. Also, data was coded from secondary source reviews, and recommendations were made for further areas of research and study on the societal impacts associated with 3-D Printing.

Keywords: 3 D Printing, CAD, additive manufacturing, rapid prototyping RP, three-dimensional solids

Introduction: The Literature Review

This literature review sets out to define what Three-D printing is for the reader and examines its applications in schools, business, and society. Some secondary sources studies results done recently based on survey information are presented. Those studies recommendations are restated as well as recommendations of those studies. The results of a small survey of teachers who have students in schools that use 3 D printers are included. In the past few years, interest has exploded with more and more applications in school, businesses and socety with some now predicting the Third Revolution in the way products are made.

Purpose of this review;

The primary purpose of the review is to examine the current state of literature on 3 D printers in schools, businesses and society and to give examples of how 3 D printers are being used especially by teachers and students. The second area is to examine what research topics are being written about 3 D printing and the third area of research is to identify areas of research that should be conducted to answer questions raised.

The research's first study group was schools. Many articles were found which showed the ability to allow student's to experiment with 3 D printing opens up tremendous opportunities for practical learning. *Students Take Top Awards in Textile Digital Print and Product Design Competition (Winter)* cites the positive outcomes for jobs after graduation "students need to be experiencing all of these technologies so that when they graduate, they'll have the skills to work anywhere, from small firms using traditional methods to enormous firms like Liz Claiborne, where design and production are highly computerized." [1]

A common constraint raised was the availability of 3-D printers in schools. Huffman discusses the capabilities and costs citing how printer prices can range from $500,000 in businesses to schools with discounts at $40,000.00. Does the cost out way the value of their capabilities? From a scientist perspective in 1999 a 3-D craft was sent into space to gather data on the Northern lights. [2] An article describes how with the use of a CAD file a school technology program can be created. Examples of all sorts of products can be made.

[1] Winter(2006)
[2] Huffmaan(2001)

Flowers in *Historical Rapid Prototyping, While Costly, Can Afford Students a Unique Opportunity to Bring Their Ideas to Reality*(2002) discusses the 3 D Modeling process, and its benefits to students. Printers costs in 2002 range from $49,900 to less than $8000. Despite high costs for schools, Flowers says these have to be weighed against the outcome of empowering students to make their models thru rapid prototyping. "One of the biggest impacts of rapid prototyping at that university has been the increased empowerment of students Model-making has long been an element of the design process." [3] Flowers also felt students have limitless possibilities because of 3 D printing.

One of the best examples of this is in *Student Engineers Design, Build, and Fly "Printed" Airplane. Science and Children, Shuffler***.** (2012). The Army hired college students to build an unmanned aerial airplane using 3-d for a project to study the feasibility of using such plane. "Rapid prototyping means rapid in small quantities," [4] Sheffler said. "It's fluid, in that it allows students to evolve their parts and make changes as they go--design a piece, print it, make needed modifications to the design, and print a new piece. Army researchers used students for this project another project may excite science students as discussed in an article on *Researchers Use 3-D Printer to Make Parts from Moon Rock.* "'It doesn't look fantastic, but you can make something out of it,'[5] says Bandyopadhyay. Using Moon Rock things can be made with the hopes that vice versa if we have space travel we could make what we need in space. This opens up a whole new set of opportunities for students.

[3] Flowers, Moniz(2002)
[4] Sheffler (2012)
[5] Bandyopadhyay, Science and Children, (2013)

At what age is it appropriate for children it use this technology? To increase stem experiences, an elementary school in Tennessee bought a MakerBot 3-D printer. Kindergarten and first graders used it to design a piece of play equipment. The school successfully installed it and they used it. This highlighted children are often left out but can accomplish great things with the right equipment. The playground project demonstrated that this age group benefitted by being part of the process. [6] *Practical Applications Printing the Playground: Early Childhood Students Design a Piece of Playground Equipment Using 3-D Printing Technology. Science and Children, Wendt, S., & Wendt, J.* " [7]

Based on the above the study concludes that in the area of schools tremendous opportunity exist s and that 3-D printing can be a valuable aid to students despite constrained costs.

The second area that was reviewed was: How has 3-D printing been used in businesses?

A Harvard Business review study (2013) 3-D *Printing will Change the World*, D'Aveni, (2013) discusses the innovation and impact of businesses being able to make things cheaply locally and how that will change our culture. Made in China will be replaced with made locally; China will deal with its population instead of the global market. The cost of production will drop because shipping costs will be removed.[8] Over the last five years many articles are based on surveys. *Research Using or Evaluating 3 D*

[6] Wendt and Wendt(2015)
[7] Students Design Build, (2012)
[8] D'Aveni,(2013)

Printers in the Enterprise June 2014, Maddox was a survey that was done globally. It had 624 respondents: 60 were using or evaluating 3D enterprise currently or for future planning for 3D printing.: Most were using printers currently and 12% were evaluating printers to buy in next 12 months; 31% evaluating plans to purchase and 29% had no plans. 40% indicate changes in enterprise if it were more widely used. Current users used them for testing ideas 73%. 67% used for prototyping fulfilling and specific needs. The survey went on to ask barriers, or why they were not using them, 66% responded business. The majority felt in the future this type of printing would be lower labor and cost production goods to sell. [9]

Another study showed the practical applications of 3 -D printing, *The Road Ahead for 3D Printers*, Earls and Baya (2014). In this PW Survey of 100 industrial manufacturers 2/3 were using 3-d printings. Questions were similar to another survey except the survey pool was industrial end users. Typical questions were: How does your company use 3-d printing technology. Most responded - Rapid prototyping. Prototyping 24. 6 % not using 33 %. The study indicates services are expected to grow 2.5 billion in 2013 to 16.2 billion in 2018. Questions were asked about the emerging market -The emerging market for printers: high capability low cost. Cube jet under 5,000 expected to be 1,000 in 2016 .Positives was seen to be: Advances in the coloring of polymers; Advances in printers and printing methods software, materials used in printing; Cube jet sells for under 5,000 and can create objects in multiple colors.[10]

[9] Maddox (2016)
[10] Earls and Baya (2014)

Based on the above the study concludes that in the area of business there is tremendous opportunity which will continue with drop in costs of #-D printers.

The third area of literature review was on articles about *how does it impact society?*

Many of these articles discussed the legal issues raised by 3-D printing in the area of patents and the use of 3-D printers in developing nations. *Legal and Ethics Evaluation of Potential Fair Trade Standards for an Ethical 3-D Printing Filaments* in the Journal of Sustainable Development, Feely, Wijnen,& Pearce, Ethical issues in 3rd world countries using polymers[11] *Legal and Ethics The End of Post-Sale Confusion: How Consumer 3D Printing Will Diminish the Function of Trademarks*. Ratto, M., & Ree, R. Survey subjects were Materializing information: 3D printing and social change. This was an environmental literature scan and open-ended workshop to discuss concepts surrounding 3-D.[12] Moilanen, J., & Vadén, T. (2013). 3D printing community and emerging practices of peer production. Community and emerging practices of peer production. These articles discussed the impact of revolution on manufacturing predicted by theorists. Conducted in 2012 the survey self-identified. The purpose was gain insight into people using 3- d printing which were End users; early adopters; and developers: Survey instrument 2012 Used Mailing list, hackers, Twitter and Rep Rep mailing lists

The survey had 358 respondents most were Male dominant average age 35; 56% had college or above. There was a higher % maker movement seen in peer production the survey identified open space and other projects. Questions were asked as to when they

[11] Grace, J. (2014)
[12] Ratto, and Ree (2012)

started using 3-D printing. Response 2005, 2006 which coincided with Rep-rap introduction. Survey results showed high usage in production models and for Artistic items, Spare parts/ High usage continues in research and education purposes Bottlenecks were identified as patents costs, object quality, speed, cheaper materials, need for metal materials and cheaper printing prices.

A summary of business survey findings showed those most interested in 3-D as a movement are 30 yr. old make living in Europe or the US with a college degree. They would use it for enjoyment, fun. They are part of the open source, maker movement more likely than-than peer production.

The article went on to discuss the rapid growth since 2005 and the immature ecosystem of cad/ cam software lagging behind as an organization weakness. It concluded with a graphic showing the Ecosystem as consisting of early adopters, service providers, end users, the development community, hardware vendors and future users . It contended that all make up the system which is a continuous circle of all users interdependent on each other.

Based on the above the study concludes that in the area of societal issues there is a strong potential for a revolution in the production business due to 3-D printer's emergence in the marketplace.[13] A 3D revolution is underway and will pull in more as a market as demand for 3-D printing grows and technological abilities expand. It also concludes there will be a need for continuing research on the legal and moral issues of its use.

[13] Moilanen, J., & Vadén (2013)

Methodology

The review of literature was conducted in two phases; peer-reviewed articles on line searching 3 D printers; a second search of literature on 3 D printing that conducted surveys, and a small survey the researcher conducted on teachers.

Data analysis – Each article was coded on an excel spread sheet. Example Appendix B. Coding was done to answer the first question: schools, the second question, business and the third question: society. Each paper was examined to fit into one of the three categories. Primary survey results were added to the first question. Articles with Survey were noted and the added the survey results of our own study are added to the school category.

The research was descriptive supplemented by a small survey of teachers. A survey is attached in Appendix A. Future research topics were identified as legal issues unresolved as patents for the parts need to be addressed as they expire and issues concerning consumer culture.

Before beginning the survey, permission will be obtained from the NJCU Institutional Review Board. The group will be the teacher of students in schools that currently use 3 D printers. Questions will be asked as to whether the participant uses 3 D printers. What do they use it for? What are the opportunities they see for their students? What are the constraints? Do they know how much their school paid for the printer?

The control group will be the 100 teachers. All will be asked to participate and receive a link to the questions on Survey Monkey. One of the questions will have they used the 3-D printer for their class? If they say yes there will be a group of questions based on that response. ? If the answer is yes you will be asked if you would participate in a face to face interview on Instant messenger. If they answer in the affirmative they would be interviewed for their satisfaction with the 3-D printer. A survey instrument of up to 10 questions will be used for all persons in the survey and supplemented by a structured interview using Skype and instant messenger. An introduction, asking them to participate in the study will be offered. The introductory contact will include the parameters needed for study information confidentiality.

Analysis

There will be an analysis of the data, a summary of the data and a T-test for those who have used 3 -D printers and those who did not. A spreadsheet using Microsoft Excel will be used to tabulate the data from the research. The validity of the testing will then be reviewed. After the survey is completed, a review of the responses will be done to make sure there are no instances of someone just being non-responsive or answering in a way to throw off the survey. In that instance, that survey will not be tabulated. The follow up interview can be structured to collect demographic data as well as some numbers that can be crunched. The information will be presented using Likert scales. It will compare the each one individually before and after as well as collectively before and after.

The primary source data collection instrument is Survey Monkey for all teachers for the study, supplemented with the Instant Messenger or Skype interview. Focus will be on assessing the outcomes for students who use or will use 3-D printers. Secondary

sources will be included. Based on a scan of literature which will be coded for input in the school, business, and society as positive negative or requiring further study (societal issues)

Outcomes

Presenting the data Test, Retest will be employed showing correlations. Teachers who use the technology 3-D printer and those who do not will be compared as to their attitudes about 3d Printing. Triangulation of data will be done using the secondary data to validate or support the primary data. Various methods will be used to present the data. An excel spreadsheet will be used to present the coding for the secondary source literature review based on thru three categories, school, business and society. The Survey questions will be presented using Pie Charts, Cluster, and Likert Scales. Cross tabs will be used for some correlations work in presenting the analysis. Examples of data presentation is in Appendix B

Conclusions:

As shown in the literature surveys, even though 3D printing seems male-dominated for the time being it's also becoming less expensive and more reliable. While there are legal issues as reported in the surveys, it still has purposes that can help companies. Surveys have also shown the ecofriendly focus of 3D printing. The most obvious trend is that costs have dropped dramatically, and the market has increased. It is anticipated that this trend will continue. Legal issues resound unresolved as patents for the parts need to be addressed as they expire and issues concerning consumer culture.

As America seeks economic opportunity in the 21st century, 3D printing offers an unexplored and lucrative path. The new global economy is more competitive than ever, and leveraging 3D printing technology could again make the USA a leader in another technology-based marketplace. As political debate swirls in this election year regarding jobs for Americans in the global market, 3D printing can become a new avenue for the technology challenged workers as well as American small businesses. This is especially true given the need for American-based manufacturing competing against the 3rd world, lower-wage companies. Made in the USA can again become a meaningful phrase. As US companies create goods that can support medical and engineering applications in global markets. Once considered a fad with a limited future, 3D printing can become a lynch-pin of the US modern economy.

In today's society where more companies are looking towards ways to cut budgets when it comes to travel 3D printing can see as a competitive advantage. It's evolution since the 1980's have led to more and more moments of opportunity. You can create endless amounts of structures and technologies all from the convenience of your own office. As more time goes along and more 3D printers become available, the price will continue to become more affordable and more common.

Printers are no longer for printing paper. The possibilities of what these can print seem to be endless. From this literature review, you can see firsthand that by the year 2018 it will have expanded to a level where 3D printing will be a household name to many. It will change the world and the more we take advantage of this the better our society will be. Development of ideas become faster as you can print some ideas in that

morning and have them ready for a showcase that afternoon. It also leaves little to the imagination as the precision and accuracy of each item. Having an item in front of you that you can touch and feel also makes it differ from what you can see on a computer screen. That for many can make a world of difference when a decision needs to be made and makes 3D printing one of the technologies to watch in the years to come. In February 2011 the Economist magazine asked where 3D printing will be in a decade or two. With dramatically dropping costs and market increases 3D printing is a trend that is here to stay. This literature review set out to define what Three-D printing is for the reader and examines its applications in schools, business, and society and has begun to answer that question. The result of the survey of teachers in schools using 3-D printers supplements this information.

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Surveys

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Maddox, Teena, http://www.techproresearch.com/article/research-31-using-or-evaluating-3d-printers-in-the-enterprise/accessed on the web 8/1/16

Moilanen, J., & Vadén, T. (2013). 3D printing community and emerging practices of peer production. *First Monday, 18*(8). doi:10.5210/fm.v18i8.4271

Ratto, M., & Ree, R. (2012). Materializing information: 3D printing and social change. *First Monday, 17*(7). doi:10.5210/fm.v17i7.3968 accessed on the web 7/25/16

Researchers Use 3-D Printer to Make Parts from Moon Rock. (2013). *Science and Children, 50*(5), 12. Retrieved from Questia.

Student Engineers Design, Build, Fly "Printed" Airplane. (2012). *Science and Children, 50*(4), 19. Retrieved from Questia.

Wendt, S., & Wendt, J. (2015). Printing the Playground: Early Childhood Students Design a Piece of Playground Equipment Using 3-D Printing Technology. *Science and Children, 52*(5). Retrieved from Questia.

Winter, M. (2006). Students Take Top Awards in Textile Digital Print and Product Design Competition. *Human Ecology, 34*(2), 21. Retrieved from Questia.

Appendix A

Survey questions

3 D printers in the classroom

1. Do you use 3 D Printers for your students?

- ☐ Yes
- ☐ No

2. Does your school have 3 D Printers?

- ☐ Yes
- ☐ No
- ☐ No not at this time
- ☐ No not at this time but in the future

3. What grade do you teach?

- ☐ K-5
- ☐ 6-8
- ☐ High School

4. What subject do you think 3-d printers are appropriate for?

- ☐ Math/Stem Courses
- ☐ Design
- ☐ Architectural/Pre-engineering
- ☐ Art
- ☐ other

5. Did your students enjoy the project they made using a 3 D printer?

- ☐ Yes
- ☐ No

6. Did you see the educational value to the student?

- ☐ Yes
- ☐ No
- ☐ Not sure

7. Are there opportunities you see for your students with the use of 3 D Printers?

- ☐ Yes
- ☐ No
- ☐ Other, Please list

8. Would you be willing to take part in a Skype interview if so leave your email below

- ☐ Highly likely
- ☐ Not likely
- ☐ Please list your email address if you answered highly likely

9. What are the constraints of 3 D printing for your students?

- ☐ Ease of using
- ☐ Materials
- ☐ Lack of printers due to costs
- ☐ Lack of printers due to space
- ☐ Other (please specify)

10. Is there anything else you would like to tell us about 3 D Printing?

- ☐ Yes
- ☐ No
- ☐ Other (please specify)

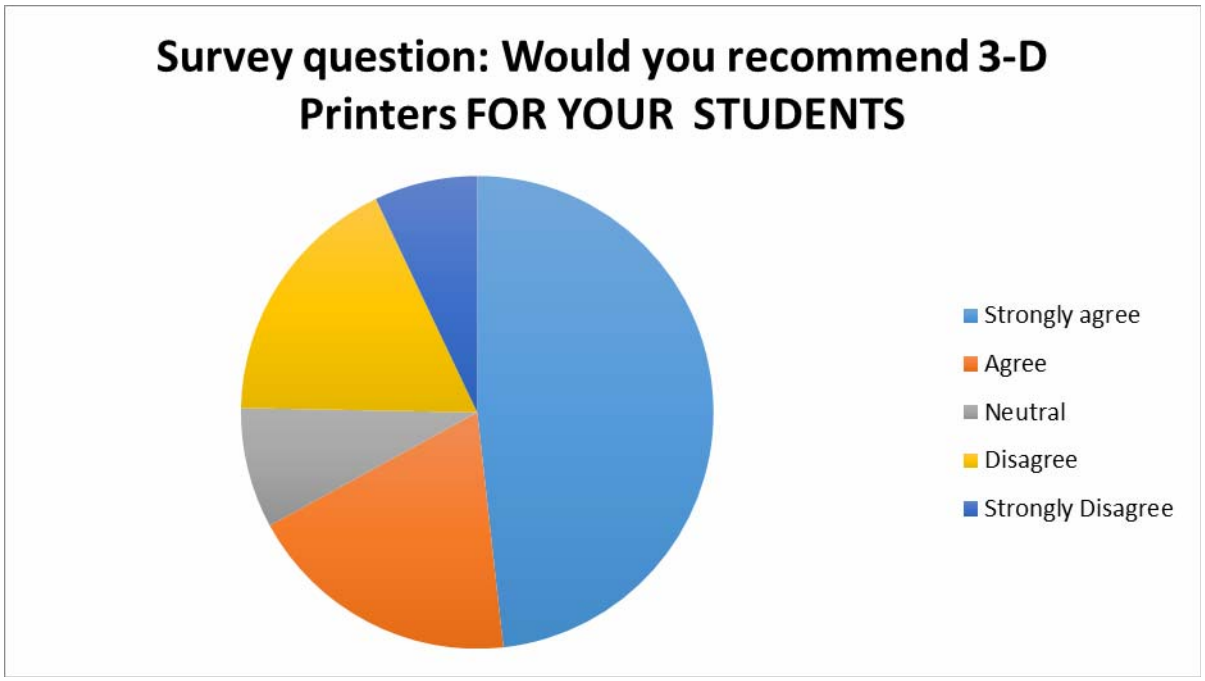
APPENDIX B. Presentation of Data

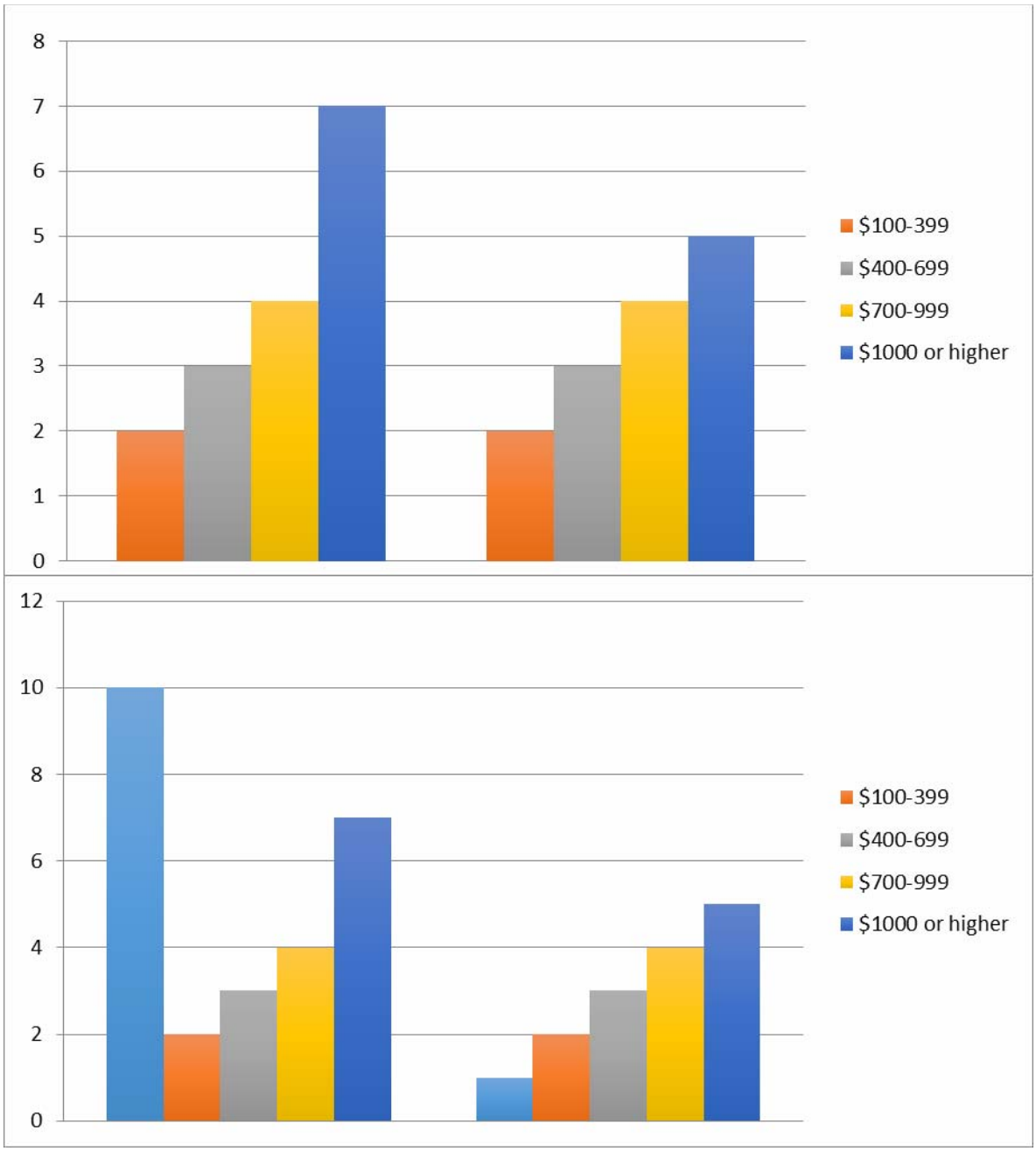
Data Analysis

Review of Literature 3-D Printing			Coding			
Article	Type	School	Business	Society	Survey Used	Further research
x		X				
x			X			
x		X				
x		X				
x			X		x	x
x			X		x	x
x				x		
x				x	x	x

Review of School Survey Results (supplement and validate secondary source conclusions)

Pie Charts


Survey question: Would you recommend 3-D Printers FOR YOUR STUDENTS
Strongly agree
Agree
Neutral
Disagree
Strongly Disagree



Clustered Column Chart

How much would you be willing to recommend to your Administrator should be spent for a 3-D printer

Likert Chart Excel

I'd recommend a 3 d PRINTER FOR MY STUDENTS)	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	No opinion
For Math/Stem Classes	6	3	1	2	2	1
For Design/Pre-engineering classes	3	1	1	1	6	3

Outcomes will be presented for what subjects 3 D printing is appropriate.

Correlation in Excel

The **correlation** coefficient (a value between -1 and +1) tells you how strongly two variables are related to each other. We can use the **CORREL function** or the **Analysis Tool pack add-in** in **Excel** to find the correlation coefficient between two variables.

- A correlation coefficient of +1 indicates a perfect positive correlation. As variable X increases, variable Y increases. As variable X decreases, variable Y decreases.

Appendix C

Examples of 3 D Printing Outcomes

Model version of Plane made for US Army by University of Virginia college students using 3-D printers
https://www.google.com/search?q=3d+plane+made+by+university+of+virginia+students&rlz=1C2CHFX_enUS566US566&biw=1120&bih=611&tbm=isch&tbo=u&source=univ&sa=X&ved=0ahUKEwjbyLCJz7HOAhUD5SYKHVybA78QsAQIJA

Moonrock to be used in 3-D printing - https://news.wsu.edu/2012/11/28/3-d-printer-makes-parts-from-moon-rock/

Cover of Economist, 2011 featuring violin made with 3-D Printing
http://downmagaz.com/business_magazine_economics/2986-the-economist-12-february-2011.html

Printing the Playground

Early childhood students design a piece of playground equipment using 3-D printing technology.

By Stephanie Wendt and Jeremy Wendt

With grant funds in play, teachers at Prescott South Elementary School in Cookeville, Tennessee, were looking for innovative ways to engage students in new and exciting STEM experiences. One outcome was the purchase of a MakerBot 3-D printer. The printer provided opportunities for previously inconceivable projects. Teachers submitted ideas about ways to interest students in 3-D modeling processes while meeting standards and school objectives. The school STEM advisory committee posed a vision that challenged both teachers and students: Kindergarten and first-grade students were charged with designing new playground equipment to create a solution to a problem: The school playground was in need of additional equipment. Students jumped at the opportunity to solve an issue they were dealing with daily.

This project would engage students in Science and Engineering Practices as described in the *Next Generation Science Standards* (see "Connecting to the Standards," p. 47). Several tech-savvy teachers (and two middle school students) were trained to use the printer and 3-D modeling programs such as SketchUp—chosen as the primary implementation software due to its ease of use and free access for educators. In turn, they became facilitators and troubleshooters for student learning projects.

The playground project began with a week of interdisciplinary planning by teachers across the K–1 classes, followed by the weeklong implementation. For the culminating project, students presented the principal with a 3-D printed model of the playground equipment selected from their designs. In turn, the principal ordered the equipment for the school. Throughout the authentic learning experience, the students engaged in Science and Engineering Practices: They asked questions and defined problems, developed and used models, planned and carried out investigations, and constructed explanations and designed solutions. The interdisciplinary project incorporated literacy, science, math, and physical education. In addition, throughout the unit, teachers reported an increased level of engagement.

Prescott South Elementary School https://sites.google.com/a/pcsstn.com/pses/

Appendix D Literature Scan

Year	Author	Type of Technology	Questions		Type of Resource
2016	**Ko, Yokin,**	**Research on 3- D Printers**	20 question On line	TBD	Monkeysuvey.com
2016	Maddox, Teena,	3D printers in the enterprise			
2013 *First Monday, 18*(8). doi:10.5210/fm.v18i8.4271	Moilanen, J., & Vadén,T	3D printing community and emerging practices of peer production			Survey
2012 *First Monday, 17*(7). doi:10.5210/fm.v17i7.3968	Ratto,M., & Ree, R.	Materializing information: 3D printing and social change			Survey
2014	*Earls,Alan Baya, Vinod*	The Road Ahead for 3 D Printers			
2014	. D'Aveni Richard A,	3 D Printing will change the world			
(2014).	Feeley, S. R., Wijnen, B., Pearce, J. M	Evaluation of Potential Fair Trade Standards for an Ethical 3-D Printing Filament.			Questia: *Journal of Sustainable Development* , *7*(5), 1

2002	Flowers, J., & Moniz, M.	Rapid Prototyping, While Costly, Can Afford Students a Unique Opportunity to Bring Their Ideas to Reality.			Questia: *The Technology Teacher, 62*(3), 7.
2014	Grace, J.	Confusion: How Consumer 3D Printing Will Diminish the Function of Trademarks. The End of Post-Sale.			Questia: *Harvard Journal of Law & Technology, 28*(1), 263.
2001	Huffman, R. W.	3-D Printing: Solid Model Fabrication with a Touch of a Button			Questia: *The Technology Teacher,61*(3)
2005	Rivas, R., & Gobeli,.	Accelerating Innovation at			Questia: .
2015	Wendt, S., & Wendt, J.	Printing the Playground: Early Childhood Students Design a Piece of Playground Equipment Using 3-D Printing Technology			Questia *Science and Children, 52*(5).

2006	Winter, M	Students Take Top Awards in Textile Digital Print and Product Design Competition.			Questia *Human Ecology*, *34*(2), 21
2012		Student Engineers Design, Build, Fly "Printed" Airplane.			Questia: *Science and Children, 50*(4), 19.
2013		Researchers Use 3-D Printer to Make Parts from Moon Rock.			Questia: *Science and Children, 50*(5), 12.