Role of 3D Printers Industry in Strengthening R&D Collaboration between Academia and Industry

Muhammad Fiaz[*], Amir Ikram[†], Amna Saleem[‡] and Arooj Zahra[§]

Abstract

The paper is set out to explore the factors, like cost and time saving, that shows how 3D printing strengthens R&D collaboration among academia and industry.3D printers are becoming the need of era and are applicable in many sectors like medical, aerospace, automotive, architecture, construction and consumer goods etc. R&D collaboration leads to the leverage of knowledge and drive innovation within the companies. R&D collaboration is two-way teamwork where teams can work by the give and take principle. For the collection of data face-to face in-depth interviews were conducted. N Vivo 12 software has been used for the in-depth qualitative analysis which shows how additive manufacturing strengthens R&D collaboration among academia and industry. Many techniques have been used for the validation of different themes of the study such as coding nodes, thematic diagrams, word tree, word tag clouds and tree map. The theoretical and practical significance of the study includes its contribution towards qualitative research, establishing innovation nexus, bridging the gap between science and technology, and stimulating regional development.

Keywords: *3D printing, R&D collaboration, qualitative research*

Introduction

3D printing allows the printer to print solid objects that can be touched and felt (Kaur, 2012). 3D printing process is also known as Additive manufacturing; it's an additive printing process. Charles W. Hull was the one who replaced Traditional manufacturing by additive manufacturing. It's a technology that gives a print in 3D object form. It is predicated on the ink-jet rules and can also print objects in different materials. Through special software the file is being processed through

[*]Dr. Muhammad Fiaz, Institute of Business & Management, University of Engineering and Technology, Lahore, Pakistan. Email:Fiaz0128@gmail.com
[†]Dr. Amir Ikram, Institute of Business & Management, University of Engineering and Technology, Lahore, Pakistan
[‡]Ms. Amna Saleem,Institute of Business & Management, University of Engineering and Technology, Lahore, Pakistan
[§]Ms. Arooj Zahra, Institute of Business & Management, University of Engineering and Technology, Lahore, Pakistan

computer Aided-Design (CAD) software and it is being spliced into two dimensional layers. The 3Dprinters work in such a way that it prints the object layer by layer with extra help from a soluble stuff. The supportive stuff is used to join the portions of the object. This can be understood by the example that the top of the hammer is printed and then attached with the body of the hammer. Files that are used in 3D printing are Stereo-Lithography files or in short are known as STL files. The process can be understood in such a way that you have a source files which represents an object, the source file can be created or it can be downloaded from internet. Then you have to transfer the file from your desktop to the 3D printer (Martin, Bowden, & Merrill, 2014). The history of 3D printing dates back in 1984 when Grynol started his research on three dimensional printing that the first machine specified for 3D printing known as the Stereo Lithography Apparatus (SLA) was advanced by Charles Hull. DTM Inc. then in 1989 a refined version was produced known as Selective Laser Sintering(SLS) machine that used a powder coating rather than liquid for creating the model. The advancement kept on going and in 2013 the Market-bot Industry executed a digitizer desktop 3D scanner that turned the physical objects into digital designs. 3D printing development can be used as a piece of diverse fields, for instance; footwear, advanced diagram, advancement, auto, avionics, dental and therapeutic organizations, direction, geographic information systems etc. 3D printers can be used by archeologists and chronicled focuses, to make duplicates of prominent ancient pieces. It also includes works of model, tweaked I-Phone case, make toys for kids, ultra-light and climaxed fitted shoes, custom bike packaging and road cycling defensive tops for bicyclists, electric guitars can be handmade, kitchen utensils, vehicles, Models of bone breaks, split organs, compact speaker producers to make ear structures and shells for patients, broken jaws substitution, make crowns and frameworks by dental pros gnaw engraving wounds plastic toys, coffee makers, plastic containers and compartments ceramic creation and pearls(Walters & Davies, 2010).

Gibbons and Barnes (2004) suggest that a better coordination between the university and industry can be achieved only if there is an appropriate stability in the goals of the academics and the industry. R&D collaboration efforts in the research and development projects help to cut costs of research and in the development of competitive products. In 2010, Yildirim and Guven stated in their research study that the idea of university industry collaboration contains all the efficient works in the field of exploratory and mechanical change by uniting the potential

results, for instance, students, analyst, specific devices with making of business area, and the situation of students, apprenticeship, and practicing the learning of analysts. The purpose of this study is to emphasize on 3D printing technology along with the way it is over powering the industrial equipment. A number of companies have entered the new horizons where the next technology which is 3D printing is on a rise. This study will show how 3D printers industry will strengthens the R&D collaboration of academia and industry collaboration basically main aim of collaboration is to share benefits among each other. This thesis will draw attention to the factors that how 3D printing industry will strengthens the collaboration and will result in their succession.

Literature Review

History of 3D Printers

Devin Peek and Elizabeth Stark (2010) stated that3D printing is a process which is known as additive printing which is based on inkjet printing rules. By using such technology a wide variety of materials can be used to make a three dimensional product. Recently this technology is quite expensive but is it becoming affordable. As this technology has the potential to bring change in medical model production and prototyping as it can produce beneficial products in future as well. The main aim of the research is to find the technological advancement that can bring different aspects of industries it covers different areas such as high-risk surgery, dentistry and prosthetics. Kaur (2012) stated in the study that 3D printing means designing solid items from a set of digital data, in this whole process a 3D printer is used which starts processing an electronic file and finally turning it into solid model, forming an imaginary form of reality or instead an item built with coatings of plastic. A 3D printer can make whatever a student, teacher or a librarian can design. A limitation of printers can be its size or scale nevertheless 3D printers allow anything to be formed originally that exists in the world.

The Co-founder, executive vice president and also known as the chief technology officer of the 3D structures was the Charles W. Hull, he was also known as the Chuck Hull. He was born on 12th May 1939. Basically he was the one who gave the idea of physical objects which was later known as stereo lithography which is known as 3D printing. Hull was able to build a patent portfolio that cased up many significant portfolios which are the main characteristics of the present additive manufacturing technologies this can be understood by an example that is it is made by triangulated models in a file format of STL that is layering

and then revelation of the strategies like hatch directions. Hull salary in 2011 was $307500 for the 3D systems CTO. The advent of 3D printing emerged in 1976 when the inkjet printer was initiated. Gradually with advancement in technology related to the inkjet concept it was no soon that the technology from printing with ink moved towards printing with materials. 3D printing has taken over many industries since recent decades (Chuck Hull, 2015).

Revolutions of 3D Printing industry in Developed Nations

An analysis by an organization envisages that 3D printing can bring the new development cycles as the system becomes inexpensive. Companies will implement the new technology in creating products while centering their attentions towards customer feedback and customer centered design. The cost of entering the industry has reduced by a lot allowing niche businesses to develop quickly. This technology can affect the current large scale manufacturing industry of the China (Greengard, 2013). Almost 2.6 million euro has been invested by the Airbus with the University of Exeter for the Additive Layer Manufacturing in 2011 (Gilpin, 2014).

Pros and Cons of 3D Printing

Three dimensional technologies is the one that can be used in all fields as it is a valuable knowledge. It is the quickest and easiest way to make accurate prototypes of anything. The 3D printing technology facilitates extremely modified and minor scale manufacturing usually less than 1,000 units with complex parts(Kim, Zhao, & Zhao, 2016). 3D printing gives your idea the speed to match its brilliance. When there are strengthens of something then there are weaknesses as well same goes for 3D printers, it seems quite easy. Likewise 3D printing turns into all the more standard. Most of designs can be stolen and they can be copied easily. By this act replicated items of the expensive designers can be made and sold by the stealers at a cheaper price.

Importance of R&D

Fiaz et al. (2017) suggests that manufacturing industry witnessed a paradigm shift as traditional manufacturing is gradually transforming to additive manufacturing. It is further observed that technology diffusion is a challenge for the industry because it often faces difficulties in enlightening potential customers regarding benefits of the new technology. Many international R&D projects do not get off the ground,

and it frequently happens that international units are shut down because organizations have difficulty reaping the benefits from their research satellites. R&D is found to be an essential tool for the policy planning for the developed countries. (Alhammadia et al., 2016).Companies are also gradually being dependent on external R&D organizations, such as universities, to upkeep innovation(Vandevelde, Ville, Conradie, & Saldien, 2016).The university, outside get ready people giving high education, grows basic research, science, working headed for the state of the art and the expansion of the boundaries of knowledge and the industry is accountable for taking many of the discoveries to market(Vedadi et al., 2013; Da Silva, et al., 2016). Analysts of academia have inclinations towards leakage of knowledge and their thoughts on stake with their partners as organizations to be sticky for their information to avoid any spillage keeping in consideration the competitive advantage (Fiaz & Naiding, 2012).

R&D Collaboration

Collaborative revolution is understood as a learning method directing at emerging a new invention, procedure or method between two firms. (Broek, Benneworth, & Rutten, 2016).Developed countries like USA has also a good faith in the university industry collaboration, according to them the industry demands has become the projects of the universities. In this regard both gain advantage from each other and succeed. According to academicians, worth of university and industry collaboration is greater than before and with this the issues related to this are also increasing day by day. As academicians believe that the collaboration between university and industry has two aspects one is that it is a source of income which comes on priority for them and secondly they access many beneficial things like technology transfer as an open access for public. As a result, the collaboration brings them new opportunities and as well as create issues for them but most importantly it develops the academia capital (Welsh, Glenna, Lacy, & Biscotti, 2008).

Pros and Cons of R&D Collaboration of Academia and Industry

Dasgupta and David (1994) stated in their research study that Universities would determine toward societies that draw attention to scientific performance without keeping market and profit. At the same time, a number organizations outlook universities' request for elite proprietorship for protected property rights Likewise an obstacle to attempting for universities(Hemmert, Bstieler, & Okamuro, 2014).3D

printing technology can be promoted among students with the help of tripartite nexus of university-industry-government (Fiaz et al., 2017). University–industry research collaborations (UICs) would progressively paramount advancement mode that permits organizations and the institutions to help each other by taping under integral abilities of one another which is used to save the cost and also used in upgrading research outcomes (Ikram et al., 2016; Ikram et al., 2018).

Research Methodology

Qualitative research methodology is used to explore the factors like cost saving and time saving which shows that how 3D printers strengthens R&D collaboration among academia and industry. For data collection,5 face-to-face recorded interviews have been conducted with structured and sometimes semi-structured questions with the help of interview protocol. Yin (2017) provided guidelines for enhancing the applicability of qualitative research and suggested that any number of respondents is fitting as long as the interview protocol is fully countered. These respondents were the permanent employees who were working in this domain for many years. Snowball sampling technique has been used because of the nature of study and reference-based sampling. NVivo 12 software has been used for the in-depth qualitative analysis. Many techniques have been used for the validation of different themes of the study such as coding nodes, group query analysis, word tag clouds and tree map.

Data Analysis

Interviews have been conducted by the companies of Pakistan who are already working in this domain. Five companies were selected for the research and their managers responded to the questions very well which showed that the 3D printing helps strengthen the collaboration of university and industry. The respondents were the permanent employees of the companies and have been working with the company since many years. After interviewing five managers the data is analyzed by NVivo 12 software. Data has been analyzed in different phases: first of all recorded data has been transcribed into textual form, then different themes have been identified from the textual data, after that all related textual data has been coded into different related themes. This study also used “word tree map” and “world tag clouds” for collecting more evidences for the strength and validity of different themes. After

applying all these techniques, the study also used "Tree Map" to check the significance of each critical success factors(Ijaz et al., 2014).

Tree Map For Critical Success Factors Analysis

Tree map shows the significance and the worth of each theme of the study.

Do you think if there are any factors which impact 3D printing industry with reference to the R&D collaboration of U-I?

Respondents were asked that they think is there are any factors which shows that 3D printers will help in strengthening R&D collaboration among academia and industry. As per Figure 1, all the 5 respondents said yes to the question the bar chart shows the respondents view that all respondents said yes to that answer.

Figure 1. Factors impacting 3D Printing Industry

As u said there are certain factors which impact 3D printers industry with reference to R&D collaboration of U-I. Please name the factors which in your opinion strengthen the R&D collaboration of U-I in 3D printers industry?

When all the five respondents agreed that there are some factors which strengthen the collaboration of academia and industry with the 3D printers then they were asked for the factors which they think are helping in their strengthening collaboration. The most important factor of it is that material costs are finite, and can be accurately budgeted before prototype design. Figure 2 shows that how many respondents responded for all the factors like for the cost saving factor 5 out of 5 respondents said that its save cost, then 5 out of 5 respondents said that it saves time, 2 out of 5 respondent said that it's a tool less machine, there is less wastage of material and it gives a better product design in few minutes.

How these factors of 3D printers industry will strengthen R&D collaboration of U-I? How 3D printers industry helps U-I collaboration in reducing cost?

Figure 2. Factors strengthening R&D Collaboration in 3D Printing Industry

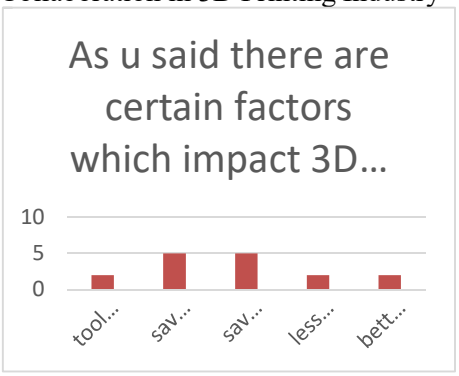
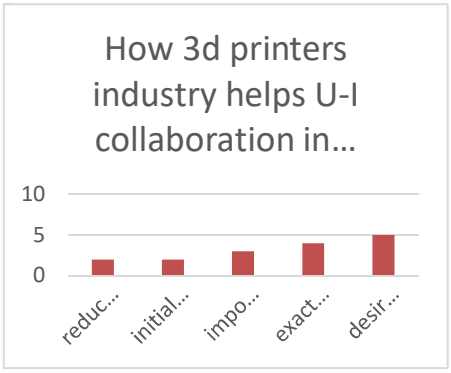


Figure 3. How 3D printers industry helps U-I collaboration?



The most important factor is reducing cost which helps 3D printers will strengthen R&D collaboration of U-I.Figure 3 shows that 2 out of 5 respondents said that it reduces the prototype cost, and the initial prototype can be tested for functioning which saves the cost. 3 out of 5 respondents said that it reduces the cost for the import of raw materials. Then 4 out of 5 said that exact cost can be determined for the prototype manufacturing. 5 out of 5 respondents said that only desired material is used to make prototype which saves cost.

How these factors of 3D printers industry will strengthen R&D collaboration of U-I? How 3D printers industry helps U-I collaboration in consuming lesser time?

Another most important factor is consuming less time which helps in strengthening R&D collaboration through 3d printers.It saves time to manufacture the prototype and that can be modified on spot as well it is considered as cheap manufacturing.

Do you think that government supports the working of 3D printers industry for R&D collaboration among academia and industry?

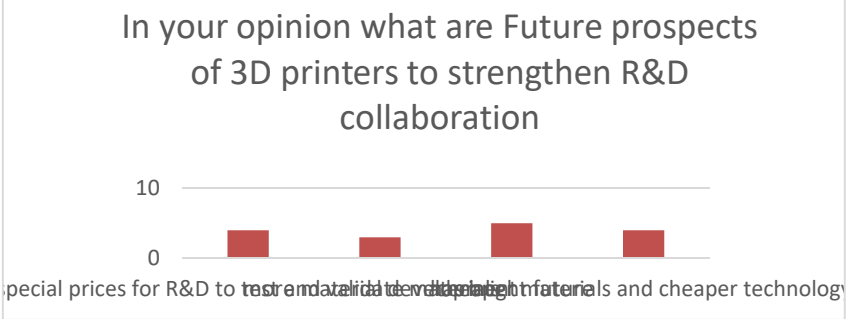
According to respondents up till now, no Government authority knows the importance of this technology. Thus there is an exigent need of awareness among technology leaders in Pakistan about this technology. When Government doesn't know the importance of this

technology how can they support this on the contrary they have imposed banned on the import of 3D printers by Ministry of Interior of Pakistan.

In your opinion what are Future prospects of 3D printers to strengthen R&D collaboration?

Figure 4 shows that 3 out of 5 respondents said that it is a technology that says it helps in more development by using different materials and 4 out of 5 said that it is a cheaper technology for both university and industry and are available in special prices for them through which they can test and validate the functioning of the prototype. And 5 out of 5 said that is as a most bright future for the welfare of the collaboration of university and industry.

Figure 4. What are the future prospect of 3D Printers?



Finding of the Study

Word tag clouds

Figure 5 shows "Word Tag Clouds" which shows the size of different words according to their frequencies of repetition in textual data. Words having more frequency show their big size. Using text search query a group query has been explored for the words: "3D printers and R&D collaboration".

Figure 5. Before Funneling Word Tag Clouds

By reading line by line data where the word "3D printers and R&D collaboration" has been used, the study observed that 3D printers strengthen the R&D collaboration among academia and industry.

Conclusion And Discussion

The aim of the study is to find out the factors which helped in the collaboration of academia and industry with the help of 3D printers, so the proper channel can be followed to know the factors that strengthen the collaboration. Those factors are discussed in detail like cost saving as it saves the cost because only desired material is used to make the prototype and that prototype can be modified on spot if required this all saves the cost, only desired raw material is imported which is also a point to save money and it saves time as well by giving the output in few minutes and it can be modified there and then if required very less or no material is wasted for the manufacturing of prototypes. Most research in innovation management builds on quantitative designs, which is unfortunate as qualitative studies provide a unique contribution to the domain of regional development. Our study contributes to the domain of qualitative research and offers a pragmatic perspective of the 3D printing industry of Pakistan.

The study further suggested that with respect to adoption of 3D printing technology, Pakistan is suffering from one major issue that is immaturity of technology and other related issues are lack of public awareness, difficulties in product promotion and problem in technology diffusion. Fiaz (2013) contends that U–I collaboration is established and exhilarated due to factors such as: R&D tendency, R&D risks, and R&D

promotional factors such as state incentives. While investigating industrial clusters of China, Ikram et al (2018) advocate that research institutions should develop feasible business models to transform the imitation-oriented cluster into an innovative cluster.3D printing technology can be promoted among students with the tripartite nexus of university-industry-government. Technology diffusion is a challenge for the industry because it often faces difficulties in enlightening potential customers regarding benefits of the disruptive technology (Fiaz et al., 2017). Pakistani government is not supportive of 3D printers as there is severe lack of awareness about the potential benefits of these printers. With respect to recommendations for future research, there is a need to quantify the proposed factors which will show that how 3D printing industry strengthened the R&D collaboration.

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References

Alhammadia, y., Algahtany, m., Kashiwagi, d., Sullivan, k., & Kashiwagi, j. (2016). The Current State of Research and Development Approach (R&D) in the Saudi Construction Industry. *International Conference on Sustainable Design, Engineering and Construction*, 1462 – 1469 .

Al-tabbah, o., & ankrah, s. (2016). social capital to facilitate the engineered university industry collaboration for technology transfer: a dynamic perspective. *technological forecasting and social change*, 1-15.

Automotive. (2015). Retrieved may 3, 2015, from stratasys: http://www.stratasys.com/industries/automotive

Broek, J. v., Benneworth, P., & Rutten, R. (2016). Exploring the factors related with scientists' willingness to incorporating external knowledge. *CHEPS WORKING PAPER*.

ÇEL, A. T. (2009). *Factors Affecting Research and Development (R&D) Collaboration of Multinational Enterprises (MNEs) and their Local Partner Firms: A Case Study of Turkish Automotive Industry.* Retrieved 4 20, 2015, from academia.edu

ÇEL, A. T. (2009). *Factors Affecting Research and Development (R&D) Collaboration of Multinational Enterprises (MNEs) and their Local Partner Firms: A Case Study of Turkish Automotive Industry.* Retrieved 4 20, 2015, from academia.edu

Chuck Hull. (2015, May 12). Retrieved may 12, 2015, from Wikipedia: http://en.wikipedia.org/wiki/Chuck_Hull

commercial-products. (2015). Retrieved may 3, 2015, from stratasys: http://www.stratasys.com/industries/commercial-products

CONSUMER GOODS. (1997 - 2015). Retrieved MAY 3, 2015, from javelin-tech: http://www.javelin-tech.com/3d-printer/industry/consumer-goods/

Da Silva, F. R., Simões, E. A., Azevedo, M. M., Galegale, N. V., Pinto, R. d., & Fabricio Junior, R. d. (2016). The maturity level of information technology management to support innovation within research and development (r&d) centers in brazil. *Independent journal of management & production (IJM&P)*.

Fiaz, M. (2013). An empirical study of university–industry R&D collaboration in China: Implications for technology in society. *Technology in Society*, 1-12.

Fiaz, M., & Naiding, P. Y. (2012). Exploring the Barriers to R&D Collaborations:A Challenge for Industry and Faculty for Sustainable U-I Collaboration Growth. *International Journal of u- and e- Service, Science and Technology, 5*.

Fiaz M., Ikram A, Qin S, & Farooqi, A. (2017). Development of 3D Printing Business Model in China. *Journal of Quality and Technology Management*. 14(2): 113-143.

Gajšek, B., & Kovač, J. (2016). Key Factors for the Successful Operation of Clusters: The Case for Slovenia. *Organizacija, Volume 49*.

Gilpin, L. (2014, February 12). *10 industries 3D printing will disrupt or decimate*. Retrieved may 2, 2015, from techrepublic: http://www.techrepublic.com/article/10-industries-3d-printing-will-disrupt-or-decimate/

Gross, B. C., Erkal, J. L., Lockwood, S. Y., Chen, C., & Spence, D. M. (2014). Evaluation of 3D Printing and Its Potential Impact on Biotechnology. *American Chemical Society publications*, 3240−3253.

Hemmert, M., Bstieler, L., & Okamuro, H. (2014). Bridging theculturaldivide:Trustformationinuniversity–industry researchcollaborationsintheUS,Japan,andSouthKorea. *Technovation*, 605–616.

Ijaz , A., malik, R., LODHI, R. N., HABIBA, U., & IRFAN, S. M. (2014). A Qualitative Study of the Critical Success Factors of ERP System-A Case Study Approach. *International Conference on Industrial Engineering and Operations Management Bali, Indonesia*, 7 – 9.

Ikram, Amir, Qin Su, and Muhammad Asif Sadiq. "Technical efficiency and its Determinants: an empirical study of surgical instruments cluster of Pakistan." Journal of Applied Business Research 32, no. 2 (2016): 647-658.

Ikram, Amir, Qin Su, Muhammad Fiaz, and Ramiz Ur Rehman. "Cluster strategy and supply chain management: The road to competitiveness for emerging economies." Benchmarking: An International Journal 25, no. 5 (2018): 1302-1318.

Industrial 3D Printers. (2015). Retrieved may 3, 2015, from 3d-printers.toptenreview: http://3d-printers.toptenreviews.com/industrial/

Iskanius , P., & Pohjola , I. (2016). Leveraging communities of practice in university-industry collaboration: a case study on Arctic research. *Int. J. Business Innovation and Research*.

Kaur, S. (2012). How is "Internet of the 3D Printed Products" Going to Affect Our Lives? *IETE TECHNICAL REVIEW, 29*(5).

Kim, H., Zhao, Y., & Zhao, L. (2016). Process-Level Modeling and Simulation for HP's Multi Jet Fusion 3D Printing Technology. *international workshop on cyber-physical production systems (CPPS), vienne, austria*.

Martn, R. L., Bowden, N. S., & Merrill, C. (2014). 3D printing in technology and engineering education. *technology and engineering teacher*.

Ramli, M. F., & Seninb, A. A. (2015). Success factors to reduce orientation and resources-related barriers in university-industry R&D Collaboration particularly during development research stages. *Social and Behavioral Sciences*, 1-8.

Schmidt, S., Balestrin , A., Machado, R. E., & Bohnenberger , M. C. (2016). Collaborative R&D and project results within Brazilian incubators and science parks. *Int. J. Entrepreneurship and Small Business*.

Sendogdu, a., & diken, a. (2013). A research on the problems encountered in the collaboration between university and industry. *Social and Behavioral Sciences*, 966 – 975.

Stark, D. P. (2010). Three Dimensional Printing: Modern Medical Applications. 1-43.

Tesařová, M., Zikmund, T., Kaucká, M., Adameyko, I., Jaroš, J., Paloušek, D., . . . Kaisera, J. (2016). Use of micro computed-tomography and 3D printing for reverse engineering of mouse embryo nasal capsule. *IOPscience*.

VANDEVELDE, C., VILLE, J. D., Conradie, p. D., & SALDIEN, J. (2016). Prototyping Tangible User Interfaces: Case Study of the Collaboration between Academia and Industry. *International Journal of Engineering Education*, 726-737.

Vedadi, S., Aris, B. B., Iqbal, S. M. J. & Muneer, S. (2013). Street Children and its Impact on Educational Attainment in North-Western State (Punjab) of Pakistan. Journal of Education and Vocational Research, 4(12), 366-372

Venkateswaran, P. S., Sharma, A., Dubey, S., Agarwal, A., IEEE, S., & Goel, S. (2016). Rapid and Automated Measurement of Milk Adulteration Using a 3D Printed Optofluidic Microviscometer (OMV). *IEEE SENSORS JOURNAL*.

Walsh, M. (2003). Teaching qualitative analysis using QSR nvivo. *TQR*.

Walters, P., & Davies, K. (2010). 3D Printing for Artists: Research and creative practice. *Norwegian Printmaking Council Publication.*

Yin, Robert K. Case study research and applications: Design and methods. Sage publications, 2017.