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Impact of Visualization on Engineers – A Survey

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by

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of the requirements for the degree of
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DEDICATION

To my parents, thank you for always believing and supporting me. I love you.

ACKNOWLEDGMENTS

I would love to use this opportunity, which is not enough to thank my Professor, Dr. Paul Rosen for giving me this opportunity and believing in me. I cannot express enough appreciation to Dr. Rosen for encouraging, supporting and giving me this learning opportunity. I would not have completed the project without Dr. Rosen

I would also like to thank all of my committee members, Dr. Yao Liu, Dr. Les Piegl, Dr. Swaroop Ghosh, and CSE Graduate Director Dr. Srinivas Katkoori for the support and encouragement. I would also thank to all my Professor from masters, bachelors, and diploma for making me capable enough to achieve my goals. Finally, to my caring and lovely family for being there always.

A special heartfelt thanks to Dr. Paul Rosen.

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ABSTRACT

In the recent years, there has been a tremendous growth in data. Numerous research and technologies have been proposed and developed in the field of Visualization to cope with the associated data analytics. Despite these new technologies, the pace of people's capacity to perform data analysis has not kept pace with the requirement. Past literature has hinted as to various reasons behind this disparity. The purpose of this research is to demonstrate specifically the usage of Visualization in the field of engineering. We conducted the research with the help of a survey identifying the places where Visualization educational shortcomings may exist. We conclude by asserting that there is a need for creating awareness and formal education about Visualization for Engineers.

CHAPTER 1: INTRODUCTION

Visualization has been portrayed as form of art, design, or as a scientific discipline [1, 12]. Visualization is the helping factor in depicting abstract, meaningful informative data in analytical way which helps in understanding the contents of the data through perception. Visualization aids individuals at their work place, in school course-work, and in critical decision making [2, 5].

The volume data that society produces has increased exponentially with new advancements in processing and storage, but the process of accessing and analyzing the data through Visualization has not progressed as quickly [3, 7, 11, 14]. Visualization tools have been built with more concentration on reducing the expense of analysis and increasing the efficiency of the output, regardless of an individual having any prior user knowledge of Visualization [12, 23, 10].

For an Engineer, as well as people with less a technical background, reading graphs of information may be overlooked for the level of importance it carries. For example, significant research has determined that Engineers tend to practice Visualization while working with data [12].

This research primarily focuses on *"how and why Engineers use Visualization".* The answer to this question will give an idea about how Engineers interact with data through Visualization. The research has been done through a survey of Engineers to analyze the "*Impact*

of Visualization on Engineers". The survey is conducted through two techniques, online survey and interview questions. Visualization plays an essential role in data analysis, as it helps in presenting precise amount of data for breaking down logical and relational patterns where raw data would be incomprehensible[3,4,16]. Thus, there is a need to educate or create awareness of Visualizations at early stages of education, which will result in more skilled users, better Visualization techniques, and help make better decisions when using Visualization.

This research hypotheses that Engineers have been utilizing Visualization without being properly educated in its usage. Additionally, the breadth of Visualization techniques they have been exposed to is quite limited. The ability to visualize has been assumed to be learned easily. Although this process of interpretation and projection appears intuitive, there is a vital need to improve education for utilizing these techniques to their fullest. This could be implemented by creating awareness of this important amongst the educational system and in daily work routine simultaneously.

CHAPTER 2: PRIOR WORK

Numerous research have tried to explain Visualization and its importance in day-to-day life. In previous research on impact of Visualization on computer science [35], it has shown that Visualization is losing its importance in education. Similar research on Visualization techniques, models, and challenges [1, 12, 5, 36] offers a descriptive amount of proof that Visualization, being a very important aspect in day-to-day life, is losing ground [30, 31, 32]. This research has shown the lack of acknowledgement of the value of Visualization in real life [10, 34].

The literature on Visualization challenges in human factors, human Visualization frameworks, and models of Visualizations [35, 37, 10] focus on displaying Visualization that have been matured enough to handle complex analysis, and its capabilities in accessing and analyzing data are at a pace enough to provide handy solutions for decision making[5,33,37,38]. Different models have been developed, keeping human analysis in mind, to help provide better Visualizations results [36, 37, 17, 25]. Various tools have been developed providing different analyzing and Visualizations capabilities, which can help in providing better and accurate graphs.

We see that research has made improvements to Visualization techniques, but the research has only loosely connected these issues. Drawing on that, we argue that, despite advancement and research, Visualization has not kept up to the pace of the requirements. Some researchers assert that it's because there are no tests to measure insight about Visualizations [27,28] while others researchers defend it by asserting that Visualization instructors do not provide a high quality Visualization education [29, 30, 18].

Numerous research have portrayed the adoption of Visualization in education [32]. Project Chem Viz, which is used at the National Center of Supercomputing Activities, and a project initiated for image processing titled, “Image Processing for Teaching,” are examples of adoption of the Visualization in education [32, 13, 12]. In bridging the literature gaps, we have developed research that gives a brief idea of how Visualization is impacting the education of Engineers. The most important contribution of the research is that it provides a systematic investigation into how Visualization could impact on Engineers, where education and awareness play an important role.

CHAPTER 3: TECHNICAL APPROACH

To pursue this research, we developed on online survey and interview questions that were given to Engineering students at the University of South Florida. The concept behind this methodology was to assess the importance of Visualization to Engineers and answer: “how is Visualization making a difference in the life of an Engineer?” and “what improvements are required to make them more proficient?”

Every Engineer who contributed in the interview and online survey depicted a different perspective to Visualization. The fluctuations of opinions and perception of Engineers with regard to Visualization resulted in a great amount of qualitative and quantitative data. The set of questions were made up of general questions, which conveyed the abilities of Engineers in analyzing data and Visualization.

3.1 Online Survey

The online survey is used to collect quantitative data. The survey contained polling questions about the tools used for Visualization and preferences towards analyzing data, which demonstrated the analysis skills of Engineers. The survey questions were formulated by making groups of questions focused on extracting useful information about Visualization.

3.1.1 Usage of Visualization

This section consists of questions focusing on identifying a pattern about how often an Engineer makes use of Visualization.

Question 1: How often do you analyze data?

A) Highly often (>80% of your work)

B) Very Often (50-79% of your work)

C) Less often (20-50% of your work)

D) Sometime (10-20 % of your work)

The above question is framed to get hold of an idea on how often Engineers need to analyze data. This in turn assists to understand the need of Visualization in analyzing the data.

Question 2: When analyzing data, do you use:

A) Statistics (tables, numbers, raw data, etc.)

B) Visualization (Graphs, charts, etc.)

The main purpose of the above question is to demonstrate whether an Engineer utilizes Visualization when analyzing data.

Question 3: What percentage of the time do you use Visualization?

A) Never

B) Rarely (0-25%

C) Sometime (25-50% of working with data)

D) Very often (50-75% of working with data)

E) Highly often (>75%of working with data)

The purpose of this question is to quantify the need of Visualization in an individual's daily life. The goal is to determine how they use the Visualization and how well it facilitates their work.

Question 4: Do you use Visualization in your work?

A) Personal life

B) School work

C) Job

D) Other

The motivation for this question is to see where Engineers utilize their knowledge of Visualization, reflecting on how it contributes in their daily lives.

3.1.2 Uncovering Thinking

This section tries to uncover the mystery behind how Engineers think about Visualization and uncover how Engineers select the Visualization approach for the data.

Question 5: While working on Visualization, what data types do you feel you are comfortable with?

A) Numerical data (statistical data, raw data)

B) Geographical data (location, latitude, spatial)

C) Your Answer

The thought behind this question is to extract the purpose of Visualization, while working on the data type that is best for an individual's interest.

Question 6: How do you select your data?

A) Based on some past references

B) Based on Visualizations

C) Based on need

D) No particular preferences

The above question is intended to grasp how and why a certain data is selected by the Engineers to facilitate Visualization.

Question 7: What do you select first while working on Visualization?

A) Dataset

B) Software

C) Visualization

D) Random

The above question tries to identify the significance behind the preference given by the Engineers on whether they choose the data or software prior to visualizing the data itself. This reveals the impact of Visualization in decision making and analysis in a sequence.

Question 8: Do you choose Visualizations prior analyzing your data?

A) Yes

B) No

This is one of the most important questions which helps to reveal if Engineers choose Visualization tool prior to the need or after the need arises.

3.1.3 Tools Used

This set of questions had tried to understand the tools used by Engineers, and the source of their knowledge about Visualization and its tools.

Question 9: Which of the tools have you used before?

A) Tableau

B) Excel

C) D3

D) Processing

E) Informatica

F) Chart sheet

G) Google Charts

H) Other

The above question attempts to identify to what extent Engineers been exposed to tools.

Question 10: How did you find out about these tools?

A) Self-explorer

B) Friends

C) Course work

D) Work

E) Other

The above question was posed to gain an understanding on where and how Engineers were exposed to these tools, intending to examine that if Engineers are self-explorer or limit themselves to tools introduced during their coursework or job.

Question 11: How did you learn to use these tools?

A) Self-explorer

B) Friends

C) Course work

D) Work

E) Other

This question was posed to comprehend how these Engineers acquired knowledge about the tools they use. This information discloses the ambiguity between Engineers and Visualization, and how they limit themselves on learning.

Question 12: Select which the following software you most prefer to use

A) Tableau

B) Excel

C) D3

D) Processing

E) Charts

F) Graphs (Google, Data etc.)

G) Informatica

This question enhances the purpose of the previous question by digging specifically into the most preferable tool used by an Engineer. This question generates a hypothesis about how Engineers tend to favor the tools that they are more familiar with, regardless of how well it aids in their data analysis.

Question 13: Referring to the previous question, select all the other tools you use often for Visualization?

A) Tableau

B) Excel

C) D3

D) Processing

E) Charts

F) Graphs (Google, Data etc.)

G) Informatica

These question further aids in clarifying how specific and exploratory are Engineers with the mentioned tools.

3.1.4 Perception of Visualization

This set of questions tries to uncover the details about how the Engineer thinks about using Visualization. We also try to extract if the process of Visualization is fun to Engineers, and they find it useful in communicating their ideas to people with the help of Visualization.

Question 14: What helps guide your selection of Visualization software?

A) Familiarity with software

B) Available set of Visualizations

C) Ease of use

D) Ability to share Visualizations with others

E) Other

This question assists understanding what guides their path to select a particular tool and work with it. It adds a general perception on how Engineers might have restricted themselves on a particular feature that plays a role in selecting a tool of their interest that helps in Visualization.

Question 15: What kind of Visualizations are you familiar with?

A) Bar Graph

B) Line Graph

C) Histogram

D) Pie Charts

E) Your Answer

F) Bubble, Radar charts

This question identifies specific Visualization Engineers are familiar with.

Question 16: How did you know about these Visualizations?

A) Self explorer

B) Friends

C) School/College

D) Work

E) Other

The above research question has been asked to find the source of knowledge that exposes Engineers to Visualization and discover if the learned about the tools by their own exploration or an external guidance.

Question 17: How did you learn to use Visualizations?

A) Self explorer

B) Friends

C) School/College

D) Work

E) Other

This question aids in research by adding a component that explores the process of learning that Engineers might have chosen used.

Question 18: Does Visualizations help in communicating your ideas to other people?

A) Yes

B) No

C) Sometimes

The above question extracts whether Engineers value the use of Visualization in showcasing and transform their data to forms that enhance the communication of their ideas.

Question 19: Have you taken a course in…?

A) Graphics for Engineers

B) Visualization

C) Something similar to Visualization

The question intends to get information on how many Engineers have deliberately gained knowledge on Visualization. Some Engineers may also not utilize Visualization claiming a lack of clarity for their usage. Collecting information about how many Engineers have studied Visualization showed it was helpful for the majority of them.

Question 20: Is the journey from data to graph fun?

A) Yes

B) No

C) Sometimes

This question assists in understanding the mindset of an Engineer on the path established to convert the dataset into a Visualization. Enjoyment is often a critical part of continued usage of a technique.

Question 21: Do you consider human perception when selecting Visualizations?

A) Yes

B) No

C) Sometime

Human perception plays an important role in creating and developing ones Visualization. This question eases the process to confirm whether Visualization is based on perception or merely past or habit.

Question 22: How long have you been working with Visualization?

A) 1-2 years

B) 3-4 years

C) 5-8 years

D) Greater than 8

This question intends to acquire information about how long the Engineers have been using Visualization as part of their skillset in analyzing data and how it has impacted in their work throughout.

3.1.5 Demographic Information

Question 23: What is your background?

Question 24: Where did you complete your primary and secondary education?

Question 25: What degree are you seeking currently?

Question 26: Your Gender

Question 27: Your Age

The demographic questions intended to get general information on the background of the Engineers, their age, level of education and their field of interest in Engineering, which helps to get a better idea on how Visualization impacts an Engineer of a particular group.

3.2 Interview Questions

The motivation of the interview questions is to support the online survey. The interview questions were the same as those asked in the online survey. However, the interview question had an in-depth component, which could help understand in detail about the answer provided by the Engineers. The quantitative analysis is supported by qualitative data extracted from the interview questions.

CHAPTER 4: RESULTS

These results have been generated after collecting the data from the online survey that had been taken by Engineers from various fields and many of them were interviewed individually. The online survey was published online, open from dates January 15, 2016 to March 30, 2016. 395 Engineers participated mostly from the University of South Florida. The interviews of Engineers took place between the same dates, 46 Engineers participated in the interviews.

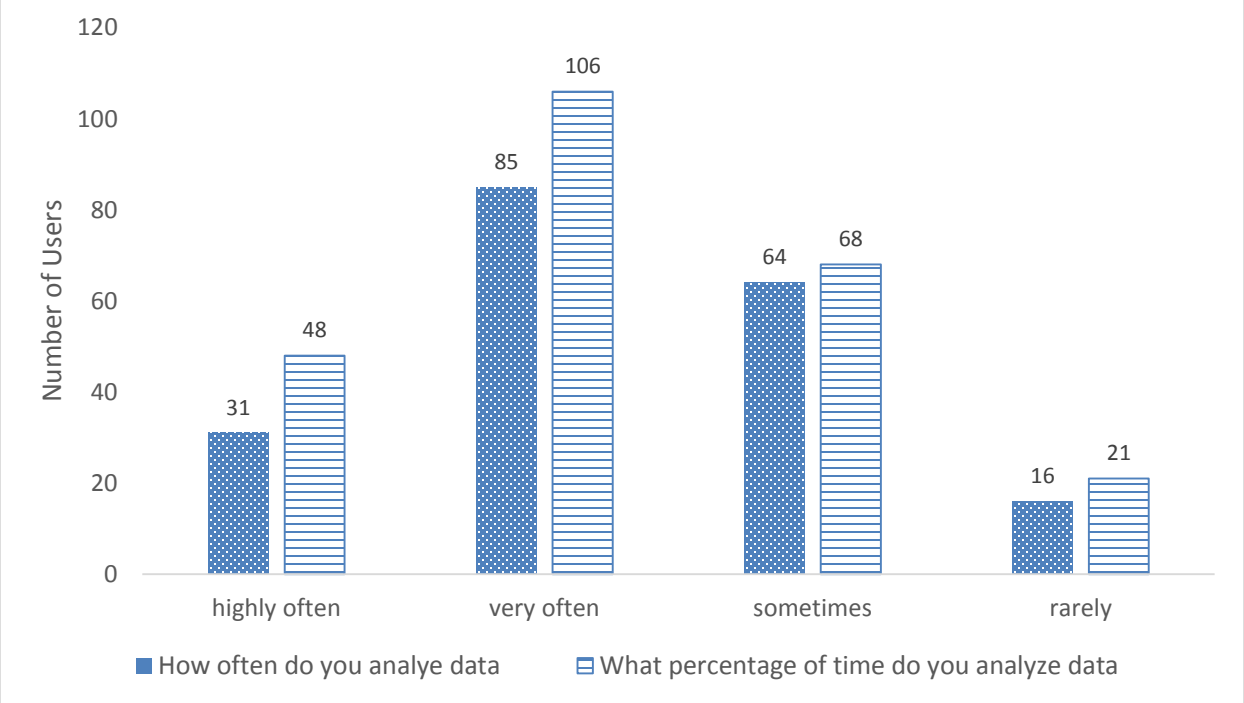

Figure 1 Visualization usage and frequency. The bar graph shows the number of users analyzing data and those using Visualization to analyze data.

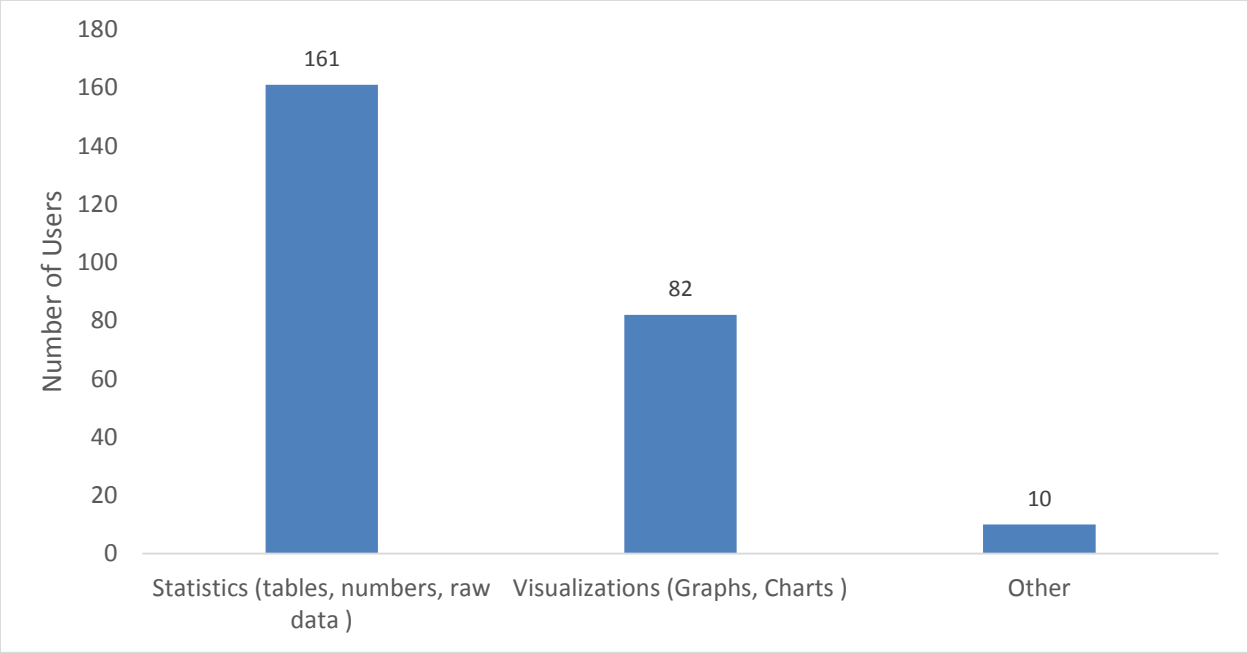

Figure 2 Types of data used by Engineers. Bar graph plots of the number of users against different types of data.

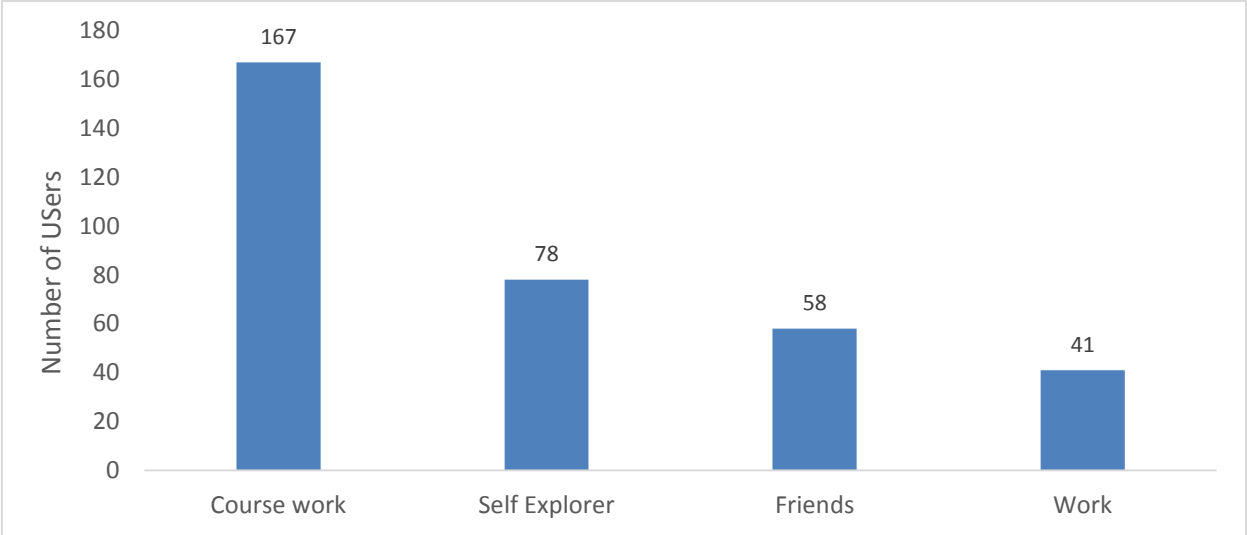

Figure 3 Source of Visualization knowledge. Bar graphs repressing number of respondents against the source of their knowledge of Visualization.

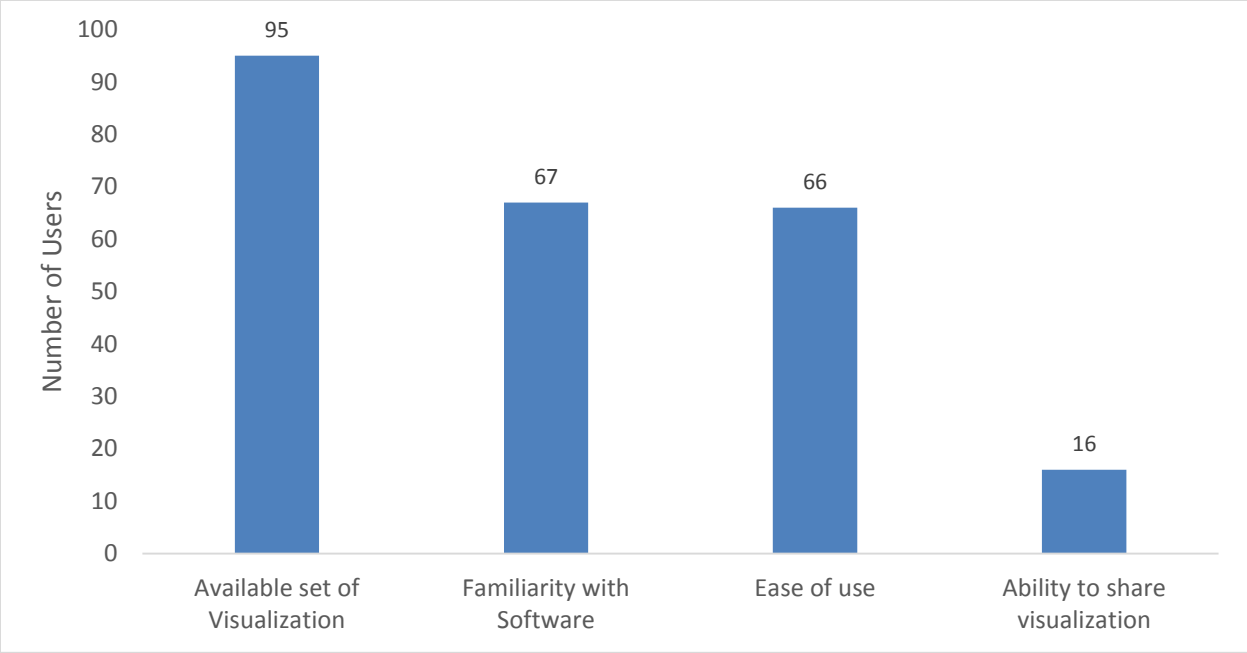

Figure 4 Reason of selecting a Visualization tool. Bar graph representing the number of users against their logic for selecting a Visualization tool.

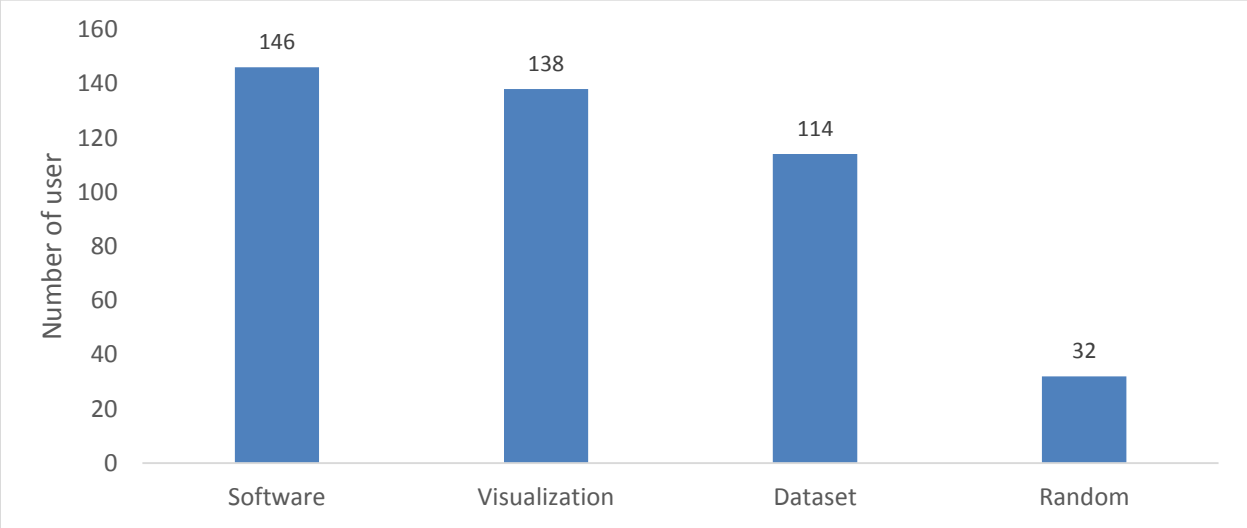

Figure 5 Preferences for selecting Visualization tools. Bar graph represents the number of respondents against how they select their Visualization tool.

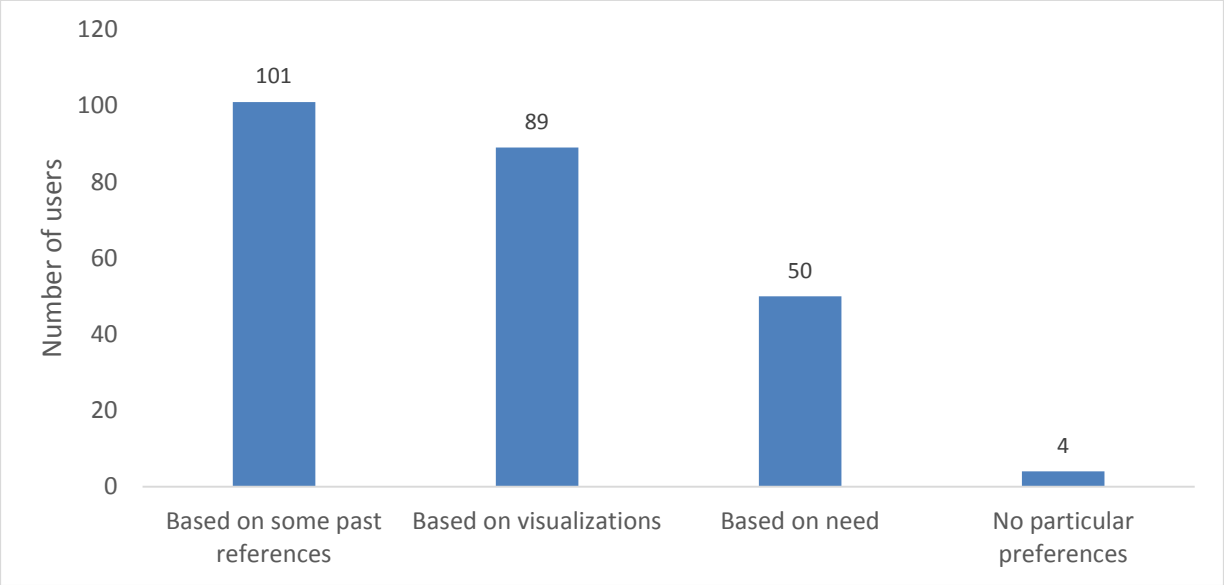

Figure 6 Data set selection methods. Bar graph represents how user selects data sets for Visualization

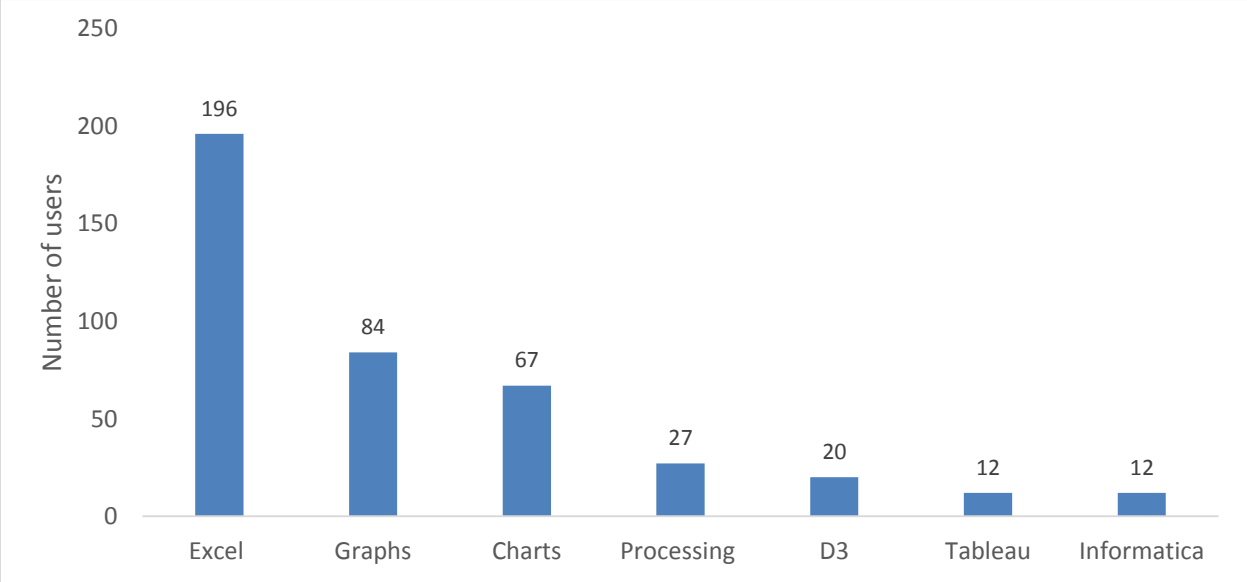

Figure 7 Visualization software tools. Bar graph represents the preference of Visualization tools selected by a respondent.

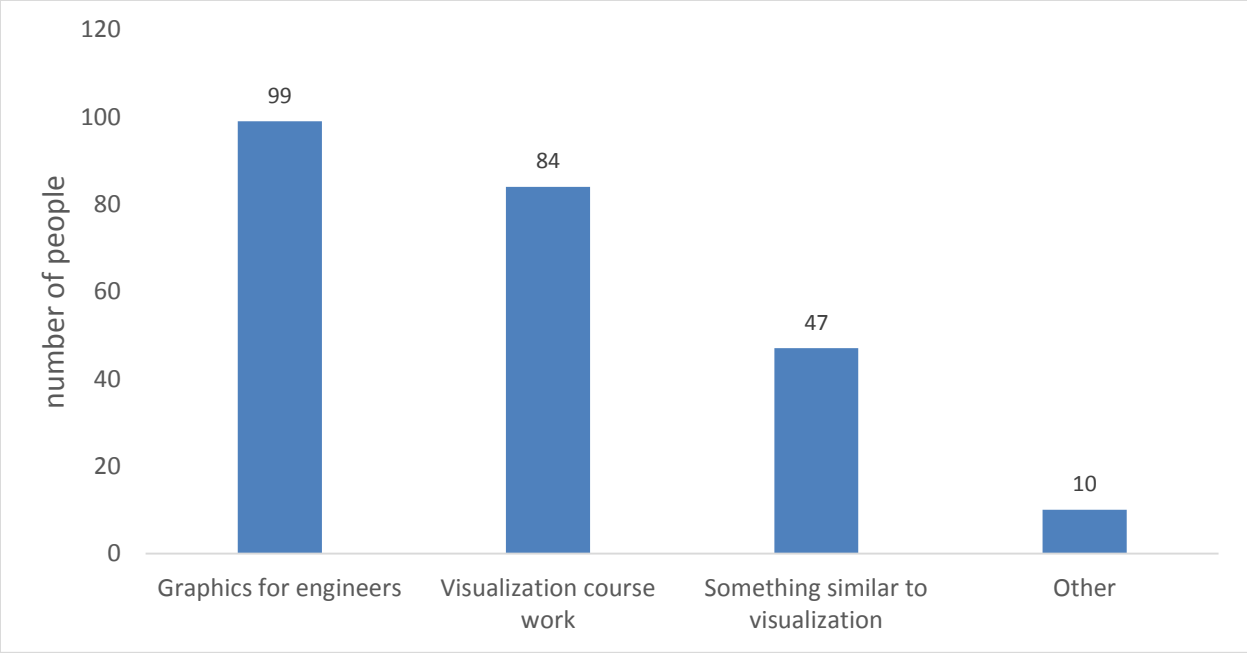

Figure 8 Visualization courses. Bar graph represents the courses taken by respondent in school/college relating to Visualization.

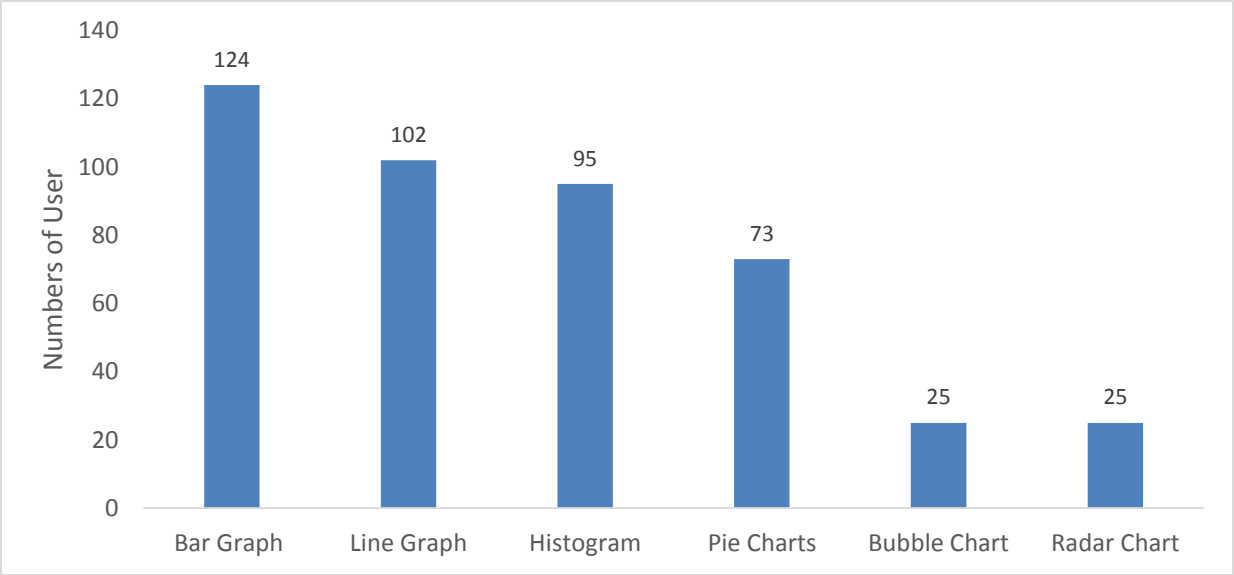

Figure 9 Preference in types of Visualization. Bar graph represents the most preference Visualizations used by Engineers.

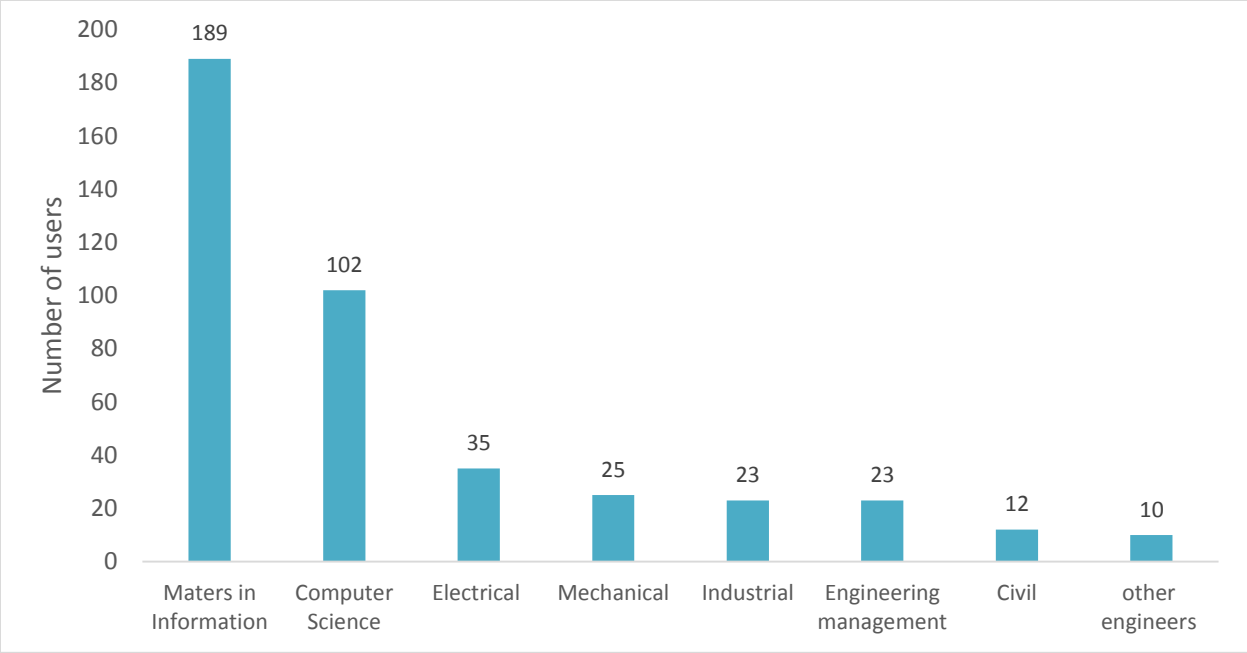

Figure 10 Engineering backgrounds. Bar graph shows the number of Engineers from each field who prefer Visualization.

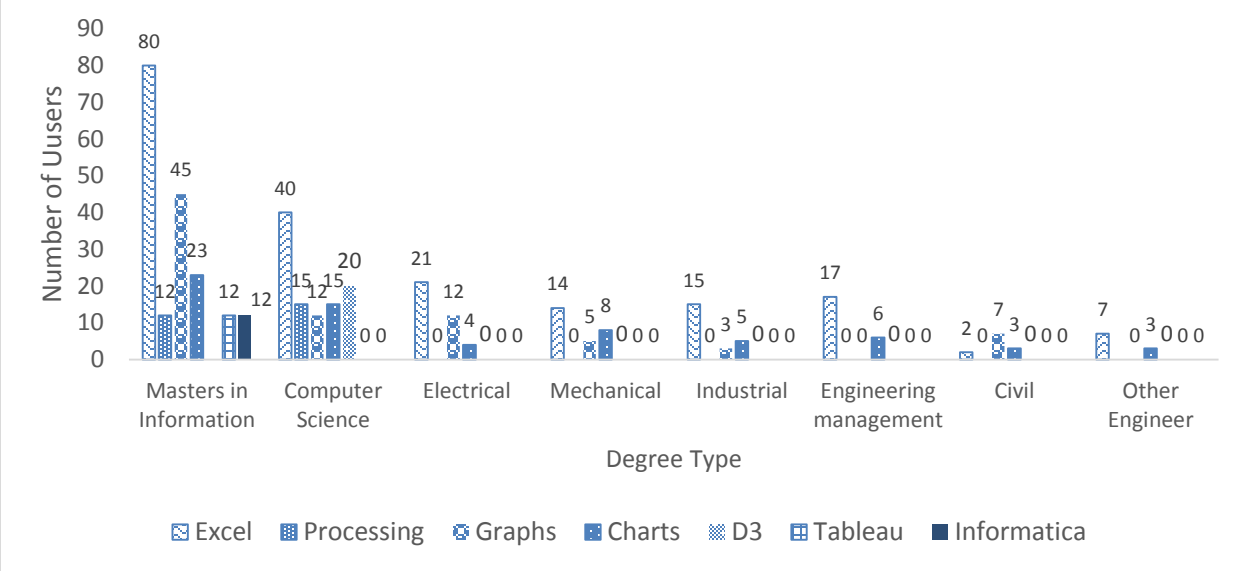

Figure 11 Tools vs Degree. Bar graph represents the different tools used by Engineers from different background.

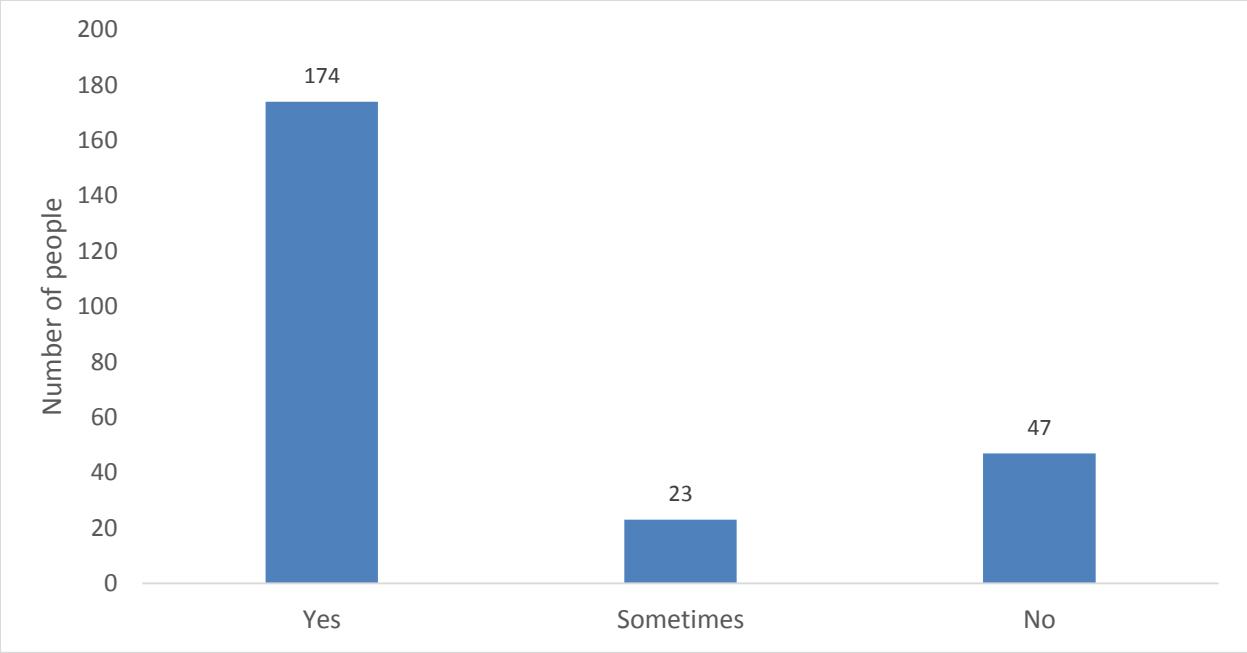

Figure 12 Is Visualization helpful? Bar graph represents the number of respondents that find Visualization helpful.

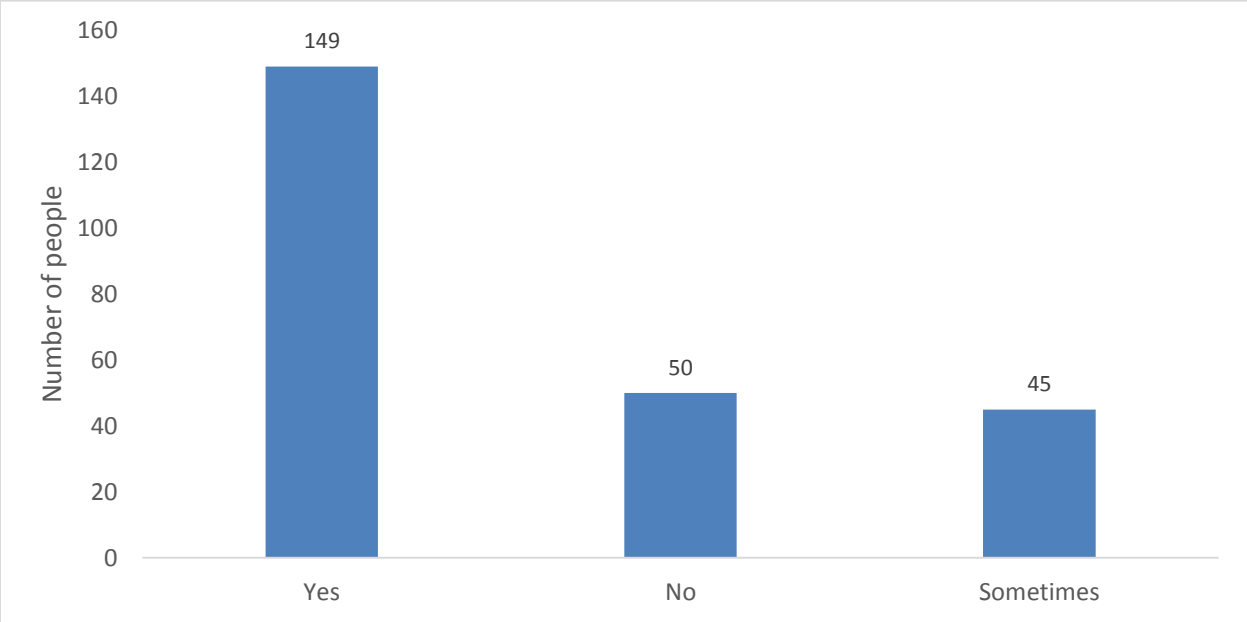

Figure 13 Visualization fun. Bar graph represent – if visualization is fun or not?

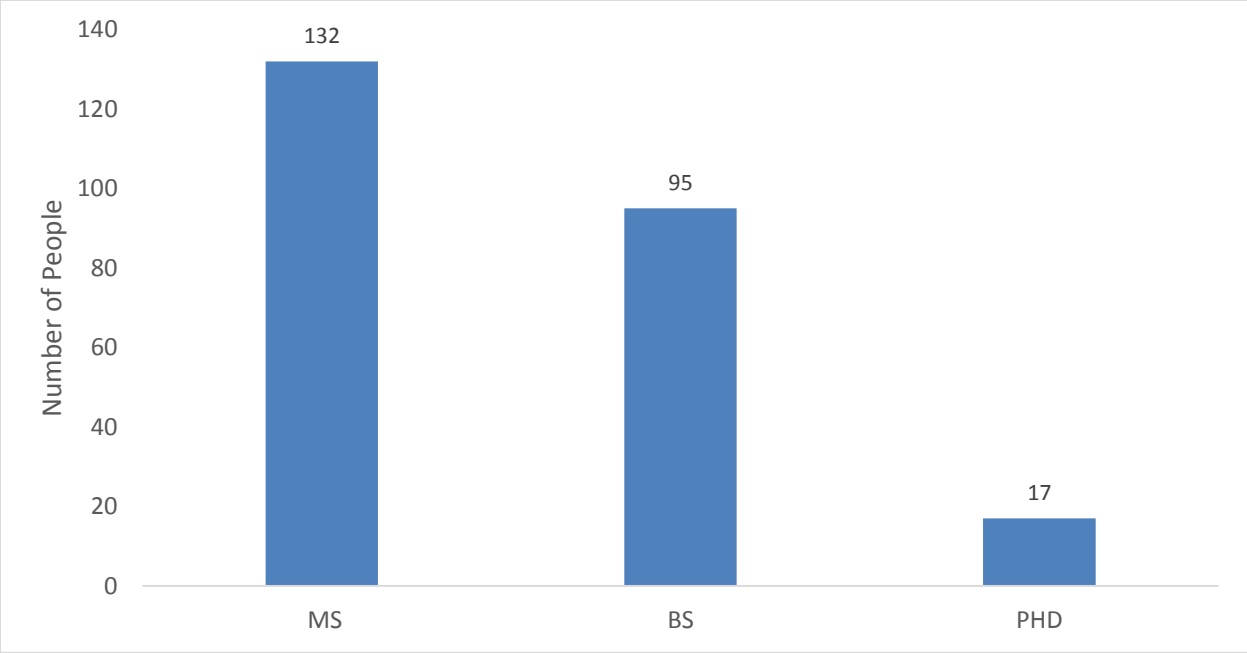

Figure 14 Engineering Degree. Bar graph represents degree respondents are currently pursuing.

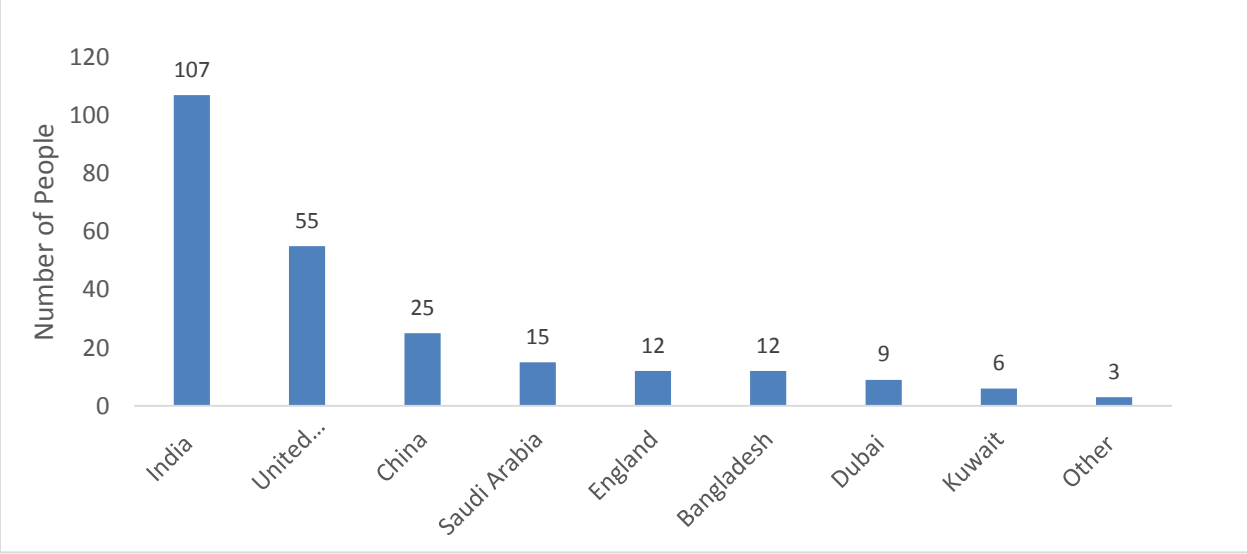

Figure 15 Engineers from different countries. Bar graph represents the country of origin of those who participated in the research.

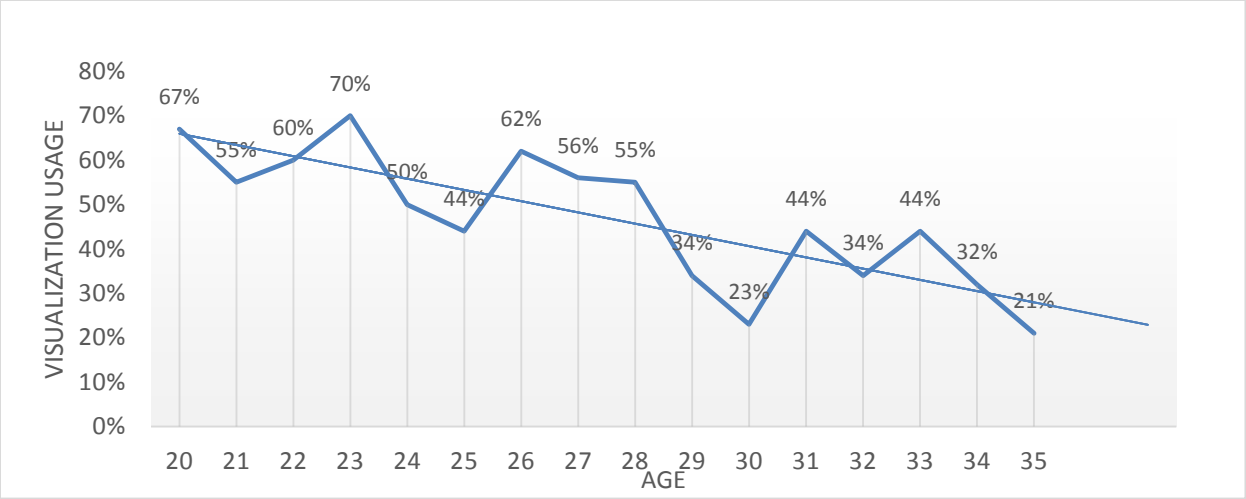

Figure 16 Age distribution of Engineers. Line graph represents the age distribution of Engineers participated in the research.

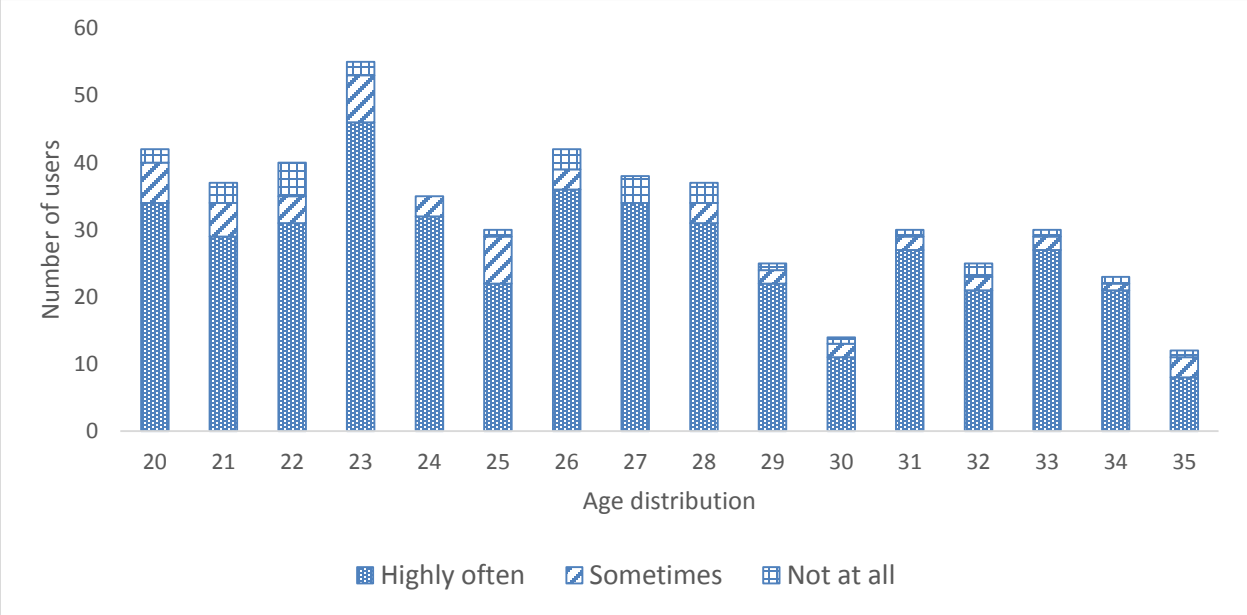

Figure 17 Number of Engineer using Visualization sorted by age. Bar graph represents age distribution of Engineers with usage frequency of Visualization.

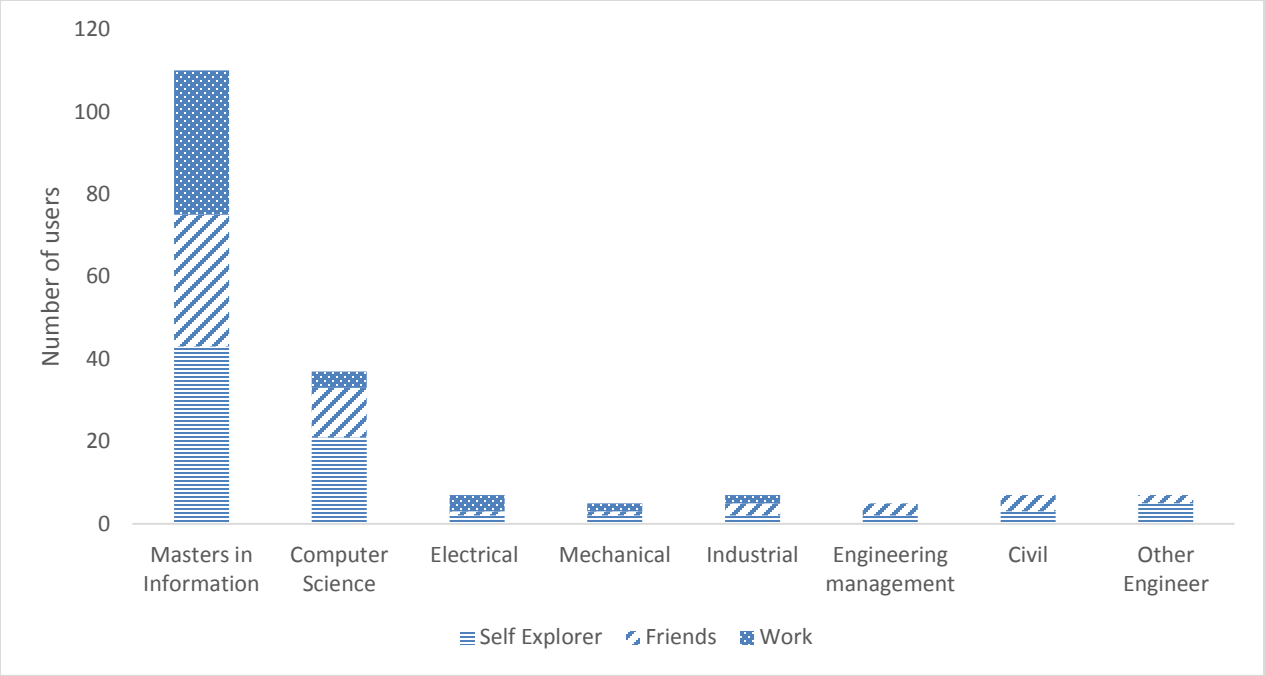

Figure 18 Source of Visualization knowledge among different Engineers. Bar graph represents the source of Visualization of Engineers from different background.

4.1 Description of Result

4.1.1 Usage and Frequency of Visualization

Looking at the data, Visualization is considered as the most important aspect while considering working with data. We had hypothesized that Engineers spent most of the time on Visualization, particularly while working on large data sets. The analysis of the result demonstrate that the Engineers have spent a significant amount of time with Visualization. This signifies that Visualizations plays a vital role in an Engineer's work.

Figure 1 explains, with the help of histograms, the relation between time and percentage of respondents using Visualization. Figures 11, 14 and 15 show Engineers from different background and countries all using different Visualization tools.

4.1.2 Data Type

Critical analysis being an essential part of an Engineer's coursework, data types plays an important role on Engineers. The results of our analysis showed that numeric data is most often used data type by the Engineers. This concludes that Visualization is a very important aspect in Engineers work, as most of engineering data contains significant amount of this data (see Figure 2). The interviews also showed that Engineers have difficulty when visualizing large data.

4.2 Source of Knowledge of Visualization

It had been concluded after analyzing the results that, most of the engineers who participated in the research have some minimal amount of information and skills about Visualization, gained and developed by the coursework. Based on our results and analysis, we can see that Engineers rarely explore more about Visualization and limit themselves to the skills that have been received during the coursework itself (see Figure 3).

We further study what courses help Engineers to understand and learn Visualization. This information is vital to identifying the courses that facilitates the learning process. The courses that serve the most in developing the base and understand the core of Visualizations are tabulated in Figure 8. Most of the courses have seemed to be offered in the field of Computer Science and related field of Engineering. These courses are highly recommended for Engineers to improve the quality of their data presentation skills.

This also showed that Engineers who have not taken courses in Visualization are much more likely to have gained Visualization knowledge through course work (see Figure 6). Digging further in detail resulted that most Engineers did not appreciate the value of Visualization during their course work either because it was not presented with more importance or teaching was restricted only to course work (see Figure 4 and 7).

4.3 Preferences

Although Visualization plays an important role in an Engineer's coursework, they tend to limit themselves to the perceived skills or past knowledge through their school or work. So, these Engineers limit their preference of visual schemes and tools to the software they are familiar with, and the data tool that is unambiguous to their theoretical or practical needs. The preferences are tabulated below that have been generated after analyzing the statistics and surveys referred from Figure 3.

The results of the analysis are categorized based on how Engineers prefer using Visualization tool. The interesting fact of the result depicted that most of the Engineers follow the pattern on familiarity. They prefer knowledge of graphs and software as their primary medium while working on Visualization. Digging further, we can also conclude that, Engineers have predilections to working with limited set of graphs and Visualizations tools (see Figure 5).

4.3.1 Data Set Selection Method

There are many data types known to Engineers that they can work with, but not everyone prefers to use the same or the similar ones. The most common data type, which Engineers have their hands worked on are geographical data and statistical data (see Figure 2).

According to the analysis, Engineers first preference of data type is statistical data, which had been shown earlier. To get deeper insight of this preference, we divided our results in four categories. These categories helped to understand how Engineers chose their data. The results of the analysis portrayed that most of the Engineers chose their data either based upon some past reference or some Visualizations done before, either at work or school (see Figure 6).

4.3.2 Software

Most of the Engineers lack knowledge of Visualization due to no proper exposure in their school curriculum or coursework. At most, they might have explored tools like Excel, Tableau, or Google Charts on their own. This shows that they have confined themselves to limited knowledge of Visualization. Based on our analysis, we can tell that most Engineers are prone to use Excel—one of the most basic Visualization tools used in school and business. Since the coursework does not insist or enforce the use of different tools, Engineers often lack the information regarding other tools that may better serve their needs in critical analysis and decision making (see Figure 9).

We looked further to gain better understanding of the tool preferences of Engineers. The analysis explains the preferences of tools used by Engineers from different background. The results depict that Excel is the most preferred tool by Engineers from all the disciplines. Further insights from the data depicted that Excel is the most common tool taught to Engineers (see Figure 7).

4.3.3 Visualization Method

According to the research, the most common Visualizations used by Engineers are forms of graphs. Bar graphs, line chart, histograms, and pie charts are the most common ones that Engineers have used at least once in their coursework. They lean most on generating a bar graph, since it could be graphed effortlessly and effectively used to convey the data (see Figure 9).

4.4 Demographics

The research had been conducted and targeted Engineers from the age group of 18 to 40 years to gain an insight of who are the most familiar with the tool of Visualization. The research implied that Engineers who belong to the age group of 20 to 28 years seemed to have more knowledge and information regarding Visualization. This age group seemed to be keener on making efficient use of Visualization in their coursework (see Figure 17).

The research indicates that the trend of being familiar with the tool of Visualization has been seen more in the young age group that gradually declines with growing age group. Further research depicts that young Engineers showed familiarity with the tools of Visualization due to exposure to new visual schemes and related skills at the start of their careers. The importance of Visualization declines eventually with growing age due to very little guidance and undermined effort of creating awareness amongst Engineers (see Figure 18).

Majority of the Engineers that belong to the age group of 20-30 years affirm that Visualization is very convenient in reflecting their thoughts and ideas in nonverbal communication, and they find the process quite enjoyable (see Figure 13).

CHAPTER 5: CONCLUSIONS

Engineers have considered Visualization as a form of art or a scientific discipline. Being a discipline strongly grounded in data, they have been among the highest utilizers of Visualization tools. The main problem of the paper have been bifurcated to two different categories: one that shows Visualization playing a vital role in an Engineer's daily coursework, and the other depicting Engineers having limited knowledge about Visualization data types, tools, and techniques.

It can be seen from the results that Engineers belonging to the younger age group tend to explore more themselves when it comes to Visualization. They find it fascinating and an intellectual process to communicate their thoughts using visual schemes to reflect their ideas. However, this excitement is not universal.

The only feasible solution to the address problem is to create awareness of the importance of Visualization and its tools in the fields of Engineering and increase the availability of courses available to all the Engineers. This would initiate, and eventually enhance the development of Engineers. Engineers rely greatly on the wisdom of Visualization. So much so, they seem to take it for granted.

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