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Research Article

The effect of digital technology on graphic design ideation output

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Abstract
Digital technology has changed the face of design creativity. The traditional dependence on paper and pencil is gradually replaced with the digital approach, which uses digital technologies during the ideation stage. This study explores how digital technology influences the graphic design ideation process and outcomes. This study adopts qualitative methodology as it ontologically assumes a subjective stance and is epistemologically constructive in nature. The methods of data collection adopted are interviews and observation. The twenty-eight (28) participants of the study were made of twenty-four graphic design students and four lecturers from two universities in Ghana. It was discovered that participants used digital devices, design software, and the internet during design ideation. The study also revealed that digital technology aids designers in generating a variety of quality ideas which helps in achieving novelty in design. Vector software is crucial for digital concept illustration, but less than half of the participants use it. It was recommended that students should be exposed to vector software for design ideation as constant use of this software will help them develop the fluency required to create digital design ideation with ease.

Keywords: Design ideation, Digital technology, Design inspiration, Design software and ideation outcomes, Graphic design training

Extended Abstract

Introduction: Design idea development, also referred to as design ideation, started several decades ago. The concept of ideation is essentially the exploration and transformation of conceptual spaces to generate ideas. It is the most creative and essential aspect of the design process because the quality of the final design solution is greatly dependent on the quality of the initial idea generated. Digital technology has also affected current design approaches among students in institutions of higher learning (Sreekanth & Viswanathan, 2019: 39). As stated by Barnes (2017), the use of computer software for creative design is gradually replacing the traditional way of hand drawing, which has become an inevitable trend. Easy access, use and continuous improvement of these technologies have completely transformed how things are done in today's world and this has resulted in a considerable change in the expectations of consumers over time. The use of traditional approaches to problem-solving does not attract recommendations anymore as these approaches fail to meet the expected standards of today's clientele. They expect to interact with digital images from the beginning to the end of the design process. It has become necessary to adopt digital technologies in the design ideation stage to meet today's clients' expectations. It is, therefore, important for students to know the various technologies being adopted and master the use of the digital technologies employed in the current design ideation process for effective ideation and customer satisfaction.

Purpose and scope: This study seeks to identify the various digital technologies used among graphic design students, how they are used and their impact on design ideation outcomes. The study is backed by the following research questions: 1. Which digital tools do designers use in today's graphic design ideation process? 2. How do these technologies impact on ideation outcomes regarding the quantity, variety, and novelty of design ideas? These questions were answered by first exploring the various digital devices and software that are generally used at each stage of the design ideation process. Ideation effectiveness can be measured in terms of quantity, quality, variety and novelty (Shah et al., 2003: 113). The study, therefore, explores the impact of digital technology on the quantity, variety and, novelty of ideas developed. Data collected from the participants were presented, analyzed and recommendations were given to improve design ideation practice.

Method: This study assumes the constructivist and interpretivist paradigm because individual students have different digital exposures, design approaches, design experiences, varied studio environments (setups) and technology fluency. This can only be understood and appreciated when hidden facts are communicated and interpreted. By this, the subjective interpretations of the various participants can be reconciled and the differences that make the phenomena complex will be exposed. Constructivism allows a flexible process of interactions between the researcher and research participants (Bhatta, 2018: 73), which leads to openness and richness of data. As a result of this epistemological stance, the research methodology adopted is qualitative in nature, and the methods of data collection adopted are interviews and observation. Purposive sampling was conducted to select only lecturers who taught ideation-related courses like Graphic Application, Advertising Design and Computer Graphics because they had the needed information and formed the most appropriate participants. Student participants were purposively grouped into three categories: first-class, second-class upper, and second-class lower students.

Findings and conclusion: This section presents the findings on how digital technologies affect design output. It examined the various technologies used by the designers in the design ideation process in two selected Ghanaian universities. The essence of this chapter was to identify the various digital devices and applications software used by the designers and how they affect design ideation outcomes. It was generally observed that the devices used by students include laptops, smartphones, tablets and digital cameras. Students predominantly use their personal laptops and smartphones for their design tasks. While the laptop is seen as the main digital device necessary for design in general, the smartphone is considered to be one of the most important device that supports the laptop for effective design ideation output. It is almost impossible for a graphic designer to work without a smartphone. Participants considered this device to be so important that they wondered what the design work will be like without the use of it. While students widely use the phone for quick access to information, gathering images for inspiration, and for research purposes, it is also used as a source of internet for browsing on their laptops. Most participants admitted using the data on their phones to access the internet connection on their laptops because the Wi-Fi on campus is not reliable. The smartphone is highly indispensable in the design ideation process. It was evident that students used smartphones as a substitute for the computer. They reported during an interview session that they sometimes use Adobe applications and some other software to do their design works on the phone. According to them, they use the phone when the laptop is not readily available. This is helpful as it saves time and the work output is as good as that of the laptop in terms of quality. The impact of digital technology in ideation includes gathering inspirational materials in great quantities for ideation using the internet, manipulation of vector types of images to obtain varying ideas and testing color variations. By these inspirational materials, designers were able to generate more ideas from which creative ones were selected. Lack of personal access to laptops among some of the students was a significant concern, and the institutions needed to intervene to help students in such a situation.

Keywords: Design ideation, Digital technology, Design inspiration, Design software and Ideation outcomes, Graphic design training

INTRODUCTION

Technology is always connected with obtaining certain results, resolving certain problems or completing certain tasks using particular skills, employing knowledge and exploiting assets (Lan & Young, 1996). The concept of technology does not only relate to the technology that is embodied in a product, but it is also associated with the knowledge or information of its use, application and the process of developing the product (Bozeman, 2000: 629). Mishra and Koehler (2008) make a distinction between advanced and standard technologies in education, referring to *standard* technologies as books, chalkboards, and blackboards and *advanced* technologies as the Internet, digital video, operating systems, application software, web browsers, email programs, and word processing application. Bates (2015) considers technology to include all tools used to support teaching and learning, whether or not they are in the form of computers, software applications, or

printed books. Bates gives two definitions of technology, stating that the definitions range from the basic notion of tools to systems that employ technologies and these are:

i. Technology refers to tools and machines that may be used to solve real-world problems
ii. Technology is the current state of humanity's knowledge of how to combine resources to produce desired products, solve problems, fulfil needs, or satisfy wants.

A careful look at these two definitions of technology indicates they are divergent because while the first definition focuses on tools and machines as technology, the second one focuses on knowledge, skills (how to combine), tools (resources) and the desired solution as technology. This is to say the clause, "humanity's knowledge of how to combine resources" in Bates second definition can be replaced with "human skills".

According to Jon (2020), technology is a means to an end. Short though this definition is, it is embedded with a lot of details. It suggests that technology is a means to solve a problem. In other words, technology has to be a contrivance. For technology to be a contrivance, skill is required because there cannot be creativity without skills application. This is why the statement made by Levin (1996) that technology is not a "thing" but *it is better characterized as an approach* makes a lot of sense. It is the application of scientific principles to solve practical problems. Levin's view about technology is closely linked to the assertion of Burgelman et al. (1996) as they posit that technology is theoretical and practical knowledge, skills and artefacts that can be used to develop products and services. In this definition products and services are considered as solutions to problems. It can be deduced from Burgelman et al.'s statement that theoretical and practical knowledge itself is not the technology but the use (in other words, the application) of it to solve a problem (develop products and services) that makes it a technology. Again, the "skills" or the "artefact" is not a technology but the use of it to solve a problem makes it a technology. With this, it can be said that technology has three components; 1. a thing (it may be theoretical and practical knowledge, or artefacts), 2. Process (skills or the demonstration/ application of practical knowledge) and 3. Solution or Result (products and services).

It is the search for solutions or the existence of problems that necessitate the generation of technology. In other words, where there is no problem, technology is of no use because technology is invented principally to solve a problem. The use of the tool (artefact or device) to solve a problem is what makes it a technology. The word "use" in "The use of tool" embodies the application of technique, know-how or skills. It suggests that without the "use" (application of technique, knowhow or skills) the tool cannot accomplish a task or achieve a goal. The principal idea here is that technology is a problem-solving mechanism. Until the device is used to solve a problem, technology is not achieved. It is understood therefore that technology is not a thing (artefact, tool or device). Again, technology is not a skill (technique or know-how), neither is it a product (expected end or result). These three components -a thing (artefact, tool or device), skills (technique or know-how) and solution (product, service or expected result) are very important to give the word "technology" its holistic definitions and it is inappropriate to isolate one out of these three components and term it as a technology. Each of these three things plays an important role in the definition. Therefore, technology in the context of this study, is a practical process of skills application on a tool to solve a problem.

Based on this understanding of technology, this study examines the three components of technology (tool, skills/process and solution/outcome) involved in digital ideation in graphic design. This suggests that in a digital design environment, it is expected that the designer is knowledgeable about the digital devices and applies the needed skill to the devices to solve design problems. Thus, the various digital tools used by the design students, the digital skills applied and the ideation outcomes are of great interest in this study.

Digital Technologies

There is an abundance of available digital technologies that can be benefited from in and outside of the class (Ng, 2015: 188). Regarding the need for technology, Ng suggests that digital technologies support students by increasing their motivation, developing their minds, providing real-life-like experiences, enabling research, promoting communication and collaboration, promoting higher-order thinking skills and critical thinking, maintaining learning in out-of-school contexts and catering for multimodality.

In a study conducted in two Australian universities to explore factors shaping students' engagement with digital technology within the university settings, Henderson et al. (2015) classified the digital technology resources

used by students into two categories namely: 1. official and non-official digital technologies resources and 2. non-official use.

The official digital technology resources include the following:

a. Learning Management System
b. library online resources to find information
c. E-books or e-textbooks
d. Software specific to my study area

The non-official digital technology resources used by students are:

a. Internet search engines to find information
b. Search for papers/journals
c. audio recordings or videos (YouTube, Vimeo)
d. Social networking sites for working with other students
e. web-based document for working with other students
f. Freely available courses and educational content online

It is seen in this literature that Henderson and others did not make mention of any digital (electronic) device but referred to these online resources as digital technology. This is because these search engines are accessed on digital devices to execute tasks.

In his attempt to define digital technology related to education, Lindqvist (2019) posits that digital technology refers to online resources, learning management systems, programs and applications and digital tools such as laptops, tablets and mobile phones that are used for supporting teaching and learning. The author added that this allows the storage of large amounts of media files, documents and other data in small spaces or devices. Lindqvist's definition can be put into four different categories and these are 1. Software (online resources, programs and applications), 2. Hardware (laptops, tablets and mobile phones), 3. Skills application (used for) 4. Solutions or results (Ideation and design outcomes). Technology is the combination of these four components (software, hardware, skill and solution). There must be a complete integration of all four to term it a digital technology. The omission of one makes the definition incomplete. Lindqvist's definition supports the fact that digital technology is not a tool or a product but the application of skills on a device to solve a problem. The definition is directly linked to Levin's (1996) definition of technology as a problem-solving process as indicated in Figure 1.

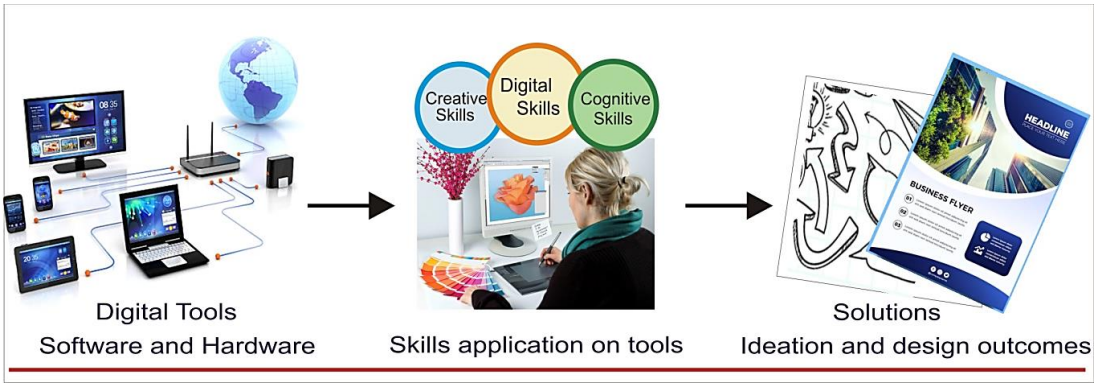

Figure 1. The application of skills on digital tools to solve a problem (technology)

Min and Hao (2008) assert that digital technology has brought new understandings of design space and user experience. This has offered various digital design tools that support design processes and decision-making in design practice. Radhika (2018) indicates that the main purpose of digital technology is to enable individuals to collaborate to achieve common goals and objectives, enhance productivity, and improve skills, abilities, and expertise among human resources. Min and Hao posit that digital tools enable designers to have more time and cognitive energy to concentrate on problem-framing and solving.

In this study, digital technology is broadly used to represent the use of digital devices and design application software, with or without the internet, to solve a design problem. Digital devices, as mentioned, include but are not limited to computers, laptops, digital camera, stylus, tablets and smartphones and the design software includes but is not limited to CorelDraw, Adobe Photoshop, Adobe Illustrator Adobe InDesign, Adobe Capture, and Adobe Lightroom.

Because digital devices cannot be used without application software installed on them, the term, "digital device" is simply used, in the context of this discussion, to refer to the digital hardware and the application software installed on it. However, if a discussion seeks to address an issue regarding a particular digital device in terms of its hardware, the specific name of the hardware will be mentioned. Likewise, the name of a software application will be mentioned if a discussion focuses only on a particular one.

According to Jonson (2005), digital technology serves as a tool for idea conceptualization in addition to technical drawing. Wang (2020) believes that digital tools make design work more convenient with good quality. Aboalgasm and Ward (2014) mention that digital tools enhance creativity and artistic expression. Again, Hods (2008) believes that drawing tools can be manipulated with ease and are capable of linking ideas and concepts in a dynamic manner later. In their study, Veisz et al. (2012) reported that there has been a substantial drop in using pencils at the initial stages of the design process among students as they prefer digital tools instead of simple freehand sketches to communicate their ideas. Although digital technology is becoming more prevalent in the design process, no study has conclusively established how this technology affects the quality and novelty of graphic design ideas. This study therefore explores how digital technology influences the graphic design ideation process and its impacts on the novelty and quality of graphic design ideas.

METHOD

The participants in this study have different digital exposures, design approaches, design experiences, varied studio environments (setups) and technology fluency. The varied realities of each design student's level of design experience, skills and exposure to digital technology can only be understood and appreciated when hidden facts are communicated and interpreted. By this, the subjective interpretations of the various participants can be reconciled and the differences that make the phenomena complex will be exposed. Constructivism allows a flexible process of interactions between the researcher and research participants (Bhatta, 2018: 73), which leads to openness and richness of data. As a result of this epistemological stance, the research methodology adopted is qualitative in nature and the methods of data collection adopted are interview and observation. Qualitative researchers draw relatively small samples from a large study population entirely made up of fairly eligible members (Asiamah et al., 2017: 1609). The sample for this study is drawn from the third and fourth-year graphic design students in a Traditional University and from the second and third students in the Technical University and the sample size for the study is 28 participants in all. This is made of twelve (12) students and 2 lecturers from each of the two universities. Because of the specific data needed on design ideation in this study, purposive sampling was conducted to select only lecturers who taught ideation-related courses like Graphic Application, Advertising Design and Computer Graphics. They have the needed information and formed the most appropriate participants. Student participants were purposively grouped based on the three categories specified -that is first class, second-class upper and second-class lower students. Random sampling was adopted to select six participants from each of the three categories of classes in each selected year group in the study universities. After the selected students were well informed about the study being conducted and had signed the consent form, they were observed and interviewed on a one-on-one basis. The qualitative data, which was collected from the 15th of February to the 24th day of May, 2023, was analyzed using Braun and Clarke's (2006) six-step thematic analysis. This was combined with a phenomenological data analysis approach. From phenomenologist's point of view, the researcher explored the "noema", "noesis", and "essence" of the data. This can also be referred to as "the what, the how and the why" of the data.

FINDINGS

The aim of this study is to identify the various digital devices and applications software used during the design ideation process by graphic design students in the two selected Ghanaian universities and how they affect ideation outcomes.

Digital Devices Used by Students during Design Ideas Development

Data collected revealed that graphic design students were at liberty to adopt their preferred approach to design ideation. This is to say the student decided whether to opt for a pencil and paper approach or use digital devices for idea development. Concerning the possession and use of digital technology, all the participants had smartphones and almost all, except one participant, had laptops. Two (2) participants used only a laptop for design work. These participants did not even use the phone for design research or search for design inspiration but strictly used the laptop for anything related to graphic design. Only one (1) participant used three (3) devices and these are Laptop, smartphone and tablet. The rest used laptops and smartphones. None of them used smartphones only for design work. Smartphones have always been used in combination with laptops.

In response to an interview question, "Which digital devices do you use for graphic design work?", the participants have this to say:

> Laptop and mobile phone. Sometimes I do work on the mobile phone and transfer it to the laptop. There is application you can use to design on the mobile phone. If I am not with my laptop and I have to design now, I will work on my mobile phone. We use Hotspot to connect the internet to the laptop. (Participant KN 2c)
>
> Some software like lightroom used for manipulating photos. I have the phone version that I have been using. (Participant KN 2b)
>
> The phone. Actually, we have Adobe software on it that can be used for design. (Participant 2b)

As stated by Hazali et al. (2018), mobile applications are designed and used for handheld devices such as smartphones or tablets. It is possible to make awesome graphic designs using just your phones and people who do not have good personal computers or graphics tablets can start their graphic design career on their smartphones (Ahmed, 2021: 1). The author states that Adobe and other popular graphic design software companies have developed several applications to help people design even if they do not have computers. Available mobile applications that can help the designer, according to the author, are Adobe Capture, Adobe Lightroom, Photoshop Fix, Adobe Comp, Canva and Adobe Spark. According to Superprof (2023), applications such as Autodesk Sketchbook, Adobe Illustrator Draw, and Procreate can be of great help to designers.

- Details of some of these mobile design applications are explained as follows: Adobe Photoshop Express-great for making collages and adding some flair to your designs. One can use this app to add text and filters along with making stickers for designs.
- Adobe Lightroom-for basic editing, cropping tools and a large number of presets, filters and styles. Lightroom has easy-to-use sliders that can be dragged up and down to add or reduce the impact of a filter or effect placed. It has an intuitive interface and is great for everyone from professionals to beginners.
- Adobe Photoshop Fix-This tool helps to remove any unwanted bits from one's design. It is similar to the healing tool in Photoshop and uses content awareness which basically means it will not affect the design while editing.
- Adobe Photoshop Mix-It is an application used to cut out and combine elements together in a single project. Similar to selecting an object in Photoshop, then cropping and dragging it to another project.

A number of these applications are designed by Adobe and this is because Adobe is the industry-standard software for graphic designers. They are readily available and easy to install. Of all these applications, Adobe Capture is the most versatile for graphic designers. It allows the designer to use the phone's camera to take photos and then use Adobe Illustrator to identify the kind of fonts, colors and styles that were used in the photo. Hazali et al. (2018) posit that mobile applications have been widely used in line with today's technology as handheld devices become more powerful.

Smartphones and other handheld devices are built for internet communication, information retrieval, images, video, and other features with countless useful applications that render the device as a need and the most sought-after one in today's age of technology gratification. Mushroor et al. (2020) indicate that the advent of touch technologies and the use of smartphones and mobile devices have made humans embrace technology and extensively dependent upon them.

Students' Use of Vector Software

The vector software used by students in both universities are Adobe Illustrator and CorelDraw. Thirteen (13) of the participants know how to use vector software. Out of this, nine (9) can use both Adobe Illustrator and CorelDraw. However, among the thirteen users, three (3) of them said they were not good at using Adobe Illustrator. This means only ten (10) among the participants can use Adobe Illustrator well. It is clear from this data that less than half of the participants use the vector software that are needed for digital illustration.

In response to a question, "Which software do you use?" one of the participants said:

> Photoshop and premier. I am not really conversant with Adobe illustrator. I used to have Corel but now I don't even have on my laptop. (Participant 5a)
>
> Photoshop and InDesign. I am not good in using illustrator. I want to learn illustrator. I will be happy if I know how to use it. (Participant KN 1a)
>
> I use InDesign, Photoshop and Adobe illustrator but I am not too good at Adobe illustrator. (Participant 3e)

As can be seen, the three respondents know how to use Photoshop. It was discovered that all the participants, except one of them, knows how to use Adobe Photoshop. That is to say almost all the students know how to use photo manipulation software. This software was used most often by students in their design tasks.

Clearly, the responses indicate that students had problems working with vector software. This is because they were not taught how to use them.

As already established, less than half of the participants know how to use vector software. There is the need for a shift to the approach of design skills development where digital technology is integrated into the idea creation stage to meet today's standards. Vector software such as CorelDraw and Adobe Illustrator help designers digitally illustrate ideas to a perfect representation of what is imagined or sketched in pencil to achieve desired ideation outcomes in terms of intricate creative details and aesthetic qualities. Students' inability to digitally illustrate intricate and complex design details in vector software influences their selection of pencil sketches for digital illustration and this affects their creative outcomes. Thus, students' inability to transform their best pencil sketches into digital forms affects their design outputs as they tend to select very simple pencil sketches for digital illustration because of their limited skills in the use of vector software.

Newer and more advanced technologies have been introduced, and individuals are learning new skills. Technology has improved beyond imagination (Ng, 2015: 189), and different software has made it easier for people to come out with new designs without having constraints that were associated with the traditional methods of graphic designing (Walter & Chimanga 2018: 29). The author adds that newer technologies cause people to imagine new designs that are not possible without the new software. The transformation brought by technology has resulted in a considerable change in the expectations of consumers over time such that the use of traditional approaches to problem-solving does not attract recommendations anymore because these approaches fail to meet the expected standards of today's clientele.

This is why graduates being produced by institutions of higher learning have to be acquainted with current approaches to solving problems. However, as noted by Sheila and Waarde (2020), the education system is one of the areas that is still focused on old methods of learning. Again, in a study, Anna (2018) lamented that the traditional methods of teaching skills have not changed. This is why there is need for periodic changes in the approach to solving problems in order to remain relevant in every industry. The adherence to the traditional approach to problem-solving in design as was confirmed by KN Lecturer 1 who stated that students were not exposed to the use of design software during the creative stage of the ideation process.

If clients do not accept pencil sketches as participants stated during the interview session, how then can the design students meet the design needs of these clients as they cannot illustrate ideas in the vector software? The fact that the traditional pencil sketch of idea communication is no longer appreciated by today's clients is a clear signal that there is a need to change the modus operandi for design ideation to meet current expectations.

The Contribution of Digital Devices in Gathering Inspiration Materials

It was discovered in literature that inspiration is an essential part of idea development. As put by Cui (2020), inspiration plays a pivotal role in the creative process as it predicts creativity, serves a transmission function, promotes productivity, and complements the exertion of effort. All the participants confirmed that they depended on the internet for design inspiration. Unlike the wide sources of design inspirations discussed in literature (Laing & Masoodian, 2015: 1201), such as, printed material like magazines, photographs and books, electronic sources and website links and other physical material such as toys, packaging, hand drawings, and sketches and the multimodal sources of inspiration outlined by Tarja-Kaarina and Pirita (2014) such as artefacts from other domains, materials, images and works of art, objects and phenomena of nature and everyday life, greater number of the students depend heavily on the internet websites for inspiration. They usually do not explore the environment for inspiration. This notwithstanding, few participants engaged in multimodal sources of inspiration, which involved taking inspiration from objects and materials in the environment, artefacts from other domains, images, and phenomena of nature and everyday life.

It was observed that digital devices, especially smartphones helped students gather inspirational materials for their design works. Commenting on whether internet technology makes ideation easier or not the participants said:

> To me yes. Because there are lot of ideas out there. You can look on someone's work and get an inspiration. Even if you wouldn't do the same thing, you get an inspiration of how the work was done and you can do something. (Participant 3e)
>
> With the phone, we visit other designers, go through their works and take inspiration from there. (Participant 3a)
>
> Sometimes like when I walk around, maybe when I am at the beach and I see something that I get inspired with, I take photograph of it. Maybe I go round and I see an artwork, I snap it. As for the phone, it actually helps. (Participant 2b)

Participants 3e and 3a stated that they get inspired by the works of designers on the internet. Participant 3e is of the view that numerous ideas exist on the internet to inspire a designer to create ideas. Again, Participants 3a and 2b mentioned that they used the smartphone in gathering design inspirational materials. To Participant 2b, the smartphone is a very useful digital tool because it helps him capture works of art and images from the environment for design work. Creative ideas never seized from the environment. They exist in great quantities and in a variety of forms but it takes creativity to perceive them. Nature-inspired designs are usually varied, unique and wonderful. Designers who know how to explore nature very well will always produce creative works. While some artists will use small sketchpads for quick sketches as they explore the environment, majority of them will prefer devices such as digital cameras or smartphones. This is because the smartphone helps them get as many images as quickly as possible. The more the images, the more the ideas they are likely to generate.

Multi-functionality of Smartphones in Graphic Design Ideation

Mushroor et al. (2020) indicate that the smartphone is a great tool that allows people to access information on any imaginable topic instantly. These mobile smart devices also make individuals available anywhere, anytime, which changes the way that individuals choose to interact within and outside the society. It is observed that students make optimum use of this device as far as their academic issues are concerned. A small device though it is, the smartphone performs multiple tasks that are of great help to the designer.

Table 1. Multifunctionality of smartphone

Function	Description
Photograph	Design students take quality inspirational pictures using their smartphones.
Voice recording	The smartphone also helps students to do voice recording during lectures, group discussions or when conducting interviews as part of research.
Video recording	Students do video recording to keep record of some activities, processes or events that may be useful for design.
Note taking	The smartphone is used for note-taking.
Research	With internet connectivity, the smartphone is a perfect device for browsing for research purposes.
Drawing/ Sketches	There are smartphone applications for drawing that students use for drawing and sketching. These include Adobe Capture, Adobe Lightroom, Photoshop Fix, Adobe Comp, Canva and Adobe Spark. Others are Autodesk Sketchbook, Adobe Illustrator Draw and Procreate. These software can be of great help to designers. Most of the time the drawings done on smartphones are transferred to the computer for further improvement.
Designing	Some of the smartphone applications allow the graphic designer to complete everyday drawing tasks.
Sourcing for inspiration	The design students use smartphones to search for inspirational images during idea development.
Connecting computer to the internet	In instances where internet service is poor on campus, design students use their smartphone to connect internet to their computers by hotspot for browsing.
Scanning images	Applications such as Handy scanner, PDF scan or Microsoft Lens are used for perfect scanning of images and pencil sketches drawn during idea development

It is quite amazing to notice that all the participants depend on the smartphone, one way or another, during ideation. It is, indeed, a multi-purpose device that has come to make work simple for designers.

> The phone. Actually, we have Adobe software on it that can be used for design. (Participant 2b)

The statement of Participant 2b confirms the earlier discussion in this chapter about the use of smartphones and Adobe applications for graphic designing. According to Superprof (2023), applications such as Autodesk Sketchbook, Adobe Illustrator Draw and Procreate can be of great help to designers.

Impact of Digital Technology on the Variety, Novelty and Quantity of Ideas Developed

When a variety of ideas are generated in good quantity, it is most likely to obtain a novel idea. This means a successful final solution is likely to originate by exploring a variety of solution principles, as stated by Pahl et al. (2007). Literature established that the use of digital tools makes design work more convenient with good quality (Wang, 2020). Some excerpts below indicate the views of participants on the effect of digital devices on the quantity, variety and novelty of ideas.

> It makes work easier. With the digital device you can test the variation of colors. You can just mask and test different colors and you can do multiple works in one day. You can have more ideas than when you are using pencil and paper (Participant 2a)

> I have to generate more designs from other designers or look for more inspiration from other designers so I will search on the net to get more information or ideas from other people's work. Through that I can gather more ideas to add to mine to help me develop mine. (Participant 3b)

These two participants established the fact that digital devices help them to generate more ideas. The principal essence of design ideation is to create more ideas from which a solution may be selected. As stated by McGlashan (2018), it is important to generate many ideas at the ideation phases of design thinking by exploring several variations that result in a range of ideas from all perspectives. In support of this, Casakin et al. (2019) observed that the main objective of the design ideation stage is to explore as many ideas as possible from different and new perspectives. Technology, according to the participants, is helping them to achieve the essence of ideation.

As can be seen from the interviews, participants agreed that digital devices helped them in diverse ways. Participant 2a was of the view that the designer "can have more ideas than when you are using pencil and paper" and that the designer "can do multiple works in one day." Participant 3b shares a similar view when he said, "I can gather more ideas to add to mine to help me develop mine". He said he goes online to take inspirations from the works of others and by so doing he gains more ideas. This helps to achieve one of the purposes of ideation which is the development of ideas in good quantities.

Expressing more views about technology's impact in design ideation, participants said,

> With Pinterest and Instagram, there are a lot of people with different styles of design. I prefer to go through people who have vector type of designs. It inspires me. (Participant 3a)

> When you are given a design work you have to brainstorm, walk around the environment, pick inspiration and with the help of the digital gadget, you can just get to your phone and research what you want and pick an inspiration from the works that are already down there. So, they really help. (Participant 2c)

Participant 3a: mentioned that "I prefer to go through the work of people who have vector type of designs. It inspires me." This designer is particularly interested in the vector types of design and not the JPG or raster type simply because the vector form of drawing gives the designer the flexibility to reshape parts of it to achieve the desired outcomes.

A vector image has infinite resolution. There is virtually no limit on how big you can make a vector image without losing its resolution. In contrast, raster files only maintain their resolution when fitted to a specific size. The bigger they are stretched, the less the quality. With the vector file the designer can add shapes, different colors, and filters to create new and unique designs. This format allows the designer to combine graphic elements and text, which is particularly important when designing vector logos or printed materials. Again, the designer can easily go back and edit over and over again. This, in effect, helps the designers obtain multiple and variety of ideas. In their response regarding the importance of using the internet during design ideation, the participants said:

> … Like I mean design a poster on sustainability. You ask yourself what sustainability is about. And when you go to the internet and type sustainability you will see various kinds of designs on sustainability and it looks like but not necessary to copy. It gives you an inspiration to just do yours. Even the colors to choose. (Participant KN 3a)

> With the phone, we go on the internet, when you are given a topic and maybe you want a wide idea. You go to internet and search; you will get various and different types of ideas then you actually take one you will work on. (Participant 2b)

Participants KN 3a from the Traditional University and Participant 2b from the Technical University expressed the view that the internet helps them to get a variety of ideas for design ideation. While Participant KN 3a expressed this view by saying "You will see various kinds of designs", Participant 2b said, *"*You will get various and different types of ideas". This indicates that students visit the internet on purpose to obtain a wide spectrum of design ideas on a given design task. The participants' statement corroborates with that of Wang (2020) who indicates that the use of digital tools (one of which is the internet) makes design work more convenient with good quality and offers the user more choices and variety. A variety of ideas is important in design ideation because it is what qualifies a design to be counted. As stated by Pahl et al (2007), the ideation stage is very important because a successful final solution is likely to originate by exploring a variety of solution principles. The extent to which the ideas vary (variety) in quantity determines the quality and the novelty of ideas. The more the quantity of varied ideas, the more the quality and novelty to be produced. Generating varieties of design ideas constitutes one of the major creative responsibilities of the designer during the ideation and the digital technologies, according to the respondents, help in achieving that.

CONCLUSION

This study sought to identify the digital tools used in graphic design ideation among Ghanaian graphic design students and their impact on ideation outcomes. It was discovered that students used laptops, digital cameras,

styluses, tablets, and smartphones for design ideation, but they predominantly used laptops in combination with smartphones for this purpose. Their design software includes CorelDraw, Adobe Photoshop, Adobe Illustrator, Adobe InDesign, Adobe Capture, and Adobe Lightroom. The internet also emerged as a very important digital tool that promotes effective design ideation, without which the designer may not be able to achieve much. In effect, the technology adopted by designers is the use of digital devices, design software and the internet for design ideation.

It is clear from the discussions that digital technology helps designers to generate variety of ideas by gathering inspirational materials to guide the design ideation process. Again, because of the multitudes of ideas gathered from the various websites, the designers were able to generate good quantities of ideas in answering design briefs and this helps in achieving novelty of design. This supports Pahl et al.'s (2007) assertion that exploring a variety of solution principles lead to a successful final solution.

Even though the impact of digital technology is notable and all the participants admitted that they used digital technology for design research and idea exploration by visiting the design websites for design inspirations, less than half of them (ten out of twenty-four) knows how to use vector software such as CorelDraw and Adobe Illustrator for actual digital idea illustration. This is a concern that needs to be addressed as today's clients do not accept pencil illustrated ideas. One of the ways to improve student's digital illustration is by exposing them to and engaging them with vector software in the design process. The more one learns about the abilities of technology, the more creative one becomes (Thangarajathi, 2020: 864). Thus, constant use of design software will help students develop the fluency required to be creative in digital ideation.

Authors' Contributions

Both authors made an equal contribution to the study.

Competing Interests

There is no potential conflict of interest.

Ethics Committee Declaration

Ethics committee approval dated 10.11.2022 and numbered 117/22 was obtained for the study from Durban University of Technology, South Africa.

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