The Impact of Using 3D Printing on Model Making Quality and Cost in the Architectural Design Projects

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Abstract

The expert educators use different techniques in the educational process targeting the teaching effectiveness considering the disciplinary of the learners. They also encourage their sense of creativity by adding the technology to the educational process, in the field of architecture as an art and science, the use of new technologies is an important reflection of the design concept. Moreover, architects use some technological programs presenting their ideas such as 2and 3 dimensional drawings, V Ray, 3D Max, Primavera etc. The new technique "3 Dimensional Printing" means using the architectural new modeling technique to show the feasibility and effectiveness of using the new technique in this discipline as a presentation tool for the learners' projects in the design process.

This paper aims to focus on different benefits and values of implementing the 3dimensional printing technology in the discipline of Architecture and Interior Design for undergraduate learners and examine the final results.

It also aims to present the advantages and the disadvantage of adding this technology to the architectural educational process for undergraduates, to help them having professional models for their projects. The study used a special methodology, which concentrated on the importance of the 3D printing, having a practical approach using an experiment implementing it on one of the architectural design courses' projects.

Finally, the study expects some results to be examined regarding the importance of using new technology in the higher education.

Keywords: 3D Printed Models, Architectural Models, Industrial Design, Printed Architecture, 3D printing, Additive Manufacturing, Architectural models.

INTRODUCTION

3D printing, also known as additive manufacturing (AM), refers to processes used to synthesize a three-dimensional object,[1] in which successive layers of material are formed under computer control to create an object.[2] Objects can be of almost any shape or geometry and are produced using digital model data from a 3D model or another electronic data source such as an Additive Manufacturing File (AMF) file.

The term 3D printing's origin sense is in reference to a process that deposits a binder material onto a powder bed with inkjet printer heads layer by layer. More recently, the term is being used in popular vernacular to encompass a wider variety of additive manufacturing techniques.[3]

3D printing allows students to create prototypes of items without the use of expensive tooling required in subtractive methods. Students design and produce actual models they can hold. The classroom environment allows students to learn and employ new applications for 3D printing.[4]

Engineering and design principles are explored as well as architectural planning. Students recreate duplicates of museum items such as fossils and historical artifacts for study in the classroom without possibly damaging sensitive collections. Other students interested in graphic designing can construct models with complex working parts easily. 3D printing gives students a new perspective with topographic maps. Science students can study cross-sections of internal organs of the human body and other biological specimens. And chemistry students can explore 3D models of molecules and the relationship within chemical compounds.[5]

The future applications using the 3D printing which may create an open-source for the scientific equipment.

To ensure a high quality 3D print it is essential to keep the design rules for 3D Printing in mind. When designing your model you need to take into account the fact that your model is build up with closed surfaces and printable wall thicknesses. The great thing of 3D Printing is that you are able

1 - Excell, Jon. "The rise of additive manufacturing". The Engineer. Retrieved 2013-10-30.

2 - "3D Printer Technology – Animation of layering". Create It Real. Retrieved 2012-01-31.

3 - Standard Terminology for Additive Manufacturing – General Principles – Terminology. ASTM International. September 2013, Retrieved 2016-07-11

4- https://www.youtube.com/watch?v=_KBxG1_WO8k

5 - "3D Printing in the Classroom to Accelerate Adoption of Technology".

to print complex shapes and highly detailed designs that will be too time consuming if they were build by hand. A 3D Printer can be used to print detailed designs, e.g.: complex facades, interiors, environmental elements (cars, trees, people), roofs etc. A large flat floor surface can also be printed, however using a laser cutter for these kind of parts might suit this purpose better.[6]

The purpose of this research paper is to propose an ultimate solution for architecture students and employees around the kingdom of Saudi Arabia in regard to building 3D models by applying the new 3D printing technology to universities and companies.

By doing so, this paper also aims to open up new opportunities in complex architectural design and construction techniques, improving the quality of both by using the technology of 3D printing.

Using the 3D printing process is helpful for the undergraduates in the discipline of architecture and design specially in research and design courses, due to the ability of making professional 3D architectural models.

The study was done at Prince Sultan University, College of Engineering Department of Interior Design and Architecture, Riyadh, KSA.

BENEFITS OF USING 3D PRINTING IN DESIGN[7]

Help Clients to Better Visualize your Design

By printing more detailed models, will help your clients to better visualize the final projects, ultimately helping your firm to win more business.

Reduce Hours Spent Creating Models

With a Stratasys 3D Printer you can significantly reduce the time and expense in producing building models, often requiring highly delicate details. 3D printed models are also stronger than traditional models and won't buckle or break over time.

Create a Library of Reusable Designs

Using 3D printing allows you to be more innovative with your model making. For instance, when you have repetitive pieces, you can print one as a mold, cast it, and then use the cast to injection-mold the required duplicates.

METODOLOGY

To investigate the availability and importance of using the additive manufacturing in the studio classes and its strategy, a studio scenario was done on a design course, the experiment was carefully planned and applied to a regular design studio course targeting the architectural undergraduate learners, we

wondered how the use of technology can help the learners on the undergraduate level to work on the design with two dimension and make the model 3D manually and using the 3D printing to identify the best practice for creating the requested model in their studios. The use of the new technology in designing would stimulate the learner's ability towards creative design ideas, which would bring change in the design concept and process leading to creative designs.

Two Hypotheses were planned and established including a n evaluation criteria and a survey were developed based on the idea of the paper.

Hypothesis -1: Propose to investigate the application of using the manual designs in the studio design classes, leading to changes in the main design perspective to design conventional designs to be easy fit the manual model. For example, if the requested design is residential the learners usually refers to use the simple design in order to avoid the details they cannot represent on the requested models.

Hypothesis -2: Propose to investigate if using the new techniques like 3D printing and its usage in studios and design classes should encourage learners to use the technology in the educational and design process, leading to transfer their imagination into a creative design form. For example, the expected results from this paper is targeting to encourage undergraduate learners to develop their design abstracts.

EXPERIMENT DESIGN

The paper focused on one of the studio courses, the selected course was Arch 211 "   " one of the design courses which ran for 14 weeks in the department of architecture in at Prince Sultan University.

Learner's project was selected as an example concentrating on the differences between the use of manual and new techniques on designing the 3D modeling, learners' marks in this studio course were distributed to examine the learners' ability to make best model designs matching their originals.

The other learners participated in this study through the distributed questionnaire to all learners from the second, third, fourth years in the discipline of architecture and they had comparable educational backgrounds seeking a clear understanding for the cognitive skills about the best use for the technology in the design process.

Although the duration time for the experiment was one semester 14weeks only and the number of learners who participated in the survey was not that big, but the study planned to investigate the learners' acceptance to use the additive manufacturing in their design courses for better model designs and developing the ideas, the sufficient data was analyzed in a qualitative way.

One of the missions of this experiment was to examine the possibility of using the 3D printing technique on the final

6 - https://www.lpfrg.com/en/professionals/architects/
7 - http://www.javelin-tech.com/3d-printer/industry/architecture/

project, and its application on the whole design. The project started to use the Auto cad to draw the orthographic drawings.

The project was an example of using the floor plan for one of the given designs in a practical course, then the learner used the 3D printer to create the 3D model in two ways the manual and the 3D printing modeling to verify the validity of the process.

This part will focus on developing the architectural drawings specially the floor Plan. The teamwork will be: the researcher, the research supervisor, and a specialist in the 3D printing.

Reasons behind designing the experiment:

-During the studio classes learners work on models manually representing their designs, during this process the 3D model as an implement to clarify the design ideas has been a quite frustrating procedure.

- Most of learners skip the step of constructing an architectural 3D model if not firmly required, because of the lack of time they actually have regarding the required time must be spent on modeling.

-The learner's failure creating an accurate and professional 3D model using foam boards and/or balsa wood, and the difficulty of accomplishing accuracy in a 3D model that represents all the details proposed in the design.

This research paper has focused on fulfilling the high ambitions of undergraduate learners who study architecture regarding the making of 3D models.

DESIGN PROCESS TASKS

During the semester the learner was asked to design 2D technical drawings for a residential unit, and by the end of the semester and before the final submission we planned to use the 3D printing technique on the design to observe the successive design tasks.

The setting of the experiment went g through 3 stages of design process to examine the idea of using the 3D printing in the studio classes instead of the 3D manual modeling, concentrating on the advantage(s) of using such a technology in the educational process, that shall help learners having professional 3D models for their projects.

This experiment is examining how undergraduate learners can use the technology of 3D printing to avoid the problems they usually face in the 3d handmade modeling, to improve the quality of their models and their performance in design. The experiment will be held according to the following setting:
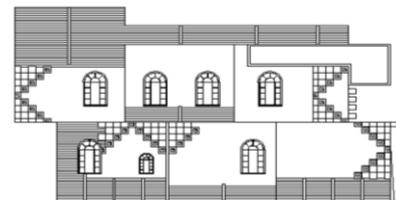
Design task 1: The learner was asked to plan the settings of a case study and the selection of the studio course that requires a 3D manual model as a practical approach to the activity. This part focused on developing the architectural drawings specially the floor Plan. The teamwork was: the researcher, the research supervisor, and a specialist in the 3D printing.
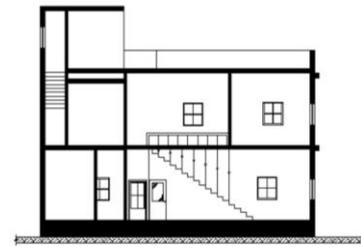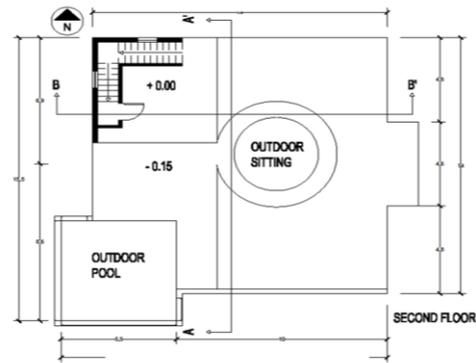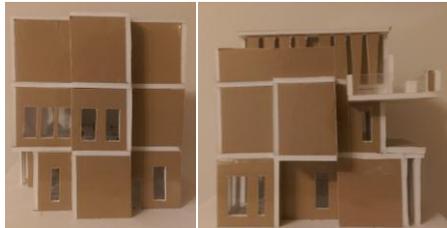

Figure 1: The Architectural Drawings

Design tasks 2: Creating the manual 3D model using the foam board and the balsa wood and observed learners work as a supervisor during the semester, and another instructor collaborated on the adjustment of the course's teaching method for the studio over this semester using one-to one tutoring if needed.

The purpose of creating a hand-made 3D model, was to compare as many aspects regarding constructing an architectural model with a 3D-printed one. Learners in the course have also made a model of the same design using 3D Max as preparation for the process of 3D-printing.

Analyses of the Design Process in Design Task 2

All the participants have already done models in different school courses using the same old known methods and materials, such as foam boards and balsa wood that are generally used by architects. Learners faced difficulties in developing the architectural abstract through the traditional methods. The given project provided various structural abstracts from all aspects.

Design task 3: Creating the 3D Printing model using the 3D printer, a presentation was planned in order to assist learners to conceptualize the new form of the design using the technology, and to examine the results through a questionnaire distributed to the learners.

The project was an example of using the floor plan for one of

the given designs in a practical course, then the learner used the 3D printer to create the 3D model in two ways the manual and the 3D printing modeling to verify the validity of the process.

The model that was done in 3dx Max had to be converted from CAD files to STL format in order to achieve the highest levels of smoothness when printing the model in three dimensions.

Different programs had been used, such as "Binary" and "Netfabb Professional" that come along with the 3D printers to ensure the ability of printing. These programs can spot any gap or unprinted 2D shape. They also examine the inconsistency of the design and show any issue in the modeling technique that could cause printing errors.

Some of these errors might be fixed automatically by these programs. Once all the errors are fixed, the design will be ready for printing. The time of printing process verifies depending on the details and the scale of the desired model. In more complicated models, the materials could affect the printing process time as well.

Figure 1: 3D Printer

Source:http://3-d-printing.blogspot.com/2008/12/advantages-of-3d-printing.html
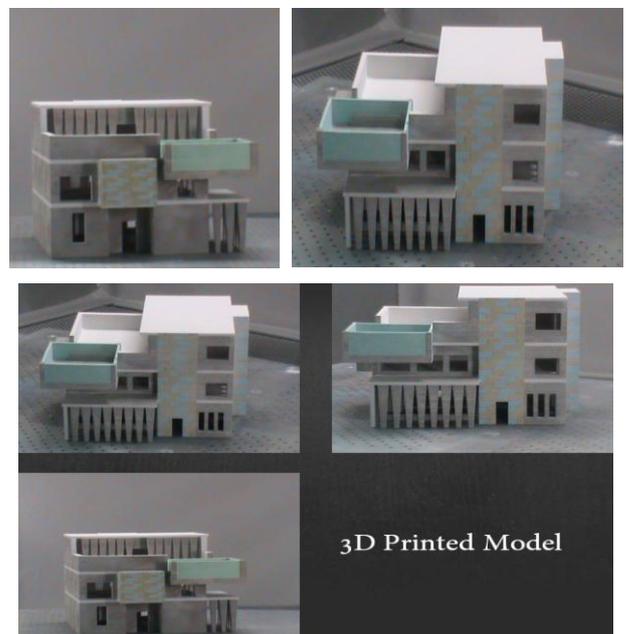
Analyses of the Design Process in Design Task 3

Each model has been evaluated separately according to specific major elements of the modeling process by female faculty members in Architecture and Interior Design Department at Prince Sultan University.

Focusing on the appropriateness of the project's design output, the learner concentrated on the design the facades with different abstracts and designs.

The handmade model, representing the conditional model was compared with the 3D-printed model, which represents the experimental model in this experiment, according to the time and effort needed for construction, the presentation quality, the financial costs, durability, consistency, accuracy and details, clearness and cleanness, flexibility and recycling and waste.

These elements were organized in a table that compares a hand-made model to a 3D printed one. The results analysis is provided to be reviewed (See Appendix A, Table 1).

To ensure having impartial data of appraisal, a questionnaire was given to faculty members and architectural learners for that purpose. The form consists of multiple-choice questions with a 3-point scale which ranges from (Agree) as point (1) to (Disagree) as point (3).

Also, open-ended questions were added by the end of the form. (See Appendix A, Form 1). The following graph analyzes the data results of the evaluation form. It has been found that 90% of the participants agree on the idea of adopting such a technology at the departments of architecture and interior design in Prince Sultan University. 8% were neutral. And only 2% were against the idea of 3D printing technology adoption.

Adoption of 3D printing technology at Prince Sultan Uninversity for Senior Projects
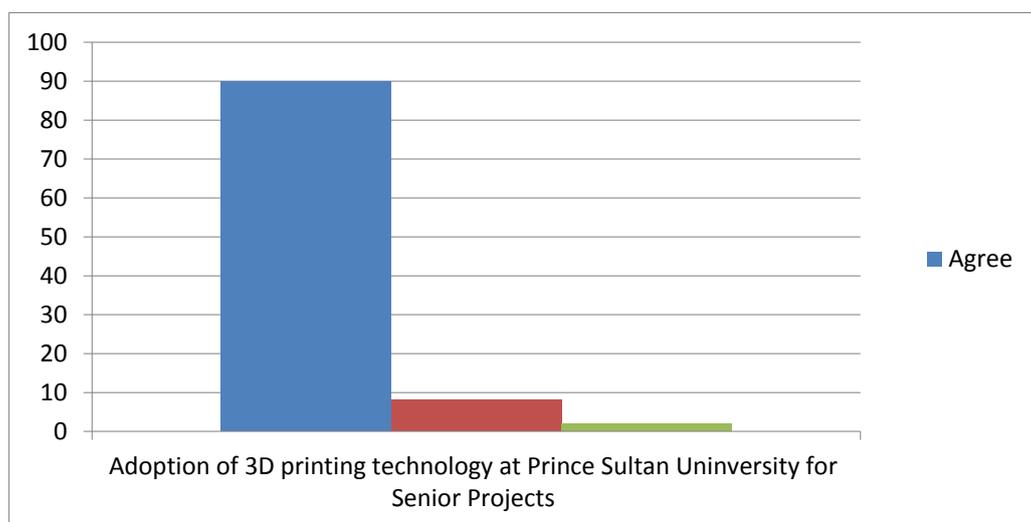
(Graph 1)

Table-1: Describes the Experiment

Challenges	Results
Decrease the time and expense required for a professional detailed architectural model.	Reduced time of creating a model for the course from weeks to few hours.
Produce professional presentation of models design and quickly respond to any changes in.	The learners can produce more professional and detailed models, which assets them gain marks and efficiently test their model designs before the submission.

DISCUSSION AND CONCLUSION

According to the results and findings of this paper, it is important to understand the strengths and the weaknesses of this technology. This section discusses the advantages and the disadvantages of applying 3D printing technology to architecture and interior design. (3-D Printing, 2008)

The research expected some results to be proved regarding the importance and usefulness of applying the new technology in

the higher education especially in the field of Architecture and Interior Design.

The table below shows the advantages of 3D printing fulfill the aims and goals previously written in this paper. There are many advantages of adopting 3D printing technology to architecture schools and companies. The advantages of such a technology could be found below.

The process of using additives in order to form solid 3D objects of from a digital model is called three-dimensional printing. 3D printing has worked into a number of markets that deals with architecture and Interior Design with different kinds of applications in interior design, architecture, building construction, automotive design, and so forth.

The paper has focused on the benefits and values of the technology of 3D printing in Architecture and Interior Design. It also has discussed the advantages of adding such a technology to the educational process that shall help students and faculty having professional models for their projects.

An experiment that has concentrated on the importance and usefulness of this technology was done in order to clarify the differences between a hand-made model and a 3D-printed one. The results analysis has proven this technology usefulness in the field of Architecture and Interior Design.

Recommendations in regard to minimizing the disadvantages of 3D printing have allowed a whole new field of research and development.

To examine the research hypothesis, Hypothesis 1 was subscribed by the researcher emphasizing on the design methodologies and gradually develop the architectural designs to produce design sketches.

Hypothesis 2 Learners became familiar with the use of technical methods, as they developed design task 2 and to more advanced ideas for design task 3.

In conclusion, this paper's results suggest the use of the new technological methods such as the 3D printing in the design process to show better representation for the design idea, this study explored the advantages of using the 3d printing in the teaching strategy for learners in studios and design courses, in addition to other design considerations in the educational process.

Title	Advantages	Dis advantages
General Advantages for Learners:	1. The 3D printers can save up to 40% of the designer's time in making 3D models. -Earlier studies have shown that 3D printing is a technology that provides a faster production of models. Instead of 5 months of handcrafting modeling, 3D printers are able to produce the same portion of units, even with better details, in less than 6 weeks, which allow saving the precious time of architects and interior designers. 2. 3D printing reduces the financial costs of 3D models. 3D models traditionally cost companies $400 or more. By using the technology of 3D printing, the 3D model would generally cost $5 or less. 3. Greater details can easily be created with the help of 3D printers. This New Technology is able to provide very precise details no matter what scale the model is. Therefore, a better visualization of the design can be achieved. 4. 3D printers are easy to use. While other forms of modeling and rapid	1. The limited materials are one of the most important issues in 3D printing. -Currently, 3D printers only manufacture products out of plastic, resin, certain metals, and ceramics. 3D printing of products in mixed materials and technology, such as circuit boards, are still under development. 2. The size of the 3D-printed model is also an issue. Currently, 3D printers are limited with the size of the products that they can create. Certain and limited sizes of models can be formed by 3D printers make it hard sometimes to print a whole 3D model at once. 3. By using 3D printing, copyrights of printed products will become more common and nearly impossible to determine. 4.The easiness of printing 3D objects could probably lead to more creations of useless stuff.

	prototyping require specialized knowledge and training, 3D printers typically come with user-friendly software. 5.More durable 3D models can be created by 3D printers. Building a durable 3D architectural model to scale by hand is an issue that was mainly solved by applying 3D printing technology.	5. None
Advantages in Architectural & design fields:	3D printing allows architects to efficiently test the product design using the 3D-printed models. 1. Complex assemblies could be made by 3D printers that are actually hard or even impossible to make by hand. Pieces formed by a 3D printer can be snapped of fitted together, which increase the possibilities of more complex designs' creation. 2. 3D printing technology ensures that the design remain inside the company, for greater protection rather than outsourcing a prototype. 3. It also allows designers to catch flaws early in the design process that could actually save the company thousands if not millions of dollars. 4. 3D printing could also be used as a tool for visualization and communication of the architects' ideas as there is no substitute for the tactile and visual feedback a physical model can provide. 5. The CAD files, prints and renderings can be misinterpreted by everyone from team members to clients. 3D printing is able of preventing this from happening.	None

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[8]   https://www.lpfrg.com/en/professionals/architects

[9]   http://www.javelin-tech.com/3d-printer/industry/architecture/

Appendix A

(Table 1)

	Hand-Made Model	3D-Printed Model
Presentation Quality	Limited accuracy and details.	More details, colors and accuracy that presents the concept in a better way.
Time & Effort	6 Days	9 Hours
Financial Costs	600 SAR	300 SAR
Durability	Exposed to damage	More durable
Consistency	The glued parts make it less consistent	More consistency in the one block model
Details Presentation	Hard to show details.	Any detail can be shown easily.
Flexibility	Doesn't allow changes in the design.	Allows changes to be made at any stage of the design.
Clearness & Cleanness	The concept is kind of clear though the final work is not that neat.	Provides a clearer and a cleaner presentation of the concept
Recycling & Waste	Produces waste materials and can't be recycled.	Doesn't generate waste and allows recycling of the materials after production