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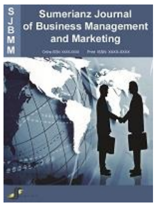

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Evaluating the Effect of 3D Printing Technologies on Innovation and Entrepreneurship: A Practical Case Study

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Abstract

Higher Education Institutions (HEI's) in many countries are drivers of innovative development economy. The innovative activity of HEI depends on both internal and external factors. Today, more and more emphasis is placed on innovative ecosystems, in which the HEI acts as one of the active actors in cooperation with business, government, public and private organizations. The research case study paper explores and compares the approaches development of regional innovation ecosystem of the United Arab Emirates (UAE), the Higher Colleges of Technology (HCT) Innovation and Entrepreneurship Teaching initiative, as well as an assessment of its impact on the results of this particular innovation method at the HCT. The case study reveals on the topic of using and adapting 3D printing technologies in the field of education. 3D printing technologies can be applied to teach technological skills in different fields, including the field of education. They also contribute to the reorientation of attention from the digital or virtual environment to the real world, since the results of educational activities are not sketches and models, but real objects with given characteristics. 3D printing technologies are among the fastest growing and promising technologies. These technologies can significantly contribute to the introduction of new forms of organization of the educational process, increase motivation and the formation of the necessary competencies of learners, graduates and teaching faculties. The objective of this paper is to review the basic issues related to 3D printing technology initiative as a process of technological transition though integrating the technological innovation into the educational ecosystem and measuring its impact on students. The paper elaborates this practical showcase experience through a case study of 'Al Ibtikar' – Innovation and Entrepreneurship Club at HCT to provide empirical support for similar industrial and education players to better predict the innovation trajectory through 3D technologies in the future. In this way, the research presents a conceptual framework that provides a foundation for discussing 3D technology and discover a development prediction of 3D printing technology in the lens of using this practice in the educational process.

Keywords: UAE; HEIs; HCT; Al Ibtikar; 3D technology.

1. Introduction

The task of developing innovative activities is becoming more and more urgent for the HEI's. In a book "The Third Generation University", (Wissema, 2009) highlights a number of challenges that universities have faced in the turn of the 20-21 centuries. One of which is a requirement for funding has to have a measurable result for the development of the economy of the regions and the country, as well as a significant increase in cost equipment and materials for the scientific research which required universities to closely interact with industry and search for new sources of funding. Different countries on the global landscape solve the designated problems in different ways. Developing an innovative ecosystem around large enterprises such as Samsung in South Korea, increase the "value and significance" of higher education and motivate learners to improve their knowledge. According to Anonymous , in the global index of innovativeness of countries for 2020, Germany overtook South Korea and Singapore to its highest ranking in the tertiary performance category (tertiary performance: total enrolment in tertiary education, regardless of age, as a percentage after graduation). A number of countries are creating professional structures for technology transfer from scientific organizations, such as ITTN in Israel (The Israel Tech Transfer Organization ITTN) or create subdivisions within research structures responsible for commercialization; some of successful examples of this approach exist in the USA (DeVol *et al.*, 2017). It should be noted that recently the term "innovation ecosystem" has become firmly established, reflecting that the implementation of the above task cannot be carried out by the university and other research organizations in isolation from industry, the business community, investment funds and private capital. "Innovation ecosystem" is a set of subjects interacting in the process of commercialization of innovations and their interrelationships, accumulating human, financial and other resources to intensify, optimize and ensure the efficiency of commercialization of innovations. A number of studies reflect that the university is one of the most powerful drivers of development an innovation ecosystem in a particular region or even a country. At Stanford, an innovation ecosystem is defined as "the interorganizational, political, economic, technological and environmental system through which a business environment develops. Stanford's example is to prove that famous industry pioneers as Lockheed, Fairchild, Xerox and General Electric formed the basis of the Silicon Valley. A similar role in the regions played by the University of Cambridge, MIT and many others.

Modern world standards require the state educational system to develop principles for mastering the basics of design and research activities, in particular, the acquisition of 3D prototyping skills. At the moment, there is a relationship between the awareness of the importance of introducing modern technologies into the educational process and the lack of scientific research on this topic. In the conditions of the modern market and the constant growth of competition, the early creation of an innovative product is vital for the successful development of any enterprise. World manufacturers have realized that in a rapidly changing world, in order to be in the leading positions, it is necessary to quickly translate new ideas into workable solutions. This is impossible without generating these ideas without new technical solutions for their speedy implementation. Therefore, the development of innovative thinking among students and learners should become a priority task of modern higher education. And the use of 3D printing technology may be one of the best technical solutions to accelerate the implementation of various new ideas into life. Future engineers, designers, architects, doctors and students of many other specialties can improve their professional skills with the help of 3D technology. In addition, students have a real opportunity to present their term and diploma projects not in the form of ordinary drawings and sketches but in the form of real three-dimensional models: engine parts, buildings, design elements, human internal organs, etc. Therefore, for the university, the installation of a 3D printer lab will allow not only to raise its overall prestige but also to prepare future specialists capable of performing real tasks. Universities have also a significant role in the shaping of these processes, as their educational and research priorities are widened by the conscious fostering of social and economic development (Etzkowitz, 2008; Mike *et al.*, 2008). A 3D printing laboratory of rapid prototyping has been created at the Higher Colleges of Technology in the United Arab Emirates, Abu Dhabi. The Al Ibtikar Club laboratory is equipped with the latest technology: Raise3D E2, Raise3D Pro 2, Formlabs Form 3, Einscan Pro 2X, a computer workstation, an interactive touch panel. Progress in the implementation of 3D technologies in the educational and research life of Al Ibtikar Club is obvious, but even where 3D printers already exist, they have not yet reached every faculty and department that could take a fresh look at the educational process, change student mentality and form the backbone of 21st century higher education.

The purpose of this article is to identify key factors necessary for development innovation ecosystem for the development of innovative activities of the HCT and its impact on the volume of commercialization through evaluating the effect of 3D printing technologies on innovation and entrepreneurship. 3D printing has the potential to significantly impact the course production and innovation takes place. It is still indefinite to anticipate where and how exactly 3D printing will transform our economy and society. According to an European Commission (2016), additive manufacturing is one of the emerging technologies of the digital era, with a significant impact on the industry.

In the context of Industry 4.0, 3D technology develops as one of the key technologic views of the next decade. The symbiosis of the Industry 4.0 technological ideas enable the digital revolution. Some authors introduce this transformation connects manufacturing systems that accelerate the time of all processes (Niaki *et al.*, 2019) and is changing the manufacturing business models, increasing the customisation, the flexibility and the interaction production, suppliers and customers Rosen *et al.* (2015). Other assumptions discuss the concept of “smart factories”, i.e., highly digitised, agile and connected production systems based on additive manufacturing, artificial intelligence, robotics, the internet of things (IoT) and the Big Data. Brennan *et al.* (2015).

The methodology adopted is exploratory and observatory and relies on some existing case studies, in accordance with case study research (Chavez *et al.*, 2017). The practical case of Al Ibtikar club case was selected to reflect characteristics and problems identified in the conceptual frameworks used in this research, with the aim to provide a comprehensive understanding of the changes, based on types of usage, brought by 3D printing technologies on challenges faced by learners.

The research paper introduces with a literature review enabling to identify the existing literature in the fields of entrepreneurial ecosystem. The second part provides an overview of 3D printing technologies adapted by Al Ibtikar club, technical aspects of hardware and software. The following section considers details and challenges the learners were taking though a mix of team efforts and organizing a completion by using 3D printing technologies, while the final section, investigates how the particular characteristics of these new technologies can help overcome traditional barriers and challenges related to the learners and participants.

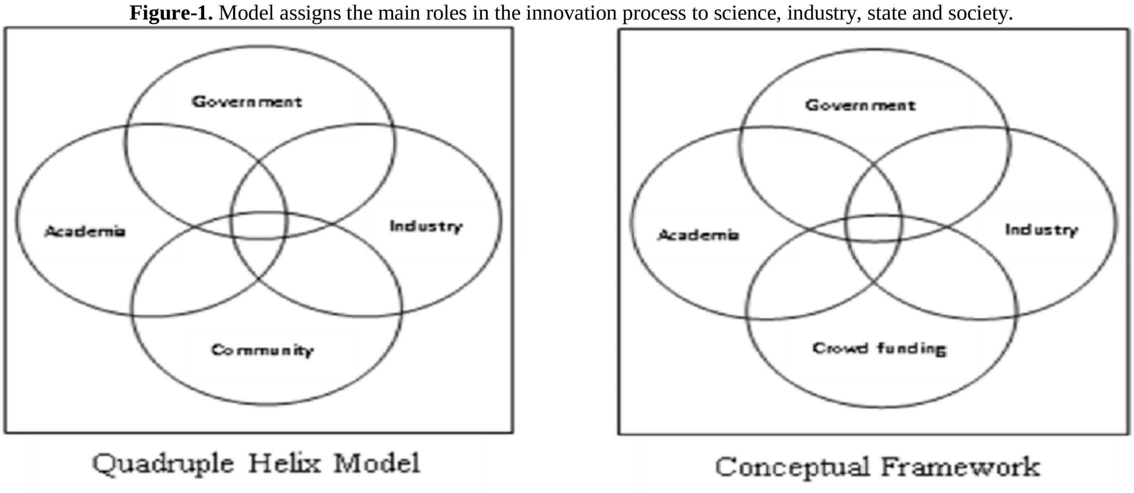
2. Literature Review

2.1. Entrepreneurial and Innovation Ecosystem. Models of Innovative Development Based on Cooperation

In the last decade, the global innovation system has experienced significant changes that lead to a reduction in terms creating innovations and accelerating the intensity of processes which is accompanied by a change functions of participants in the innovation system. Under these conditions, an important factor in the development of HEI’s s is the coordination of the activities of actors involved in the innovation process. One of the main tasks is the development of powerful scientific and educational centres capable of accumulating the capabilities of the university and academic environment, nanotechnology enterprises or start-ups. The possible formation of fundamentally new types of products and services will be considered and more importantly, competencies of human resources that meet the requirements of the modern knowledge economy. Thus, networking principles of interaction become prevalent in the medium and long term.

Furman *et al.* (2002), devoted to the study of the network as a mechanism for coordinating the actions of the economic activity and network communications as catalysts for increasing the efficiency of innovation activities. Within the framework of this paper, the model of Triple Helix Model Itzkowitz – Leidesdorff is taken as a foundation (Loet, 2012) which is suitable for describing the processes of network interaction within the national and world economic systems, a separate industry or segment. This model is a universal and most rational form of an innovation system, since it is suitable for a market and non-market structure of society. The triple helix model is a mechanism for sustainable innovation development of actors within the framework of network interaction, combining the efforts of the state, business and the scientific and educational complex. As a result of co-evolution, the three sectors intertwine their functions, partially replacing each other and evolve into hybrid networking organizations. At the same time, the state and universities interact at the stage of creation new knowledge, universities and enterprises - with the transfer of technology, and enterprises and the state - in the process of scaling the final product. An expansion" of the "triple helix" model to four and five actors shows the need to include the individual in the institutional models of the innovation process. In addition, the expansion of the "triple helix" model makes it possible to challenge the assertion about the dominant position of science in the system of innovative development. Within the framework of this article, the prevailing role in the innovation process assigned to business, which, on the one hand acts as an active developer and manufacturer of innovations, on the other hand, it is the main customer and consumer of innovations. The innovative activity of enterprises (mostly industrial) is manifested in the formation and actualization of innovative needs (the need for new knowledge, technologies, goods and services), transition of innovative products into society through replication and commercialization. Thus, enterprises to a greater extent determine the mechanisms of innovative development branches of the economy (territories). One of the main disadvantages of the model "Triple helix" is the lack of accounting the influence of various social strata on the innovation process. This takes into account the concept of four-link helix (Quadruple Helix), described by (Carayannis and Campbell, 2012). This model assigns the main roles in the innovation process to science, industry, state and society (Fig. 1). Since society is the end user of innovation, it significantly influences the creation of knowledge and technology. The most important system-forming element is the resource of knowledge, which, as a result of circulation between social subsystems turn into innovations and know-how, implemented in society and economy.

Figure-1. Model assigns the main roles in the innovation process to science, industry, state and society.



The Quadruple Helix can be used as a model to integrate interaction of four sectors involved in socio-economic processes. Government, academic sector and industry direct their actions "from above down", through the regulatory framework, conditions for obtaining education, career development, labour requirements. Community acts "from the bottom up", through an active civic position, participation in the scientific, technological and economic development of the Government. The effectiveness and sustainability of the system is determined by inter- and intra-sectoral interaction which allows to combine the existing experience and knowledge in order to solve important socio-economic tasks. Thus, the four-link helix model supports a knowledge democracy for the reproduction of knowledge and innovation, which requires a co-ordination of the knowledge economy with the knowledge society. The intensive growth of network structures in the global space, on the one hand is evidence of the relevance and a high research value of studying the phenomenon of networks.

2.2. 3D Printing Technology

3D printing is rapidly gaining popularity, more affordable 3D printers appear. In particular, there is a breakthrough in materials used for 3D printing - an environmentally friendly clean materials. Today, modern 3D printing technologies are being actively implemented in many sectors of the economy, including medicine, industry (automotive, aviation and space, military-industrial complex, etc.), architecture, science, etc. The worldwide market for 3D printing products and services was valued at around 13 billion U.S. dollars in 2020. The industry is expected to grow at a compound annual growth rate of more than 26 percent between 2022 and 2024 (Statista Research Department, 2021). There are prerequisites that in the coming years, 3D printing will be able to occupy a noticeable niche in such areas as machine and automobile manufacturing, architecture, construction, geoformation systems, medicine, clothing and footwear production, food processing, packaging, souvenirs, toys, etc. At the same time, almost everything can be made: houses, cars, art objects, prototypes and conceptual models of future consumer goods or their structural details, samples for testing, prostheses for dentistry and other areas of medicine and much more. Manufacturing can be carried out in the form of single samples or be in the nature of small-scale production. As a material for 3D printing already currently used:

1) Various types of plastics and polymers: ABS / PLA, nylon, acrylic, photopolymers;
2) Metals: from tin and aluminium to stainless steel and titanium;
3) Gypsum powder;
4) Wood fibre, paper;
5) Wax;
6) Living organic cells;
7) Food products: chocolate, sugar, dough, butter.

The development of 3D printing technologies and their high prospects make the issue of their application in pedagogical activity especially relevant: since the education system is designed to prepare future generations for life in conditions information society and digital economy, then the introduction of advanced information technology in the educational process is of paramount importance. Enhancement awareness of both teachers and students at all levels of the education system about technological innovations, as well as opportunities, principles and directions of their consistent application in the educational process has a great role to ensure high quality education in the digital age.

The purpose of this part of the literature review is to research the essence of 3D printing technologies and their definition places and roles in the modern educational process, identifying the benefits of their use for teachers and students, as well as the development of proposals for optimization introduction of 3D printing technologies into the activities of educational institutions of all levels. For a more complete description of 3D printing technology and identifying its essence, it is advisable to consider what a 3D printer is.

A 3D printer is a special device to output 3D data. Unlike traditional printer that displays two-dimensional information on a sheet of paper, a three-dimensional printer allows you to send three-dimensional data, i.e. create certain physical objects. The advantages of such devices over conventional modelling methods are - fast speed, easy to create and low cost. For example, creating a model by hand can take several weeks or even months depending on the complexity of the product, resulting in development costs and time manufacturing of products is significantly higher than when using 3D printing. The 3D printing technology is based on the principle of layer-by-layer creation (growth) of solid model, and this printing technology itself is a quick way to prototype objects without mold making. Based on the digital 3D model file, the printer builds an object by printing materials in layers. This technology needs much less raw materials than the traditional one which uses coarse pruning. Thanks to changing the configuration of the model, it can be more flexibly respond to the needs of consumers. In general, 3D printing technology can completely eliminate manual work and the need to do drawings and calculations on paper, because the program allows to see the model from all sides even on the screen and eliminate all shortcomings directly during the development process, in contrast to the manual method of forming the model, in which they are found already in the manufacturing process, and also allows to create a model in a few hours. Thus, the likelihood of manual errors when using 3D printing technologies is practically eliminated. 3D printing is actively transforming many industries in the modern world, but it is just beginning to be seen as an effective tool in education. For application 3D printing technologies in the educational process should be viewed through the prism of proven the theory that hands-on learning contributes to more effective assimilation of the material by learners compared to conventional learning taking notes of lectures. Thus, the use of 3D printing allows students to gain benefits in almost any areas of science, providing students with the opportunity to better understand concepts in mathematics, geography, history and design through the practical implementation of their own real projects. It should be noted that the active use of 3D printing technologies in world practice has already gained a certain spread: in accordance with analysts' forecasts IDC, in 2018 educational institutions around the world will spend 974 million US dollars on these technologies (IDC, 2018).

3D printing technology is unique because provides an opportunity for individual modelling and production. Based on network platforms, supply and demand can be integrated for fast delivery a variety of creative solutions. In this way, many creative products and ensure that the time and cost production of these products will be close to the time that occurs with large-scale production. This flexible production mode will meet the public demand for innovative ideas.

2.3. 3D Printing Technology in Developing Learner’s Innovative Thinking

Such a rapid pace of development of 3D technology made it inevitable the need for its widespread introduction into the educational process. Providing students with access to 3D printing technology allows them to turn from a developer of unrealized ideas into a creator of innovative solutions, to touch real production, where 3D printing will become an obligatory part of the technological process. The introduction of modern 3D printing technologies partially solves the tasks set time and new learning standards: teachers and students "adapt" to all difficulty levels. Moving from general to specific and considering implementation opportunities high school 3D printing process should note that a significant increase in the assimilation of the material during its visualization is undeniable fact. In this regard, it is necessary to increase the proportion of practical training in the structure of curricula. At the same time, a special device that can at any time create the necessary educational material that makes it easier to explain a new topic, for example, in chemistry or physics lessons, is considered as an innovative tool, it is essential enhancing effect. Application of 3D technologies in education will provide a significant innovative impetus in such areas as:

- Industrial design and mechanical engineering

- The possibility of mechanical design, functional testing almost immediately, during the educational process. 3D printing, included in the curriculum of engineering disciplines, will enable students to realize their design ideas, thereby increasing the share of innovations in their projects;

- Architecture and construction – creation architectural models and structures of the most important elements, visualization of projects;

- Medicine - anatomical modelling, surgical planning, prosthetics. 3D printing technology is also essential facilitate experiments in biotechnology (for example, the creation of artificial tissues human organs);

- Geography and archaeology - 3D modelling and visualization of the area, archaeological finds and ancient fossils;

- Biology and chemistry - the ability to create full-color molecular models, clearly demonstrate DNA chains, electric charge or the structure of an atom.

The use of 3D printing technologies opens a fast path to iterative modeming. Students can create 3D parts, print them, test and evaluate them. If the details don't work, second try is not a problem. Therefore, the use of 3D printing technology inevitably leads to an increase in the share of innovation in student projects. Introducing students to the workings of a 3D printer and the ability to print becomes very an important element of the learning process, especially for students of technical specialties and designers. The first category of students has the ability to draw diagrams, exercise calculations, create drawings, and then model parts of buildings and engines, new devices. Design students, in turn, have the opportunity not only to work with 3D modelling, but also to implement the most daring creative ideas: to recreate the art of the ancient world, sculptures, paintings, architecture, modelling of interiors and houses, development souvenirs, creation of designer collections clothes and accessories. The general benefit of using 3D printing is a significant increase in the interest of students in the educational process, since it allows to visually and tactilely evaluate and test the results of their work. There is a wealth of research and evidence that the effectiveness of training increases through active experience, especially in spatial and abstract concepts that are difficult to visualize. Penetration of 3D printing technologies in an increasing number of fields of science and education will lead to an increase in the demand for qualified specialists in this field. Using 3D printers requires an entire knowledge base necessary for modelling, physics, mathematics, and programming. Realizing this, the most progressive educational institutions, from schools to universities have already made it important element of the curriculum.

3. The Infrastructure and Challenges

The key objective of the Ibtikar Club was to provide a non-formal education and to promote creativity and inspire innovations. Innovation club was created to help to engage young students in innovative and creative activities. This served as springboards for new ideas and innovation and thus helping the society and economy to face future challenges and meet rising aspirations of the growing population. Specifically, embedding such creative pedagogies in science education through Innovation 'Hubs' and 'Clubs', would have potential to retain talent in modern science.

At the initial stage, Ibtikar club was considered as a playground for creativity. Part fabrication and prototyping studio, part hackerspace and part learning center. Thus, it was planned to provide access to a wide range of professional equipment and software to offer comprehensive instruction and expert staff to ensure a meaningful and rewarding experience for the students. Considering this, the club managers were not sure what type of equipment to choose first and some considerations, the following equipment support was taken:

- 3D Printing Workstation
- Electronics Workstation
- Laser Cutting Workstation
- Audio Visual Workstation
- Sewing Workstation
- Learning Kits
- Computer Hardware

As said at the beginning, the lab was planned to be used for necessary basic facilities to pursue creative and innovative hobbies/activities that involve model making, basic science experimentation, design and fabrication of useful gadgets of practical use, teaching/learning kits etc. Students could learn to do things with their own hands, dismantle, reassemble and remake devices/gadgets. However, after a careful consideration and budget allocations, the project infrastructure has being changed. The focus was oriented on 3D printing experience only where students could generate their own innovative ideas and create an idea bank. The best innovative ideas were chosen for experimentation/model making/project work. Another focus was to bring together deep expertise and experience in contributing to Higher Colleges of Technology 4.0 vision (Employability and Beyond) of preparing students for the future labour market, equipping them with skills for Industry 4.0 and the Innovation age. Thus, allocating equipment for the purpose of innovation became essential. This was one of the most overlooked resources, yet without it, innovative ideas can never be carried out or tested. The selected list of equipment for the innovation lab together with the software and hardware was obtained.

The list of finally obtained 3D printers and filaments is: Raise3D E2, Raise3D Pro 2, Raise3D E2, Formlabs Form 3, and Raise3D Premium PLA. Raise3D machines are known for reliable, easy to use and professional 3D printers. The current Raise3D E2 is an innovative 3D printer for the education sector and may achieve impressive results. It enables to produce prototypes, tools and small series. Formlabs Form 3 takes control of large-scale part production, increase the throughput, and brings biggest ideas to life, a cost-effective large format 3D printer that doesn't compromise on the details. In overall, after installing and testing the equipment the club has started to operate and serve as a playground for creativity. Part fabrication and prototyping has started with experimentation to ensure a meaningful and rewarding experience for the students and learners.

Picture-1. (Innovation Lab site and equipment allocation)

4. First Al Ibtikar Innovation Competition and Participant's Perception

To test the lab and equipment, it was decided to organize the first 3D printing challenge – student competition. This 3D printing challenge competition was purposed to encourage students to discover needs that can be fulfilled with 3D printing, inspire students to create innovative solutions to problems, and help students find the best ways to apply 3D printing in their projects. In the process, another goal was to use this competition to help encourage the overall development of digital manufacturing technology by working towards a better understanding the main question people have about 3D printing: "What is it good for?"

The following technical parameters were observed: an object with maximum dimensions 25cm x 25cm x25cm, composed exclusively from 3D printed material. Students could choose between 3 categories:

- Consumer Markets : Sustainable sports gear, add-ons and spare parts
- Industrial Application : Design your own consumer product
- Artistic Design : Printed complexity

The competition outlined a focus on developing prototypes, resolving issues, and bringing the projects as close to completion as possible. Applications were judged on the following criteria on a 1–10 point scale: Complexity, appropriate application, completion, soft skills, and awesomeness factor. The submission requirements included the following questions:

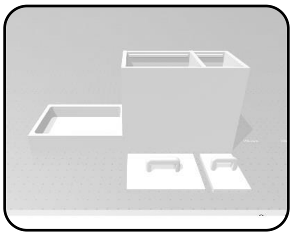
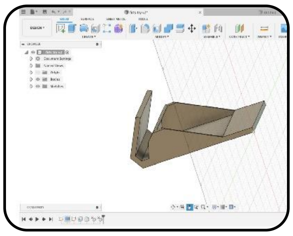
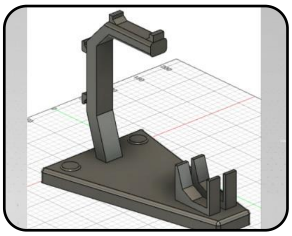
Why did you choose 3D printing in your project; How did you use prototyping in your design process; How have you used creativity in your project; How have you used teamwork in your project; How have you used critical thinking in your project; What have been the most challenging issues with your project; What have been the most rewarding outcomes from your project; Additional evidence accepted like extra pictures or videos, drawings, notes.

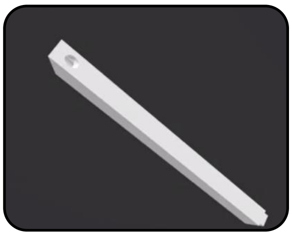
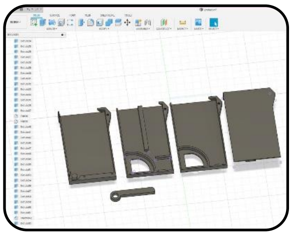
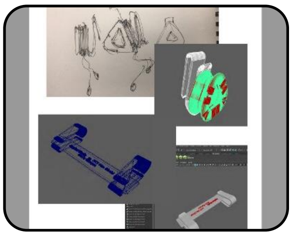
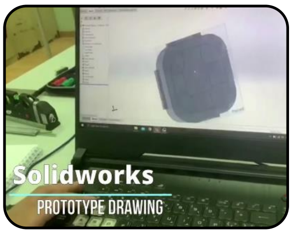
Picture-2. (Innovation completion and discussion in process)

5. The Learner's Outcomes

In total, 80 bachelor students form different programs have taken a part in the competition making up 20 different teams. Out of this number, the selection committee has chosen 7 teams with the most innovative projects. The competition set has several stages to ensure to attract the highest number of students and teams. Announcement was sent to all students along with registration link. Another registration link was shared with the faculties to nominate students. At the second stage, the students formed a team of 2 or more students in each. Participants were free to work in Al Ibtikar lab for their products and the deadline was set to submit their product prototypes. At the next stage, the student's final products were showcased virtually, along with a video describing the design and skills used and meeting the submission requirements. And finally, three teams were identified as the winners.

Below is a list of projects and description of the selected teams:

	A toothpick holder that uses gravity to come up with new toothpicks after the quantity runs out. Moreover, it does not require an external drive to do this. In addition to that, it contains a disposable incubator holder to sterilize hands in these circumstances.
	The goal of mirror projector product is to facilitate online teaching for teachers. Especially the teachers who have courses that need calculation explanation and they face difficulty to solve it on the laptop.
	Project is a headphones and controller stand which can help you organize your desktop or gaming setup.

	A LED Lamp made from 3D printer.
	A customized wallet to organize the coins instead of scattering.
	The project consists of 3D models inspired by the daily tools that are used. Laptop stand, Earphone holder, Hand phone holder.
	The button of an elevator is printed with the antibacterial material, it will prove to be more reliable and safer.

In overall, the 3D competition organized under Al Ibtikar club played an important role in the learning process as students as the faculty members taking a part in. In addition to training and competition conducted, the use of 3D printers had an impact on the modernization of pedagogy not only by revitalizing students in the educational process but also making it easy to communicate with the students.

Based on the results of the study, it was concluded that there is a very high demand for extracurricular activities related to 3D modelling and printing, and most of participants have expressed a desire to engage in 3D prototyping at the college, as well as in their future profession. The instructors noted they could update their courses syllabuses. Professional training would enable them to better understand the benefits of integrating 3D technology into the learning process. Additional knowledge and skills are required to introduce innovations into the educational environment of the HEI's. Teachers also expressed the view that developing their abilities and effective teaching requires reliable technology, peer support, learning resources, appropriate technological spaces and time to develop their abilities and create plans for extracurricular activities.

The theoretical significance of the study is that its results prove the feasibility of introducing 3D prototyping technology into the general educational process, the complex of existing basic research methods has been effectively used; the criteria and indicators of the effectiveness of the process of integrating 3D technologies in extracurricular activities have been identified.

The practical significance lies in the fact that the theoretical material contained in this case study can become the basis for the development of curricula for extracurricular activities in order to successfully integrate the innovative technology of 3D prototyping in the HEI's.

6. Plans to Further Develop the Teaching Initiative under Al Ibtikar Club

After the experience of introducing 3D printing into the college activities and conducted observation, it is possible to conclude that 3D printing technologies is the future of education. Therefore, the sooner a modern curriculum is developed taking into account the implementation 3D printers in the educational process, the more opportunities science and society will receive generally. Expansion of the range of raw materials for 3D printing also promotes its use in various disciplines. Results of a study in the field of 3D printing, its role in the educational process and benefits for educators and students make it possible to form the following recommendations for the development of the educational system of the UAE based schools and colleges:

1) Introduction of additive technologies (3D printing) in the educational process in institutions of general secondary, secondary specialized, vocational and higher education should become one of the most important directions of state policy on digital transformation and be appropriately enshrined in regulations, educational standards and curricula;

2) To meet labour market requirements of the digital economy, institutions of higher education should begin training specialists in the field of 3D technologies;

3) Effective implementation of 3D technologies in the educational process requires expansion of public-private partnership on development and application of 3D printing technologies;

4) It is necessary to resolve the issue of material and technical support of the system education in terms of 3D infrastructure that requires, first of all, the choice of the optimal models of equipping educational institutions with 3D printers;

5) It is advisable to organize courses (including webinars) for teachers and faculty on 3D printing, holding thematic forums and conferences, developing information and scientific-methodological materials for mailing to educational institutions.

Thus, the introduction of 3D technologies into the educational process will contribute to a significant increase in its quality and compliance of labour market requirements of the digital economy and the information society.

7. Conclusion

The use of 3D printing in universities and HEI's will help develop creativity and satisfy intellectual curiosity among students, preparing them for real life. They will be able to quickly develop their ideas, bring their designs to life, combine materials they have never tried before, and create amazing objects with high precision, detail and moving parts. With the advent of 3D printing in education, it will never be the same. As a result of this research, we have studied the features of the technology of rapid prototyping, as well as the possibilities of their use in the educational process. It was found that at the present stage, innovative 3D printing technologies at HCT are still at an early stage of implementation.

Nevertheless, their integration into the school educational process encourages students' interest in the further study of computer technologies, which may become a decisive factor in the choice of future professional activity. The external circumstances affecting the effectiveness of the application of 3D technologies in the educational environment of the school is the solution of issues related to increasing the technological literacy of students; training of teaching staff; development of curricula for extracurricular activities focused on the use of 3D technologies; equipping the educational space with 3D printing equipment and its maintenance; supporting educators in integrating technology into their curriculum.

The implementation of such initiatives makes sense, since the positive impact of using a 3D printer in human life is gradually becoming more obvious. At the present stage, we can say that 3D prototyping is a promising innovation that will undoubtedly contribute to obtaining a productive educational experience.

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