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Awareness Level on Additive Manufacturing (3D Printing) Technology in the Province of Bataan

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Abstract

In this paper, the level of awareness of the academic community and industries in the Province of Bataan regarding the 3D printing technology was determined. Specifically, it aims to assess the perceived knowledge of the respondents from the academe, industry and government agencies about the existence, working principles, applications and benefits of 3D printing. Survey Questionnaires were administered to three-thousand and one (N=3001) participants composed of students, faculty and administrators in secondary and tertiary institutions, industry representatives, and Local Government Unit (LGU) Department Heads in the Province of Bataan, Central Luzon, Philippines. The responses were obtained and analyzed. Results indicated that in terms of the awareness on 3D printing technology, mostly "have heard" about it, however, majority (~97%) do not know its working principle and only ~41% know the applications of 3D Printing. Majority of the respondents expressed strong interest to learn more about 3D printing. While less than 50% of the teachers and school administrators surveyed showed interest in buying/using 3D Printers. Also, majority of the respondents expressed willingness to buy 3D printed products in general. Science 3D Models had the highest response as to the beliefs of the school faculty and administrators in reinforcing learning concepts particularly in the secondary level while 3D printed machines is higher among college teachers and administrators. Majority of the respondents expressed that 3D Printing will become a mainstream practice within the next 5 years. It can be expected that the awareness level will keep increasing not only in the province but also in the country especially now that the Department of Science and Technology (DOST) has established 3D printing research and development facilities in several parts of the country as it aggressively promotes the additive manufacturing / 3D printing industry in the country.

Keywords: *additive manufacturing, 3D printing, technology, survey, awareness*

Introduction

The ever changing landscape in technology intertwined with global responsiveness foreground social sustainability. Interestingly, the emergence of advanced manufacturing technologies for one, benefits mankind in various forms. Among these manufacturing technologies, additive manufacturing, better known as 3D printing covers a wide range of production technologies that fabricate products layer by layer. Additive Manufacturing is the process of joining materials to make parts from a 3-dimensional model one layer at a time; synonymous to terms include rapid prototyping, direct digital manufacturing, additive layer manufacturing, freeform fabrication, additive fabrication, etc. (Dizon et al., 2018). Additive Manufacturing has diverse applications including health, electronics, water filtration, aerospace, construction, food, among others (Dizon et al., 2020; Advincula et al., 2020; Tijing et al., 2020; Espera et al., 2019; Diego et al., 2020; Valino, AD et al., 2019; Delda et al., 2020; Tuazon et al., 2020; Espino et al., 2020; Andres 2021).

Relatively, this study will focus on 3D printing which basically originates from a three-dimensional computer aided-design (CAD) model using a CAD software. The potential benefits of this technology may improve resource efficiency which can be realized in both production and phases of manufacturing and designing products. Through technical approaches such as rapid prototyping and rapid tooling, product design has never been faster and more economical. This may eventually reconfigure value chains having supply chains that are simpler and shorter (i.e. more efficient), production that are more localized, distribution models that are innovative and the possibility to establish new collaborations (Farayibi, 2017). It really make sense to realize that 3D printing is expected to become a key manufacturing technology in the sustainable society of the future (Huang, et al., 2013).

Globally, 3D printing has evolved to include educational applications and is now being used to empower both learners and educators in order to create more effective ways of learning, and are equipped to perform better with 3D models in classrooms (Bhatia, 2015). Further, for education applications, it is just a matter of creating and manipulating objects on using CAD softwares, and then bringing them out of the computer screen, and lastly into the hands of students for manipulation (including inspection, analysis, and etc.). In that way, 3D printers may eventually be able to bridge the gap between the physical and the digital by using the computer to find what you need, and then print it into existence. It can be used in diverse areas of education such as Architecture, Engineering, Automotive, Geography, History, Biology, Chemistry, Math Graphic, and Cooking (Staff, 2015). This emerging technology allows tangible learning patterns for students to facilitate them in free expression of interest, flexible method of engagement and presentation (Waseem, K., Kazmi, H. A.,O. Hussain, 2017). Moreover, with the vast applications of 3D printing in education it equips teachers by using 3D models that they can utilize and take advantage of in the classroom. This is particularly useful in teaching and illustrating hard to grasp concepts, and in seizing students' interests by showing models/pictorials of objects, allowing them hands-on learning by providing bigger room for interactive approach in class activities (Kharback, 2015).

Further, the emerging potential of 3D printing in education match with the necessary CAD (Information Technology), modelling and production skills, wherein students could rapidly design, prototype and modify their designs (Mark, Martens and Oxmann, 2001). Education is being transformed with the introduction of 3D Printing (3DP) into rapid prototyping in many university engineering classes; high school students are also using the 3DP to create experiential learning opportunities; medical education is being transformed by the use of 3D printing; It is also now being used in secondary schools in teaching science, technology, engineering, arts and math (STEAM) concepts (Olla (2015). Significantly, 3D printing technology has a tremendous impact in diverse fields as well as in primary and secondary schools, universities and makerspaces, but the development is slow which could be due to the limited knowledge and understanding of practitioners (Kraseentien, 2014). However, lack of knowledge and misinformation on the use of the technology may cause disruption among end users. A number of studies and reports investigating 3d printing and digital fabrication have observed that a key barrier to its wider adoption is the inadequate training/ education and skills (Royal Academy of Engineering, 2013). 3D printing is quickly gaining attention in the country due to the increasing government support, as well as several entrepreneurial/business ventures related to the technology.

Nonetheless, underscoring the great opportunities that the academe may derive from 3D printing, it may remain just futile ideas if the end users are not fully aware of the technology. What may be the sense of these innovative ideas if the benefits may not be realized into the context of alleviating responsive education? Foremost to consider is their comprehensive knowledge and awareness amidst the existence of 3D printing. Thus, the premise to determine the level of awareness of the end users in the academe including administrators, faculty, employees and students are valued to strengthen the opportunities other than the benefits one may get from this innovation.

The general objective of the study is to determine the level of awareness of the academic community and industries in the Province of Bataan regarding 3D printing. Specifically, it aims to assess the perceived knowledge of the respondents from the academe about the existence, principles, and applications of 3D printing. Also, this study intends to identify how 3D printing is utilized in the areas of teaching and learning of the respondents.

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Additivive Manufacturing (AM)

Additive Manufacturing (AM) is the creation of parts (from a 3D model data) one layer at a time (Campbell et al., 2011). Additive Manufacturing encompasses a wide range of production technologies to fabricate parts layer-by-layer, which enable on-demand printing of 3-dimensional objects (Farayibi, 2017). AM is synonymous to 3D printing, freeform fabrication, rapid prototyping, additive layer manufacturing, direct digital manufacturing, and additive fabrication (Wong, 2012). The 3D printing technology makes virtual designs which turn digital designs into solid objects. 3DP revolutionizes designs to fulfill demographic, social, economic and geopolitical, environments (Baumol, 2004). Similarly, Williams (2011) attributed 3DP to set new paradigms for engineering designs as well as manufacturing that has to be profound in demographic, geographical, economical, geopolitical, environmental, and security.

3D Printing Process

The 3d printing process starts with a three-dimensional computer-aided design (CAD) model, this can be generated using a 3d scanner or a CAD software. The model is then saved as an OBJ, AMF or STL file format. The model is then sliced into several hundreds or thousands of layers, here a slicer / slicing software is used. The sliced file will then be sent to the Additive Manufacturing device, a.k.a. 3D printer. The 3D printer will then print the part layer by layer, and repeatedly until the three-dimensional object is formed. After printing, the part will be removed from the build plate and cleaned. Post-processing may be needed to obtain the desired property. Post-processing may include curing, painting, annealing, etc. (Dizon et al., 2021).

3D Printing in Education

3D Printing technology creates a huge impact in diverse fields which include different levels of education including those in the elementary, high school, universities/colleges, as well as in makerspaces (Krashien, 2014). 3D printing indulged into educational system to build children's interest, interaction and involvement into fabrication technologies. It further encouraged engagements of recent modern technology in Science, Technology, Engineering and Math (STEM) by providing customization in designs in reduced cost. Likewise, it made assistive technology easier but raises challenges for children (Brown and Hurst, 2012). This technology has become a basic building block of learning (education) for different age groups. Implications of 3D printing technology in higher secondary education becomes a popular medium of tactile learning aid (Buehor and Hurst, 2015) Also, this emerging technology allows tangible learning patterns for students to support and facilitate them in free expressions of interest, flexible method of engagement and presentation (Meyer,2002; Kane, 2015). The study of Ford (2016) concerning the application of 3D Printing in education identifies that 3DP is being applied across K-12 spectrum and in universities as well as in makespaces, libraries, and special education settings although adoption is isolated in pockets of excellence and faces integration challenges. Results of the review revealed that 3D printing is being used to teach other students and educators about 3D printing and to develop 3D printing skills; to develop design skills and methodologies for creativity; and to create artefacts that can be used as learning aids or assistive technologies in special learning settings. Eisenberg (2013) offered several advantages of 3D-printed artefacts relative to virtual, screen based artefacts including self-directed construction, physical tactility, the improved capacity for independent and introverted work, and the improved observability of the physical artefacts that are created. More so, Kostakis, et.al. (2015) identified several challenges in the adoption of the 3D printing technology. For one, they observed that the learners acquire knowledge instead of dry information out of textbooks. Overall, studies revealed that incorporating 3D printing into teaching was positive and that it helped students be more creative. In terms of pedagogy, the use of 3D printing enabled different learning styles to be practiced, and the ability to engage certain students.

Materials and Methods

This study used a mixed method, descriptive cross-sectional design and data was supplemented by qualitative information through Semi Structured Questionnaire and Focused Group Discussion. In the Quantitative part, a descriptive cross sectional research design was used since this will attempt to describe, measure and analyze data to find out the level of awareness on Additive Manufacturing Technology in Bataan. And in the Qualitative part, a Focused Group Discussion (FGD) and personal interview with students, faculty members, engineering personnel, School, City government and industry administrators were used. Table 1 provides a thematic analysis on the result of the FGD.

Table 1 Focus Groups summary of the respondents' perceived awareness on Additive Manufacturing (3D Printing) Technology

General Categories for Responses			
Have heard than know	**Source of awareness**	**Accessibility**	**Interest in 3D Printing**
Not familiar with the working principles but interested to learn and use it.	I saw this in you tube Have read about it in the internet	Have no access to desktop 3D printer	People would be interested in seeing them run.
Not available in our school	I saw it in a movie Saw in Facebook	Find it expensive	I would have been excited to see a 3D printer in high school.
Not available in the office		No budget for this We have one at home	Make cool products that people will want to try.
No knowledge in the working principle		Use this at work We have this in our school	I wish I could have used in the 3D printer in our school project

This study involved participants of different groups from the academe, government agencies and industries in Bataan. Table 2 presents the respondents per group. Table 3, 4, 5 and 6 present the Distribution of Respondents from the Academe, LGU, Government Agencies and Industry, respectively. For the academe, sample included college students enrolled in IT, Engineering, Architecture, Industrial Technology and Education and Engineering faculty, college administrators in selected colleges and Universities in Bataan; Senior High School Students enrolled in different tracks in selected National High School in Bataan; For the industries, personnel in-charge of Product Development and operations managers.

Table 2 Respondents per Group

Group of Respondents	No
LGU/ Gov't Agency	51
Industry	119
College Teachers/ Admin	54
Secondary Teachers/ Admin	167
College Students	844
SHS Students	703
JHS Student	1063
Total	3001

Measures with tested validity and acceptable reliability was applied to truly catch the level of awareness on Additive Manufacturing Technology. For the sake of discussion, a descriptive equivalent of the scale and a verbal interpretation of the range of computed scale value were included. Validated and reliable survey questionnaires on level of awareness were used and adopted. As the study used the multidimensional perspective of awareness, the questionnaire is composed of different subcomponent surveys depending on the group of respondents. A semi-structured interview and focus group discussion guide was also developed to support the quantitative data.

The data generated from the survey were analyzed using frequencies and percentage. SPSS software was used to process the data. Qualitative data from the Focused-Group Discussion was used to support the findings of the study.

Results and Discussion

Table 7 shows that majority of the respondents (64%) have heard about 3D CAD, 23% know it while 13% said that they haven't heard nor know anything about 3D CAD. This implies that all the groups of respondents expressed familiarity on 3D CAD. See Fig. S1 for details. Among the respondents who anwered "yes, they know 3D CAD" majority or 87% have had not yet tried doing 3D CAD (as shown in Figure S2), while 13% said that they had the chance to do 3D CAD. In comparison to other countries for example, Danso (2013) found that majority of the respondents (76.9%)

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Table 3 Distribution of Respondents from the Academe

School	Senior HS	Junior HS	Faculty/admin	College	Faculty/Admin
Public Schools					
City of Balanga HS	45	68	19		
BNHS	15	75	24		
Pablo Roman HS	86	86	18		
Orion NHS	12	62	8		
Limay NHS	84	35	9		
Luakan NHS	76	41	14		
B Camacho NHS	82	12	12		
Samal NHS	31	105	13		
Orani NHS	45	102	18		
Hermosa NHS	20	31	11		
Private Schools					
Bataan Christian School	54		21		
Tomas del Rosario College		31			2
Asia Pacific College		15		24	1
Heroes Memorial College				36	1
BPSU					14
Engineering				135	
CICT				251	
Psych				84	
Educ				189	
BSBA				125	
Faculty					36
Total	**703**	**1063**	**167**	**844**	**54**
Target Respondents	1000		100		

Table 4 Distribution of Respondents from the Local Government Unit

LGU	Balanga	Abucay	Pilar	Orion	Limay	Mariveles	Bagac	Morong	Samal	Orani	Hermosa	Dinalupihan
Committee on Education	4								3			
Mayor's Office			4	1	1	1	3	3		3	4	4
Tourism		3										
Total	**34**											

Table 5 Distribution of Respondents from Government Agencies

Government Agency	No.
Tourism	3
DOST Bataan	3
Engineering	6
DTI	5
Total	17

Table 6 Distribution of Respondents from the Industry

Company	No.
AFAB	
– Finance Budget	2
– Deputy Administrator	2
– Legal Department	2
– PSS	2
– Freeport Facilities	2
– ODA	1
– OCA	1
– Community Services	1
– Administrator	1
Business Establishments in Bataan	58
PPMI	2
GN Power	6
NGPT-Mariveles Solar Powerplant	5
Bataan Baseco Joint Venture	7
Other Locators	27
Total	**119**

knew at least one CAD software program, while ~23.1% do not know any CAD programs at all.

Additionally, the authors observed that majority of the Polytechnic students in Ghana uses AutoCAD. Another interesting finding in their study was that, 72.9% of the students used at least one of available CAD softwares. The study concludes that though majority of the students knew and used CAD programs, much needs to be done to ensure application of the CAD software by all students. In our study, only 51 out of the total 564 students (Junior High School, Senior High School and College Students) or just 9.04% had experience in using CAD, as shown in Fig S2. For college students, only 21 out of 141 students (or 14.9%) has experienced using a CAD software. This is due to the lack of facilities in learning CAD softwares. Figure S3a shows that majority of the respondents (1906 or ~64.2%) have heard of 3D Scanning, 673 (or ~22.66%) said that they "know it", while 391 (or ~13.16%) said that they have not heard about it. Among the respondents who expressed that they know about 3D Scanning, majority (86%) still had not tried doing 3D Scanning (shown in Figure S4), while 14% said that they had the chance to do 3D Scanning.

Figure 1 shows that majority of the respondents (1947 or ~65.64%) have heard about 3D Printing, while 667 (~22.49%) said that they "know it" and 352 (or ~11.87%) said that "no, they have not heard or know anything about 3D printing. Based on the results in Figure S3b, Web (32%) and Social Media (24% are the major source of respondents awareness

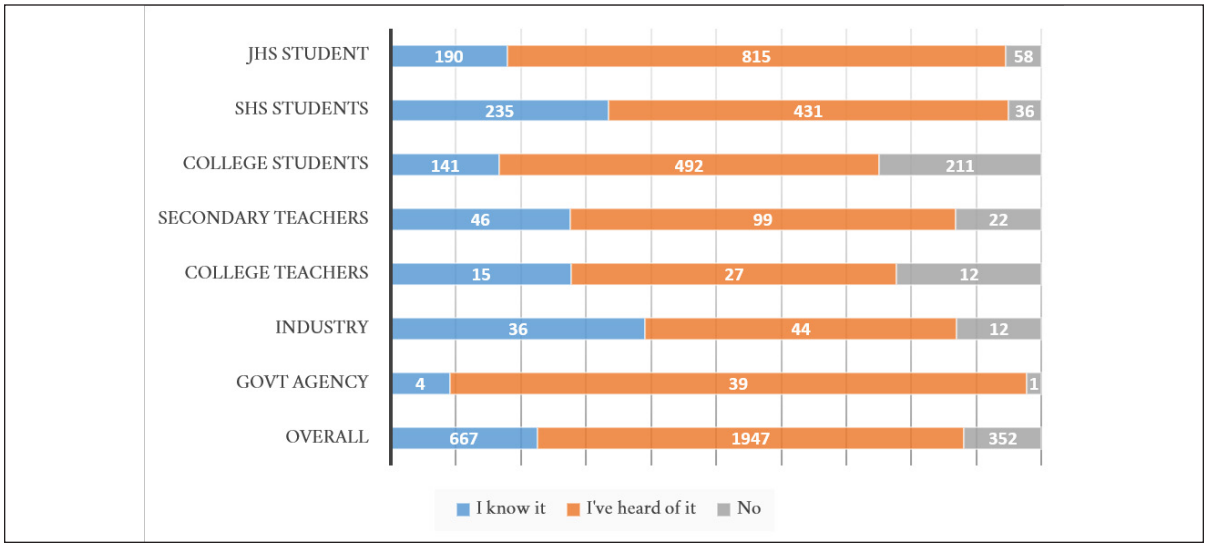

Fig 1 Respondents' Familiarity on 3D Printing

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Table 7 Summary of Survey Results on Awareness on 3D Printing Technology

	I know it	I've heard of it	Not familiar
Respondents' Familiarity on 3D Computer-Aided Design	23%	64%	13%
Respondents' Familiarity on 3D Scanning	23%	64%	13%
Respondents' Familiarity on 3D Printing	22%	66%	12%
	Yes	**No**	
Respondents' Actual Experience on 3D CAD	13%	87%	
Respondents' Actual Experience on 3D Scanning	14%	86%	
Respondents' knowledge on the principle of 3D Printing	3%	97%	
Respondents' Awareness on the benefits of 3D Printing	93%	7%	
Respondents' Awareness on the applications of 3D Printing	41%	59%	
Access to desktop 3D Printer	9%	91%	
Personal	2%		
School	98%		
	Yes	**No**	
Respondents' Interest in Learning 3D Printing	59%	41%	
Interest in Buying and Using 3D Printers in School and University	44%	56%	
Willingness to buy 3D Printed Products	94%	6%	
Respondents' Perception on 3D Mainstreaming Within the Next 5 Years	67%	33%	
Source of 3D Printing Awareness			
Family	7%		
Friends	9%		
Work	4%		
Radio	2%		
TV	14%		
Magazines	5%		
Social Media	24%		
Newspaper	3%		
Web	32%		

on 3D printing, followed TV (14%), friends (9%), Family (7%), Work (4%) and Radio (2%). Though most of the respondents expressed awareness of 3D printing, majority of them do not know the working principle of 3D printing (as shown in Table 7). This is because the 3D printing technology is being introduced only recently in the country. While it can be observed from Table 7 that majority of the respondents said that they know the benefits of 3D Printing. Table 7 shows that ~41% of the respondents know the applications of 3d printing. Figure S5 shows that nine percent (9%) of the respondents said that they have access to a desktop 3d printer while the remaining 91% have no access. Among the respondents who said they have access, only 2% of them said that they have access through their personal printer, while 98% said that they have access thru School 3D Printer.

Figure S6 shows that majority of the respondents (~94.5%) expressed strong interest to learn more about 3D printing. People nowadays, particularly the youth are interested in the opportunities of different technologies. Nowadays, an increasing number of people use the technology as it helps in shaping one's modern life. With the advancement of the technology and the benefits that it provides, people at home, in a company, in an industry, and especially in schools and universities has the eagerness to support and promote it in their everyday lives.

Figure 2 shows that Secondary Teachers and administrators expressed higher interest in buying/using 3D printers (47%) than college teachers and administrators with 41%. While Figure S7 shows that majority of the respondents expressed willingness to buy 3D printed products in general.

Table S1 shows the top 5 most preferred personalized 3D-printed products by group of respondents. For the LGU/Gov't respondents, seasonal products is the top most preferred item, followed by DIY/ Engineering, Accessories, scale models and Replicas. For Industry, scale model is the top choice, followed by replicas, DIY Engineering, Accessories and supply parts. For college teachers/administrators, scale models is the top choice, followed by DIY/ Engineering. For secondary teachers and admin, supply parts is the top most choice, for college students, parts for school projects is the most preferred choice, for senior high school students, they like DIY the most and junior high school students like accessories the most.

Science 3D Models had the highest response as to the choice of the school faculty and administrators in reinforcing learning concepts particularly in the secondary level while 3D printed machines is higher among college teachers and administrators (shown in Figure S8). In a survey conducted by Strategy& in 2015 of 38 German industrial companies, the respondents identified that the spare parts business will benefit from the 3D printing technology.

Majority of the respondents (67%) expressed that 3D Printing will become a mainstream practice within the next 5 years (as shown in Figure S9). According to Dancel (2017), the technology of 3D printing has gone a long way into the manufacturing sector, from merely being used in prototyping. Here in the Philippines, the 3D printing technology is not mainstreamed yet, most of its applications in our country are still in the prototyping stage. However, with examples of applications in our country, such as in construction and medicine, people are widening their consciousness about the potentials of the technology.

There have been several interesting applications of 3d printing in the country. One example is the successful 3d printing of the Lewis Grand Hotel in Angeles City in 2015 (Tablang, K 2015). In the health care sector, the Lung Center of the Philippines had signed an agreement with the Technological Institute of the Philippines, representatives from the Genomic Institute of Asia and Pharma Canada Ltd., to develop technology to 3D print artificial tracheae (windpipes), which is expected to extend to other body parts (Montenegro, B 2015).

In 2016, the technology was used in the spine surgery of a patient in Vicente Sotto Memorial Medical Center here in the Philippines. In the same year, 3D printed prosthesis pilot project of the Japan International Cooperation Agency (JICA) was established in the country. With these examples of the applications of the 3d printing technology in the Philippines, it is inevitable that necessity will bring about mainstreaming of 3D printing technology. For example, the technology could be applied to construction of houses in disaster- affected areas wherein construction of houses is needed at an urgent

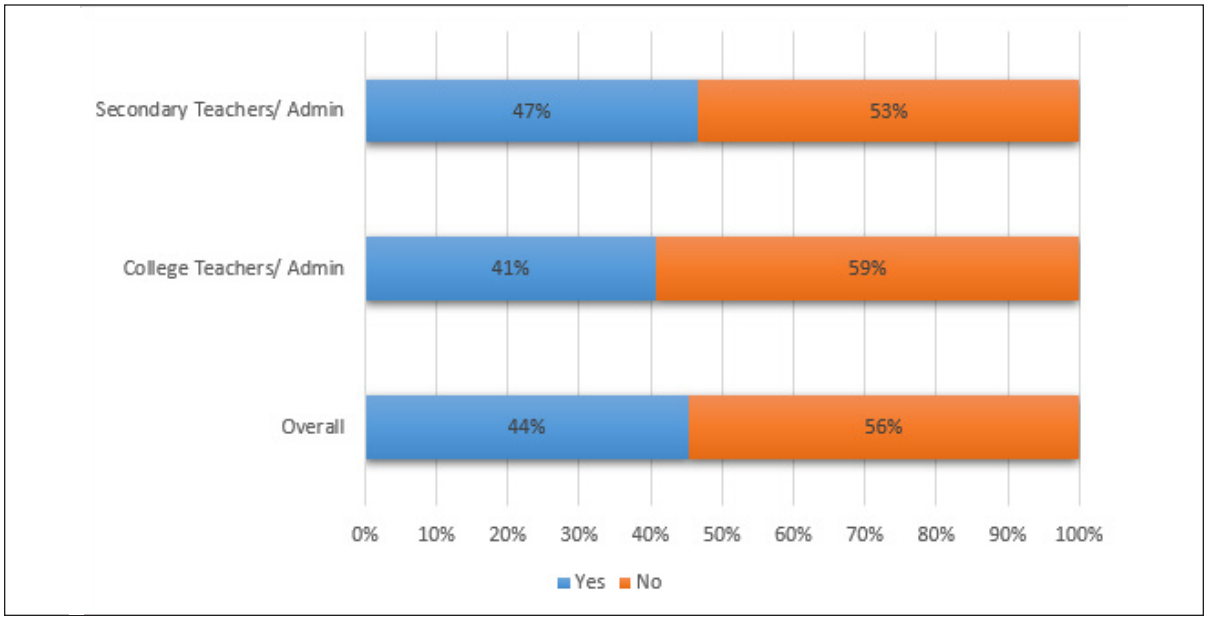

Fig 2 Interest in buying and using 3D printers in school and university

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pace that normal construction practices and processes could not deliver.

The province of Bataan is privileged to have one of the first two 3D printing research and development centers in the country (Essop, A, 2019). The 3d printing industry is expected to open the doors to previously inconceivable and unimaginable possibilities, and every single 3D-printed product will unfold more innovations. However, only few explored on the awareness and overall sentiment of people towards the potential impact of the technology.

It can be observed in the survey that very people have actually experienced 3d modelling, 3d scanning and 3d printing and fewer still know the principles behind the various 3d printing technology. Very few have access to 3d printers. It is worth noting that majority would like to know more about the 3d printing technology and that many of those surveyed would like to buy 3d-printed parts/products, and relatively few (only ~44%) would like to buy 3d printers for school/university use. The reason could be because the school administrators still do not know the potential of using 3d printers in the academic setting, but once they experience using 3d printers, it is expected that majority (if not most) of them would like to purchase 3d printers for education purposes. This research study will be a basis for training/outreach programs to teach professionals, teachers and students on the use of 3d printers. We will expect a change in perception when we conduct again a similar study in the next few years.

Summary and Conclusion

In this study, the awareness level regarding the 3d printing technology in the Province of Bataan has been determined. Specifically, it was found out that Majority of the respondents have heard about 3D Printing, however, majority do not know the working principle of 3D printing. 59% do not know the applications of 3D Printing. Majority of the respondents expressed strong interest to learn more about 3D printing. Less than 50% of the teachers and school administrators surveyed showed interest in buying/using 3D Printers. Majority of the respondents expressed willingness to buy 3D printed products in general. Science 3D Models had the highest response as to the beliefs of the school faculty and administrators in reinforcing learning concepts particularly in the secondary level while 3D printed machines is higher among college teachers and administrators. Majority of the respondents (67%) expressed that 3D Printing will become a mainstream practice within the next 5 years. The analysis indicated that there is a growing awareness on 3D Printing Technology in the province of Bataan and prospect that it will become a mainstream practice within the next 5 years. With the launching of BPSU's Additive Manufacturing Research Laboratory (AMREL), which is a state-of-the-art 3D printing research facility last March 2019, people in the province are expected to increase their consciousness and knowledge about the potential and application of the technology if concerted efforts will be made to increase the awareness and knowledge of the community on this promising technology.

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Supplemental Figures

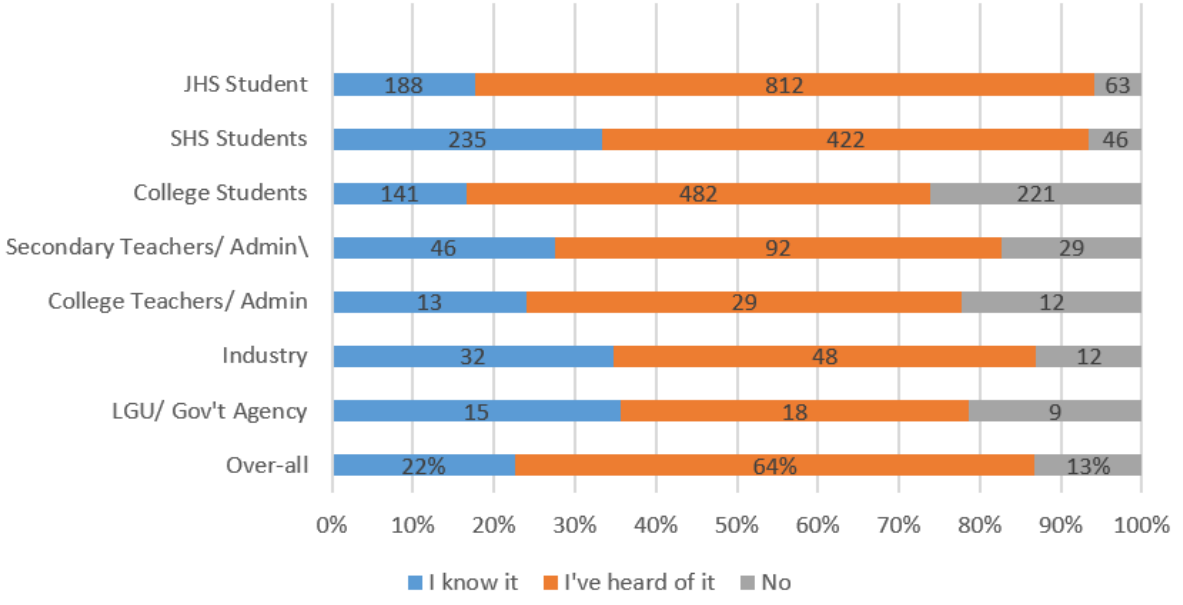

Fig S1 Respondents' Familiarity on 3D Computer -Aided Design

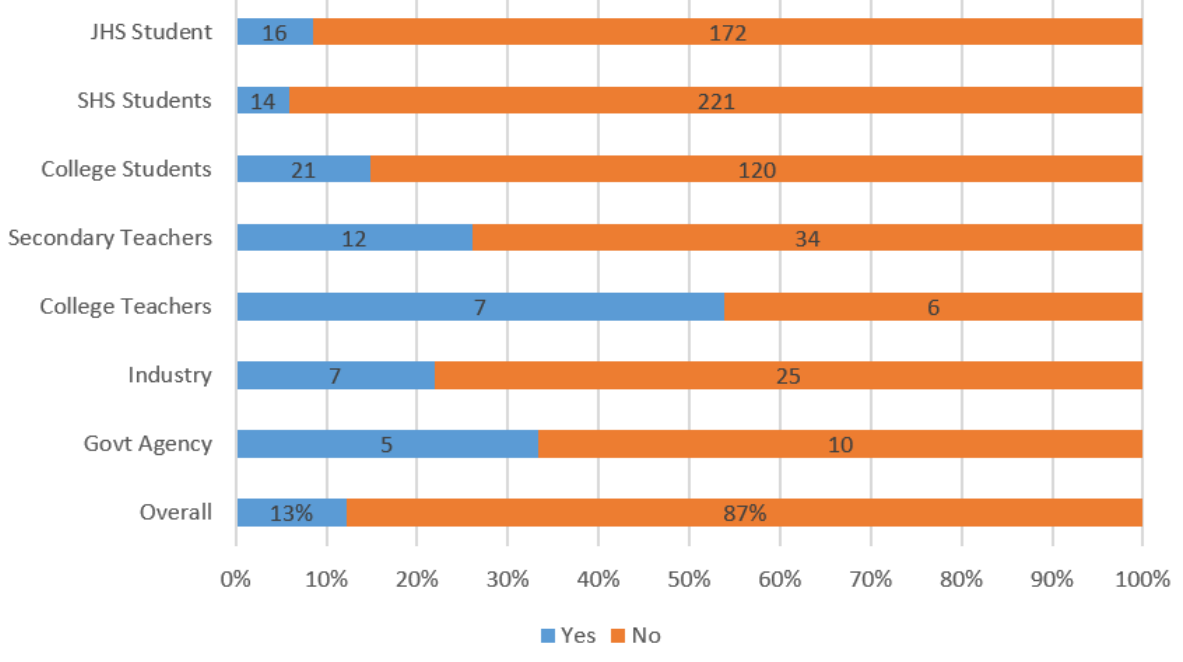

Fig S2 Respondents' Actual Experience on 3D CAD

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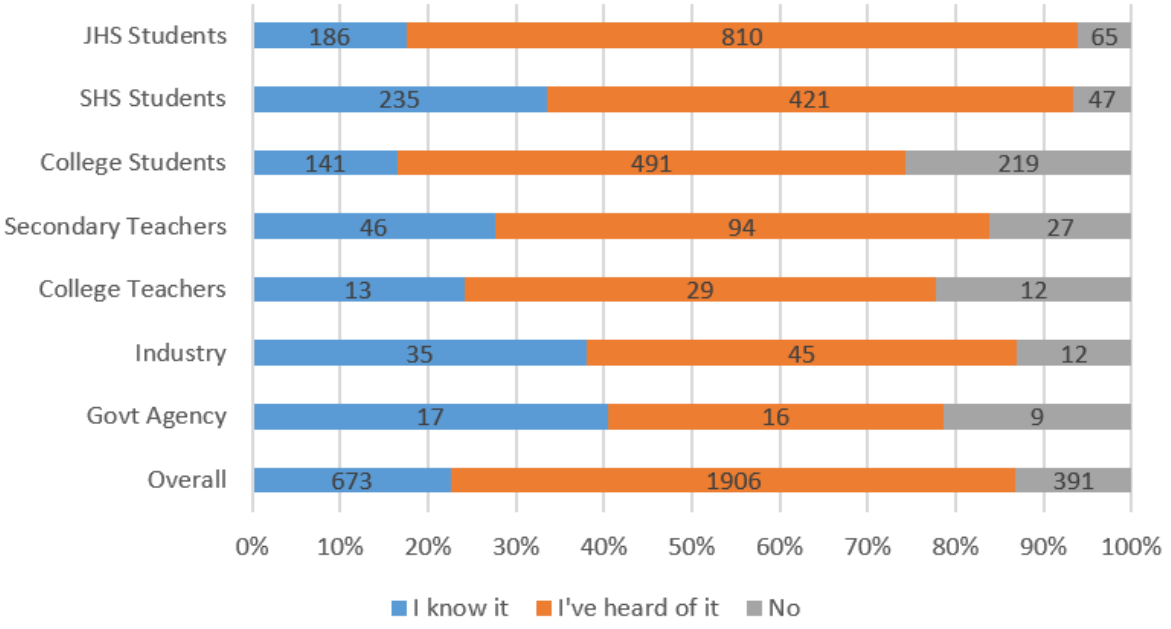

Fig S3a Respondents' Familiarity on 3D Scanning

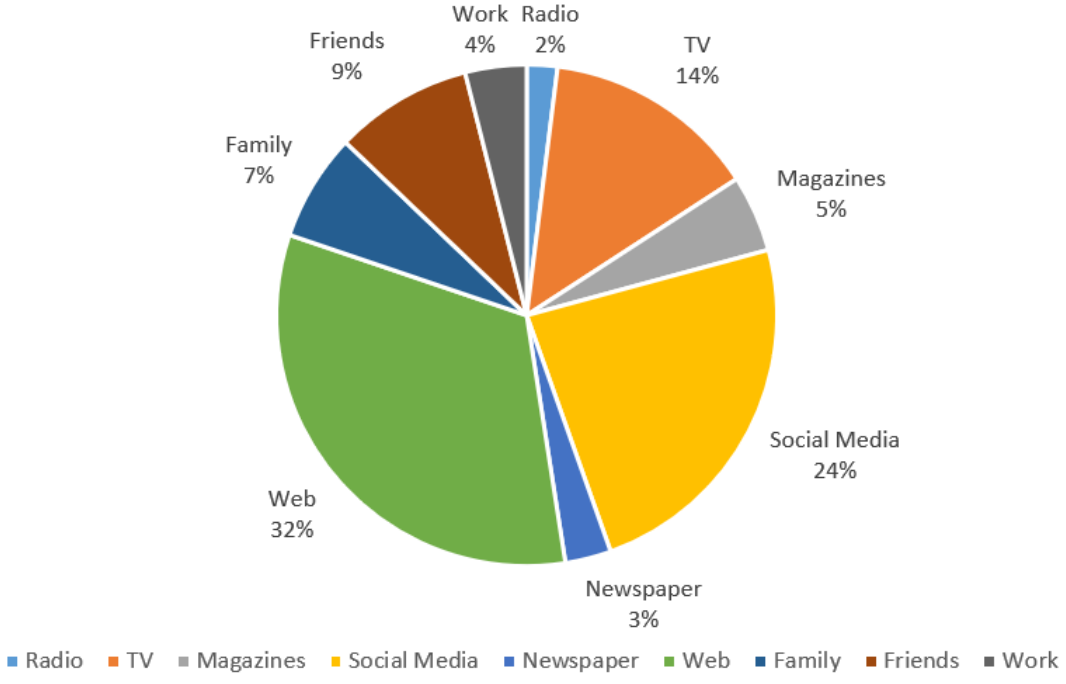

Fig S3b Source of 3D Awareness

Supplemental Figures

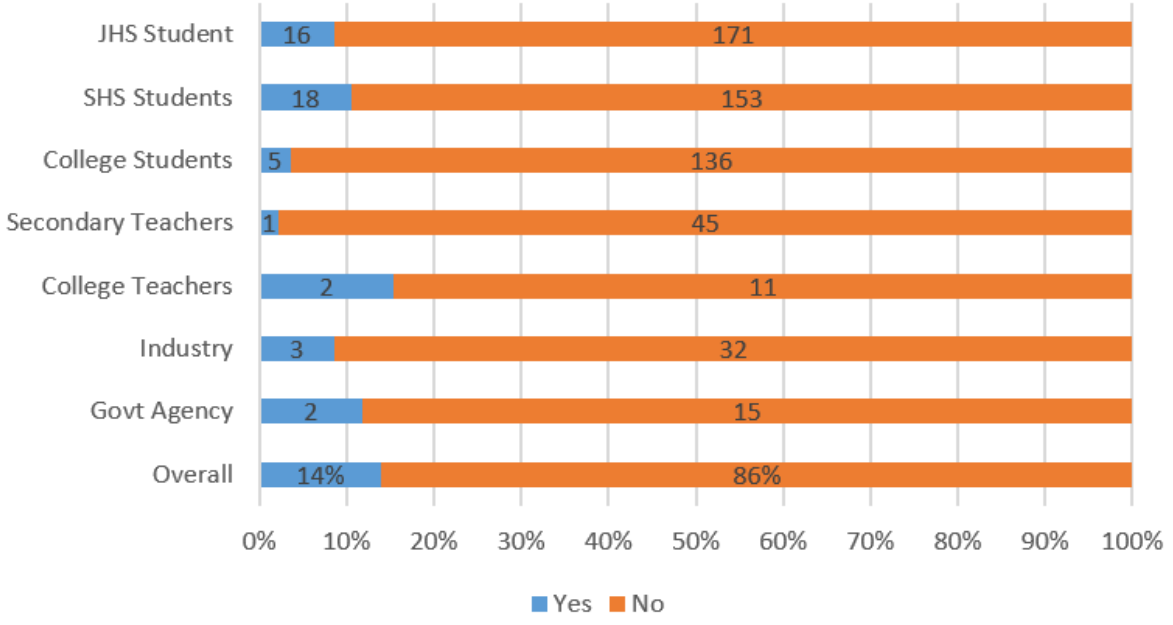

Fig S4 Respondents' Actual Experience on 3D Scanning

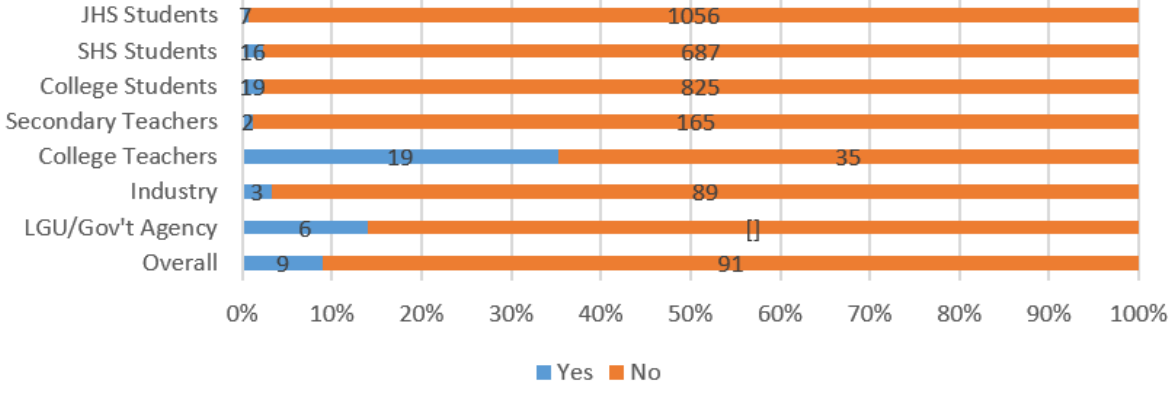

Fig S5 Access to desktop 3D Printer

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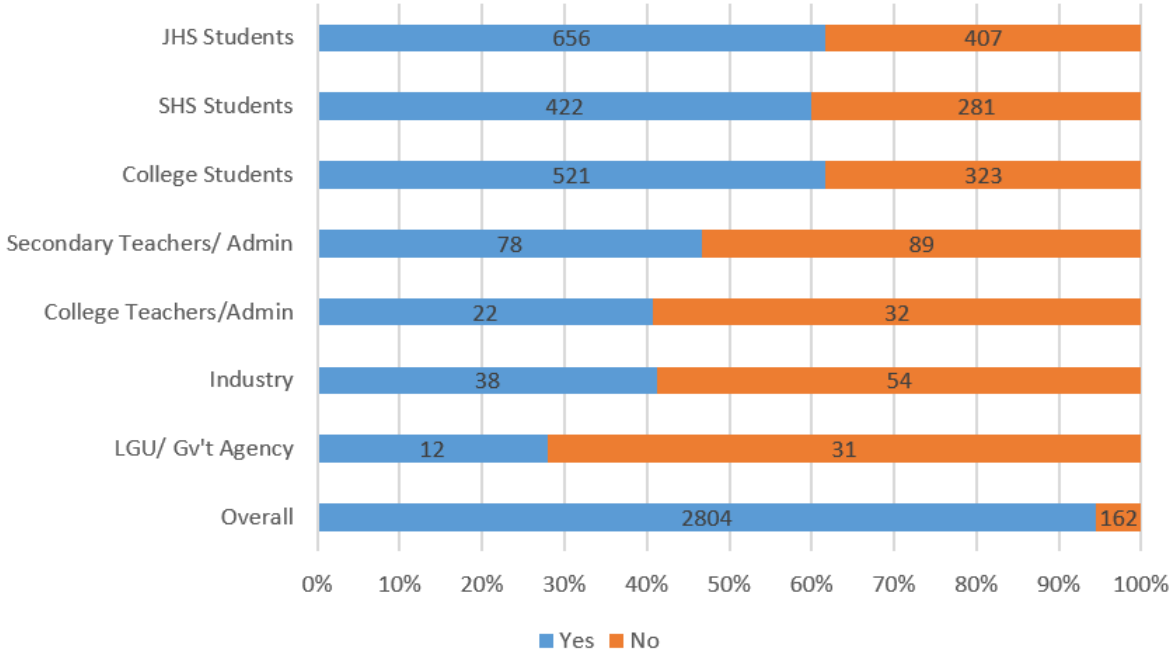

Fig S6 Respondents' Interest in Learning 3D Printing

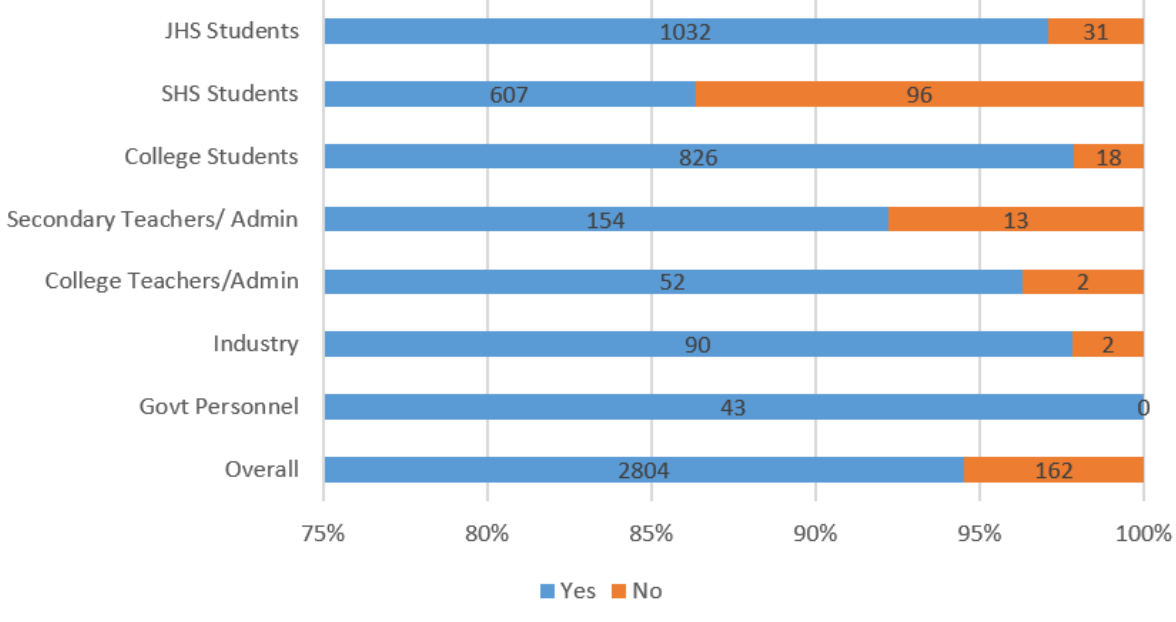

Fig S7 Willingness to buy 3D Printed Products

Supplemental Figures

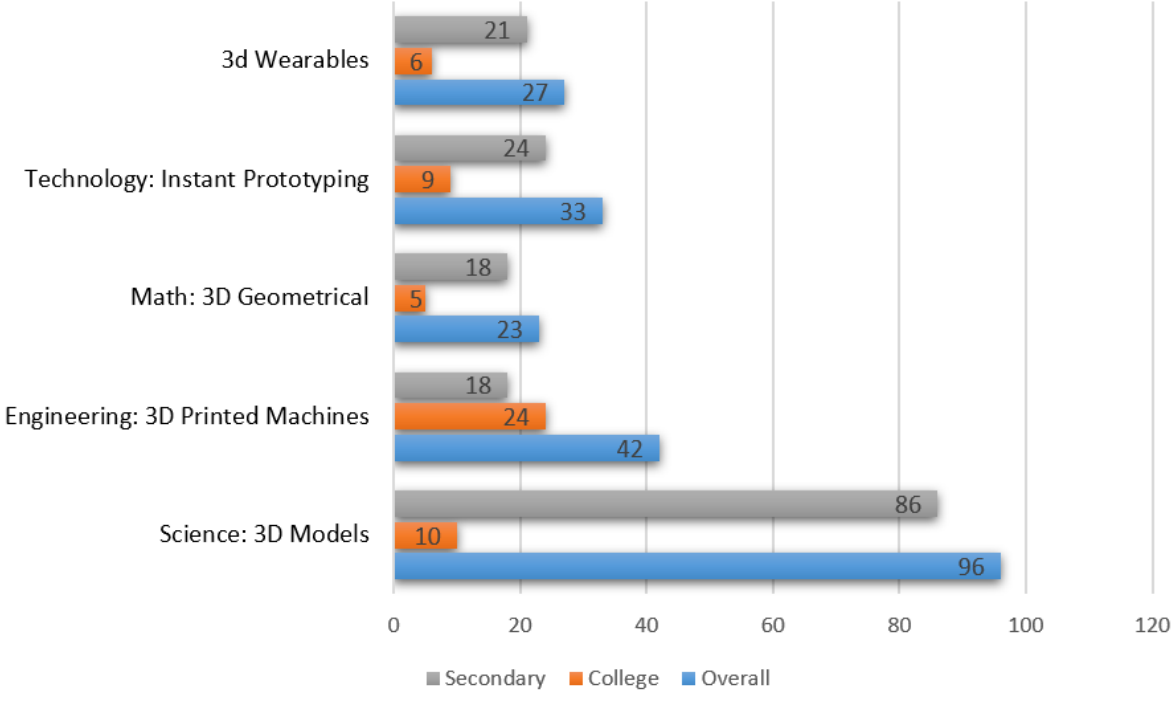

Fig S8 Respondents' Choice of 3D applications useful in reinforcing learning concepts

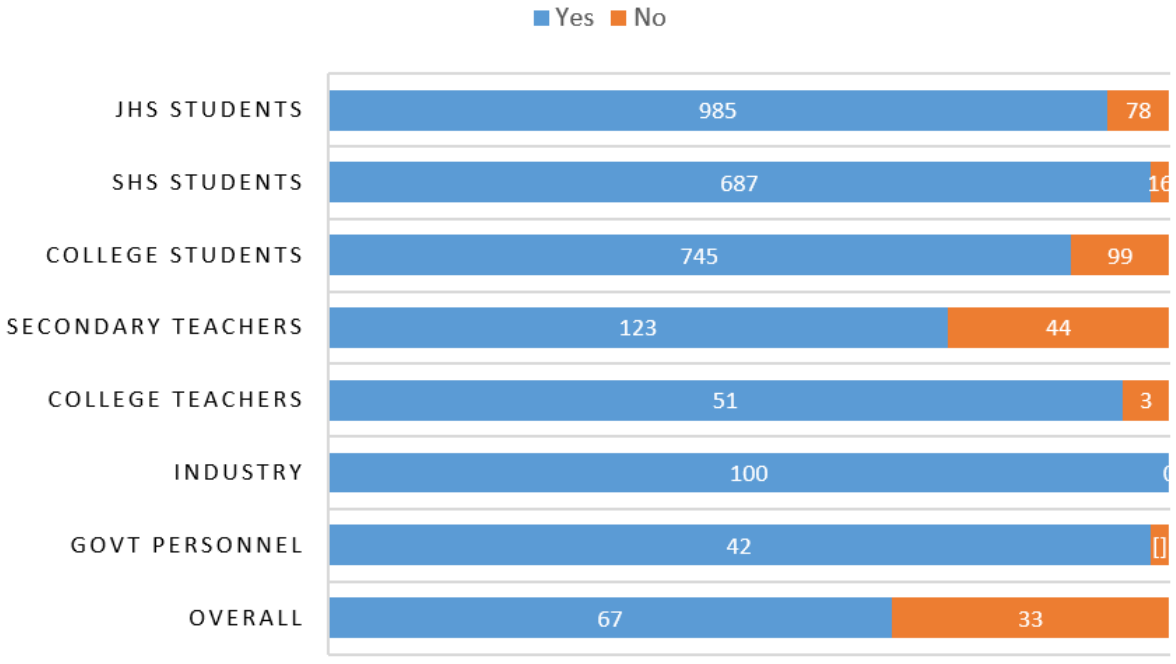

Fig S9 Respondents' Perception on 3D Printing Mainstreaming Within the Next 5 Years

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Table S1 Top Most Preferred Personalized 3D Printed Products

3D Printed Products	LGU/ Gov't Agency	Industry	College Teachers/ Admin	Secondary Teachers/ Admin	College Students	SHS	JHS
Accessories	3rd	4th			3rd	5th	1st
Art							
DIY/ Engineering	2nd	3rd	2nd	4th	4th	1st	
Fashion & Jewelry							3rd
Fan products				5th			
Figurines							
Seasonal Products	1st		5th				4th
Scale Models	4th	1st	1st	2nd	5th		
Supply Parts		5th	4th	1st			
Presents					2nd	3rd	2nd
Replicas	5th	2nd	3rd			4th	
Toys							
Parts for school projects				3rd	1st	2nd	5th

(Q15.Which kind of personalized (3D Printed) would you be willing to buy online?)