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3D printing as a part of Finnish practical nurse students' technological acceptance – a qualitative study

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Abstract

3D printing is a solid part of the health care environment, and in the future, it could assume a more innovative role in the work carried out by practical nurses. However, the educational context may not support the preparedness to face and adapt new and creative technologies on the part of practical nursing students. This study aimed to describe practical nursing students' technological acceptance towards 3D printing before and after six hours of 3D printing instruction. The technological acceptance model was used as a framework of the study. The data was collected using focus group interviews that 14 practical nursing students participated in before and after their six-hour 3D teaching course. Along with the thematic analysis, the interview themes were created in accordance with the theoretical elements concerned.

The results showed four narrative themes that described how a six-hour lesson series changed the students' technological acceptance towards 3D printing, from: 1) professional meaningless to everyday usefulness, 2) resource dominance to a part of working life, 3) special competence to ease of use, and 4) assumptions to limitless possibilities. Every theme consisted of two subthemes. Despite having been a new thing for students, 3D printing could be conceived in terms of having professional significance. The students described 3D printing as being easy to adapt to and they highlighted the meaning of its educational usage, as it could prepare them to be better with respect to applying creative working life-based technological solutions.

As a conclusion, it can be stated that even short educational sessions can promote practical nursing students' technological acceptance towards 3D technology and the know-how to implement it in working life. This requires educational institutions to target resources to 3D printing and on teacher education.

Keywords: three-dimensional printing, health education, technological innovations, vocational education, practical nursing

Introduction

In the future, educators should target their teaching so that students know more about digital technologies as part of their education [1]. This means that students should use and know the basics about various digital technological solutions when the context of the education concerned is based on creative thinking [2-4]. Health care education is a large entity that is facing this challenge [5].

Three-dimensional (3D) printing is a promising technological tool in education, because of its huge potential to utilise various material [6]. 3D printing has supported students' teaching and learning a lot in engineering, for example [6-8]. The medical meaning of 3D printing is huge in health care with regard to medicines utilising 3D printing in various operations; for example, with 3D printed dental objects for human applications [9-10]. Along with such medical utilisation, ethical considerations round 3D printing have also arisen, highlighting the importance of valid knowledge concerning the 3D printing process [11]. In addition to the clinical meaning, medical education is utilising 3D printing with promising learning outcomes [12]. Aside from the medical aspect, the research from the rest of the health care context is quite incidental [13], with some supporting results [14,15].

In order that health care teachers are able to understand the diversity of 3D printing, they first need to understand the pedagogical potential of the 3D printing; e.g.that 3D printing can be a part of the learning environment [9], it can be used to create low-cost teaching tools [8], or it can be used to support students' technological acceptance [14]. With using 3D printing, teachers can aim to develop students' computational thinking [16,17], which will be a critical element of creativeness and innovativeness in the future [17]. Secondly, teachers throughout the health care sector need more research into 3D printing and how to apply it in teaching [18]. The perspective of technological acceptance is one promising aspect to approach this new kind of technological tool, whilst simultaneously it has been validated in various educational contexts [19].

This research is connected with 3D printing as a new technology in the health care education respective to vocational instruction, where the need for research-based knowledge has been underrated [20,21]. For this reason, the qualitative study concerned aimed to describe practical nursing students' technological acceptance towards 3D printing. To identify technological acceptance with depth, this research implemented focus group interviews before and after a short course in 3D printing. Two research questions guided this study:

1. How do practical nursing students describe their technological acceptance towards 3D printing before having lessons on 3D printing?
2. How do practical nursing students describe their technological acceptance towards 3D printing after having lessons on 3D printing?

Three-dimensional printing

Three-dimensional (3D) printing means a form of technology that can produce concrete objects by adding material layer by layer in accordance with a sliced digital model of this object [22,23]. 3D printing is also referred to as additive manufacturing (AM) when any industrial use of it is discussed [8]. 3D printing can apply several different kinds of materials; for example, plastic, metal, or even biocompatible material [24-26]. The process starts with a digital 3D model of the object, which can be created with several modelling programs or with 3D scanning [23,27]. After the digital 3D model has been sliced with a certain program, the concrete 3D printing can be made with a suitable 3D printer [27].

Technological acceptance model

The Technological Acceptance Model (TAM) guided this research as a theoretical framework. It was originally created by Davis [28] and highlights two elements that are essential when new technology is adapted: perceived usefulness and perceived ease of use. Perceived usefulness means the level of the person's feeling of how useful a new technological solution can be in his/her work. Perceived ease of use means how much less effort a person thinks that they should use when adapting a new technology. The extended version from the original theory (TAM2) includes more psychological dimensions with the following scales: the social influence process (image, voluntariness, and subjective norm) and the cognitive instrumental process (job relevance, perceived ease of use, result demonstrability, and output quality) [29]. Both versions of the theory can be thought to provide a guideline for organisations with regard to which elements should be considered with new technological solutions. In this study, the following categories guide the interviews and data analysis: intention to use, perceived usefulness, perceived ease of application, image, and job relevance [28,29].

TAM is validated in several varying educational contexts [19]. It has been a suitable theoretical framework for students [30] and teachers [31], though it has not been used in health care education on the vocational level. According to various technological solutions, TAM has been guiding the students' adaption of 360° videos [32] and new eHealth services in emergency care integration, for example [33]. 3D printing technology has also been researched with TAM in, for example, home contexts [34]. TAM has been used as a theoretical framework in medical education and in occupational therapy education [14,35].

Material and method

This qualitative study design was implemented with following phases:

(1) Practical nursing students participated in the first focus group interviews concerning technological acceptance towards 3D printing.

(2) Practical nursing students had six hours of lecture-based and hands-on practice concerning 3D printing.

(3) Practical nursing students participated in the second focus group interviews regarding technological acceptance towards 3D printing.

The lessons in this study lasted six hours in total and were held over the course of two days. The teaching methods used were the lecturing format and hands-on practice. The intensive instruction was implemented with the following lesson plan:

(1) Introducing what 3D printing means and how 3D printing is utilised in a health care context (duration: one hour).

(2) Introducing the entire process of 3D printing from 3D modelling to showing a 3D printer in action (duration: one hour).

(3) Students practiced 3D modelling with computers based on their own ideas. Students worked together, and the teacher only helped with technical issues (duration: two hours).

(4) Students visited a venue where they saw different kinds of 3D printers used for additive manufacturing (duration two hours). During the visit, students were shown 3D-printed hospital instruments and dental implants, for instance.

Participants

Participants of this study were final year practical nursing students (n=14) on the level of vocational education. The sample consisted of those practical nursing students who were voluntary and at a certain phase in their studies. According to the European Qualification Framework (EQF), their educational level is four, and after graduating they are qualified as licensed practical nurses. As a whole, they must achieve 180 competence points (one point is a minimum of 12 hours of students' work), which includes professional studies; for example, nursing (145 competence points out of 180 competence points) and general studies – for example, mathematics (35 competence points out of 180 competence points) [36-39].

The participants of this study had completed two compulsory study units; *Promotion of growth and social inclusion* (25 competence points out of the total of 180 competence points) and *Promotion of wellbeing and functional capacity* (30 competence points out of the total of 180 competence points). After these units, they had been selected for the competence area of children's and youth education and care on the basis of the following possibilities: (1) the competence area of podiatric care, (2) competence area of children's and youth education and care, (3) competence area of mental health and substance abuse welfare work, (4) competence area of nursing and care, (5) competence area of oral health care, (6) competence area of care for the disabled, and (7) competence area of basic life support (BLS) together with the competence area of care and rehabilitation for elderly people. Practical nursing studies in total usually last about three years [36-39].

They all had had three practical periods in working life: one period in care work among the elderly and two periods among children [36]. The study was implemented with the students from the competence area of children and youth education and care [36], due to the number of assumed opportunities to use 3D printing in working with children (e.g. low-cost activating tools) [8].

Data collection

All data were collected between 10/2022 - 11/2022 with focus group interviews. Before data collection, ethical permission was granted by the university's Ethics Committee for Human Sciences (31/2022). Data were collected in a mid-sized social and health care vocational institute in Finland.

Every practical nursing student (n=14) received the information about the research two weeks before the interviews and signed the informed consent. Focus group interviews were conducted one week before the intensive lessons and one week after the intensive lessons. 3D printing can be quite an unknown subject, and with focus group interviews it can be easier to have authentic answers from the participants who are with their student colleagues. With focus group interviews, the researcher is in a position to also guide the interviews via a structure, though the purpose was to have as many multiple perspectives as possible. No one was absent during the study, and the same practical nursing students participated in both the pre- (n=14) and post-interviews (n=14). The practical nursing students were all from the same study group and were able to determine their own focus group for interviews. All interviews were held face-to-face and were recorded. There were three focus groups before and after the course and three to five practical nursing students in each group. The two researchers from the research group conducted the interviews. The other interviewer was also the teacher of the students at some point of their studies. The research group continuously reflected possible bias in data collection [40-42].

The theoretical framework (TAM) guided the focus group interviews. The questions for the pre- and post-interviews concerned the following categories: intention to use, perceived usefulness, perceived ease of use, image, and job relevance. All questions related to these categories were asked in the same form in the pre- and in post-interviews. In pre-interviews, the baseline of the technological acceptance towards 3D printing was established by means of three questions: (1) "Have you ever used 3D printing?", (2) "What do you know about 3D printing", and (3) "Has 3D printing ever been used in your education somehow?" In post-interviews, the experiences about the intensive lessons were also asked, in addition to the questions related to technological acceptance. These questions were: (1) "How was the experience about 3D printing lessons?" and (2) "Did your thoughts about 3D printing change after the lesson, and if so, how?" [28-29].

Data analysis

The aim of the analysis was to provide a narrative description with regard to the practical nursing students' technological acceptance towards 3D printing [43-44]. The flexible elements of the thematic analysis made it possible to have narrative elements in the analysis process, though the actual data analysis was made with a thematic analysis [44]. The unit of analysis was an expression that described the content of the theory and following words: "intention to use", "perceived usefulness", "perceived ease of use", "image", and "job relevance" [43-44]. The narrative element meant that both interviews were analysed with the thematic analysis by one interviewer. Thematic analysis process can be divided into the following stages:

(1) After being transcribed, the data was read through several times to establish familiarity. The data from pre-interviews was read first, followed by the data from post-interviews to have a complete view regarding the narrative dimensions.

(2) The initial codes were created with the guidance of the TAM. The initial codes were created from both pre- and post-interviews.

(3) Themes were searched in accordance with the initial codes.

(4) The thematic map was created in accordance with the themes to find out how the themes´ relationships apply to the data as a whole. In this phase, the relationships of the analysed data of the pre- and post-interviews were checked and the narrative element specified.

(5) All themes were determined.

(6) The data analysis was reported.

All recorded material was transcribed (three pages in pre-interview and five pages in post-interview with font 12 and line spacing 1.5). The total duration of the recorded material is 25 minutes. The initial codes followed the principles and methods of the TAM: intention to use, perceived usefulness, perceived ease of use, image, and job relevance (Table 1). The number of initial codes reflected the saturation of the data [44]. The content of the same category from TAM could have had elements in several initial codes, and one category could have affected more than just one theme. The themes followed the initial codes and represented similarities from the data. In this phase, the subthemes were also created, and the relations to the main themes were analysed. The thematic map outlined the data to be suitable for the categories from TAM [28-29, 44].

Table 1. Example of data analysis.

Example from text	Category/categories from the theory	Initial code	Subtheme	Main theme
"...when they (working life) know that you can do something unique (3D print), it can affect your value."	Job relevance, intention to use, and image	3D printing and your professionalism in the future	"Possibility to become mundane"	*"From resource dominance to one part of working life"*

Results

The practical nursing students had not used 3D printing before this study. They did not know whether 3D printing has been used in their education to support teaching and learning. This means that the practical nursing students had not been informed whether a teacher had used 3D printing with 3D print teaching tools, for example. The knowledge of the students about 3D printing technology was based on social media, news, or the visual experience of a concrete 3D printer. Practical nursing students described their knowledge based on assumptions they had about 3D printing technology.

The practical nurses' technological acceptance towards 3D printing technology consisted of four narrative themes: *"From professional meaningless to everyday usefulness"*, *"From resource dominance to one part of working life"*, *"From special competence to ease of use"* and *"From assumptions to limitless possibilities"*. Every theme had two subthemes. All results can be seen in Table 2.

From professional meaningless to everyday usefulness

The theme *"From professional meaningless to everyday usefulness"* included the following subthemes: *"Tool to create activating goods"* and *"Tool to create an individual ancillary."* Before the 3D printing lessons, the practical nursing students could not imagine any kind of professional use of 3D printing technology. They noticed that their idea of 3D printing was so narrow that they thought 3D printers were merely toys and unsuitable for professional use in health care. They associated 3D printing with a technology that could only be a burden in their working days among children. After the 3D printing lessons, the practical nursing students described that they could imagine printing various toys or something unique to activate the children, for example. They perceived that even small 3D printed objects could enrich the children's play at the day care centre. One significant insight that the practical nursing students had was the realisation that the 3D printed objects did not have to be perfectly shaped or the best of quality in order to suffice. In their interviews, the students described 3D printing as an ideal fit for a theme week at the daycare centre, where one could easily design and print various objects together with the children. The students also described 3D printing method to be an activating element and that it could be used to help children with a range of disabilities or needs. Medical equipment or aids cannot, as the students stated, be produced with this method but rather objects for everyday activities, such as tools for eating or objects to help children concentrate.

From resource dominance to one part of working life

The theme *"From resource dominance to a one part of working life"* included the following subthemes: *"Possibility to become mundane"* and *"Need for special effort."* Before 3D printing lessons, the practical nursing students imagined that 3D printing is out of reach because it is too expensive a technology in their profession. They also noticed that 3D printers and modelling programs may need a lot of space and special computers. The practical nursing students highlighted their fear of one whole room alone being reserved for this particular type of "new things." In addition to costs, the practical nursing students described 3D printing as taking too much time to be adapted in working life, as it would not be cost-effective to use. After the 3D printing lessons, however, the practical nursing students perceived 3D printing as a normal part of their tools when working with children. They noted that 3D printers can really be part of the working context without any extra things to be worried about, because it can act as an opportunity rather than a compulsory item to use. The practical nursing students thought that even though it is possible to utilise 3D printing, it requires special knowledge and time, because it can take several hours to print, depending on the object. The students also said that they did not feel ready to utilise the 3D printing at the moment and that they would need time and resources to learn it properly.

From special competence to ease of use

The theme *"From special competence to ease of use"* included the following subthemes: *"Possible future competence of a practical nurse" and "Easy to adapt."* Before the lessons, the practical nursing students stated that 3D printing would need a specialist or person who only takes care of the 3D printer and utilises it. They regarded 3D printing as requiring engineer-type thinking and that it could not be part of the competence of a practical nurse. After the 3D printing lessons, the practical nurses said that the whole process of 3D printing is quite easy to understand and adapt to. According to the practical nursing students, the 3D modelling was particularly easy. 3D modelling was also described as a source of creativeness and innovativeness, because of its many tools and possibilities. Because of its ease, the practical nursing students believed that they could include 3D printing as part of their future competence area. The main message was that although 3D printing could be part of a practical nurse's competence, it should not take extra time away from care of the children. The practical nurses also highlighted the fact that, having made it easier to start using it, 3D printing should be part of their education. By this they meant that the 3D printing process should be part of the students' activation while studying – not only a tool for the teachers.

From assumptions to limitless possibilities

The theme *"From assumptions to limitless possibilities"* included the following subthemes: *"Multiple possibilities to use and experience"* and *"Need of fantasy for future."* Before the 3D printing lessons, the practical nursing students had assumptions about 3D printing that were connected with paper printing or picture printing. According to the students, the objects would have to be small as far as object printing is concerned. After the 3D printing lessons, they noted that the total number of possibilities was beyond understanding. They discussed about how human organ printing may be part of their future patient or childcare and that 3D printing may enhance the wellbeing of humans by printing cells, for example. The practical nursing students also described having to prepare for the fact that some of their patients or clients could have an organ that is 3D printed. They said that in this kind of situation the health care professionals must have an understanding about the technological processes as well as clinical or medical understanding. Basically, according to the practical nurses' descriptions, 3D printing is totally something else and beyond what they had imagined.

Table 2. Example of data synthesis.

Theme	TAM-category	Subtheme	Example pre-interview	Example post-interview
From professional meaningless to everyday usefulness	Intention to use and perceived usefulness	Tool to create activating goods	"I don't know, it could be very different from what we have been doing, though maybe everybody could play with the printer, I don't know"	"…for example, if we had theme of forests' animals, we could print something special for the children."
		Tool to create an individual ancillary	"I really don't have any idea, but maybe someone could have a use for it."	"…if it's hard to focus for some child, maybe we could have a solution by printing something just for him/her."
From resource dominance to one part of working life	Job relevance, intention to use, and image	Possibility to become mundane	"…I don't know if anyone would have time to learn it…"	"…when we have the knowledge about printing, we could use it. Maybe not every day, but sometimes."
		Need for special effort	"…I'd guess that it would take time before someone has the courage to use it."	"…if someone says now print this and that, I couldn't do it. I'd need more time to understand it properly."
From special competence to ease of use	Perceived ease of use and job relevance	Possible future competence of a practical nurse	"I really don't know about it (3D printing), so I can't say anything."	"When this (printing) is in everyday use, schools should use it in their classes or in some other way."
		Easy to adapt	"I assume, that it (3D printing) is very expensive and hard to learn."	"It (3D modelling) was easy and fun. And the printing itself didn't seem hard."
From assumptions to limitless possibilities	Image and job relevance	Multiple possibilities to use and experience	"I've heard that they print illegal things."	"This sure is creative when you can make something that's really unique."
		Need of fantasy for future	"My brains don't say anything"	"….I still don't understand that you can print things like houses and parts of a car – unbelievable."

Discussion

The purpose of this qualitative study was to describe the technological acceptance towards 3D printing on the part of practical nursing students. The result of this study shows that after 3D printing lessons, the practical nursing students described 3D printing in a very positive way in all of the themes analysed. As a whole, the content of the technological acceptance model can be seen in the results where the practical nursing students described 3D printing to be a useful (perceived usefulness and intention to use) tool in their future profession (job relevance), with easy elements to adapt to (perceived ease of use and intention to use), and that it could enrich their value in the work market (image).

The narrative results of this study show that at first 3D printing was quite unfamiliar, and the idea of using it was based on assumptions or on quite unreliable references such as social media content. It is worth noticing, however, that the baseline of the practical nursing students' thoughts was not completely negative but based on ignorance. After six hours of lessons concerning 3D printing, the practical nursing students had an idea about how 3D printing could be used in their future working life with child care. Some of the ideas can be seen as rich in imagination, as they discovered the possibility of printing houses and human cells. The characteristic of this result is quite contrastive to former studies, in which one meaningful dimension has been frustration towards 3D printing or 3D modelling technology [45-46].

Practical nursing students related 3D printing competence as a possible competence area of a practical nurse's profession in early childhood education. This may be one element in fixing the possible gap between elementary and vocational school in cases where the former has already adapted 3D printing to teaching and the latter has not. [47]. Practical nursing students highlighted that they felt the 3D printing process to be clear and even easy to adapt, but they were also realistic about the educational needs concerning 3D printing. It was meaningful to understand that 3D printing cannot take away time from childcare. This was important to notice, because in this study practical nursing students mentioned a lot of individual and multiple possibilities with regard to how 3D printing could be part of their working life.

It was also concluded that all the descriptions about the possibilities of creativeness differed radically from each other at the beginning and end of the course. The creativeness and innovativeness were emphasised when the students were 3D modelling, even if they had not had the chance to 3D print the models. From the educational perspective, this could reduce the challenge to utilise 3D printers, because 3D modelling can also be an individual part of the process and could be a good experiment for health care education before they buy any 3D printers. It is also worth acknowledging that 3D printing and 3D modelling have previously been connected to quite clinical and structured use [48], whereas this study presents some innovative opportunities for the 3D printing process that apply not only in producing objects but also as a part of the pedagogical competence of a modern teacher [49].

3D printing has potential in various areas [5,50] and educational potential is not an exception [7,51], though the known potential the awareness of 3D printing has is mainly based on the level of "we know it is there" [45,52,53]. Practical nursing students in this study had not experienced 3D printing during their studies, which can be connected with health care educators' rare utilisation of 3D printing in vocational education [18]. This could mean that 3D printing does not necessarily imply a clear pedagogical plan in health care education except for medical education, which boasts studies in promising learning outcomes in the surgical area, for example [12].

Technological acceptance can be seen as a one of the future pedagogical goals [54,55], and 3D printing can be seen as one way to increase technological acceptance [14]. This may mean that practical nursing students see 3D printing as a meaningful part of their work and are ready to adapt it in the future. Although this study sample is small and it focused on the secondary educational level, the results are in line with the results from Benham and San [14], which focused on occupational therapy. One meaningful thing is that in this study, technological acceptance developed after quite a small pedagogical effort (six hours of lessons), and possible usage with children was emphasised (to 3D print something together, for example). However, we must remember that this result may not be applicable if 3D printing technology is used in elderly peoples' care [33], for instance.

Finally, the results of this study present the meaning of the students' perspective about technological acceptance in vocational education, whilst some research has been carried out among teachers in vocational education. With research-based knowledge, we can support the aim of a student-centred teaching and learning approach. Practical nursing students should have broader competence in their professional role [56], and to reach that goal, practical nurses must be ready for multiple technological solutions that represent everyday possibilities in their working environments.

Limitations

This study has limitations that need to be considered. First, the sample was collected from one institute and (n=14) is small. It does not provide a valid description regarding the educational system respective to practical nursing studies. This study also focused on third-year practical nursing students and may not be comparable to the perspective of first-year students. On the other hand, this phase of the studies may offer a better aspect of working life when all students have already undergone practical periods in their competence area [36-39]. Secondly, theory strongly guided this research, meaning that the dimensions may not be as open as possible. On the other hand, this study implemented the aim of technological acceptance towards 3D printing in this particular context for the first time [28,29]. This means that with theory the structure of the interviews is clearer, and the focus can be targeted on future working life. Finally, the data analysis was made from pre- and post-interviews. The size of the data was much larger in the post-interviews and this may exert pressure on the analysis in a certain manner. On the other hand, the pre-and post-interviews made it possible to analyse the data with the narrative dimension so that the description can have a developing characteristic.

Trustworthiness

This study focused on ensuring the relevant validity and reliability throughout the entire research process. The main structure of the reliability and validity of this study was the theoretical framework. With a theoretical framework, this research could focus deeply on analysing the data as well as creating valid questions. This was meaningful while the sample was quite small. On the other hand, the researchers need to reflect with each other continously to ensure a concordant approach to the data (collection and analysis) [42,57].

Conclusion

As a conclusion, it can be stated that a short period of instruction on 3D printing can develop practical nursing students' technological acceptance in a more positive direction. Practical nursing students described the ease and professional usefulness of 3D printing, which can help their adaptation in the future. For this reason, the educational organisation should integrate 3D printing as a part of the educational plan to be able to fluently support practical nursing students' technological acceptance. On the other hand, the organisations need to target more resources on educating teachers in understanding the possibilities of 3D printing. In the future, 3D printing may be a method that is used in co-operation with other health care educational levels in order to bring about more comprehensive care for the patients. More research is needed regarding technological acceptance from the theoretical aspect as well, in addition to how effectively 3D printing is capable of changing practical nursing students' technological acceptance.

Conflict of interest statement

The first three authors represent the vocational institute where the data was collected. Neither of them has any conflict of interest with regard to the organisation whose 3D printing was used in the study.

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