RESEARCH ARTICLE

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Occupational therapists' acceptance of 3D printing

ABSTRACT

Introduction: In occupational therapy, three-dimensional printing is being explored as an alternative design and manufacturing technique to the conventional fabrication of orthotics and assistive devices. The global applications and literature are rapidly growing, but the South African – specific literature is deficient. The Technology Acceptance Model depicts that one's perception of any particular technology is a significant determinant of their acceptance of it, determining whether the technology system is successfully adopted or disregarded.

Aim: To determine the perceived acceptance of three-dimensional printing technology amongst occupational therapists in KwaZulu-Natal and whether exposure to the technology system, in the form of a three-dimensional printing workshop, influences their perception of the technology.

Method: The study followed a multi-method design consisting of two phases; phase one involved the creation of the intervention tool (workshop), which was developed through a process guided by Design-Based Research. Phase two involved the implementation of the intervention and data collection. Therapists documented their perceptions in a questionnaire before and after exposure; following a pre and post-test design, enabling comparison. The questionnaires were based on the Technology Acceptance Model, including 13 questions scored on a seven-point Likert scale and five open-ended questions. The quantitative data were analysed descriptively, and qualitative data were analysed thematically.

Results: All four categories of the Technology Acceptance Model-based questionnaire displayed a significant change ($p < 0.05$) between the pre and post-test responses, with a medium effect size.

Conclusion: Exposure to three-dimensional printing influences therapists' perception of the technology.

IMPLICATIONS FOR PRACTICE
- The application of Three-Dimensional Printing (3DP) in occupational therapy practice has the potential to enable increased accuracy and precision of items fabricated by therapists; enabling customisation and individualisation to the exact specifications of a patient.
- 3DP can open doors to a broad spectrum of items that are not easily accessible, affordable, or not even available, accessing ideas and blueprints from a global pool of resources through open-source sites.
- With the process of fabrication being digital, not only does this reduce manual labour, but fabricating without touching the patient can reduce pain and prevent disruption of a repair/ surgical site/ wound.
- The digital process also allows patients to see and visualise the product during the design process, enabling input prior to printing, contributing to reduced wastage.

INTRODUCTION

Three-Dimensional Printing (3DP), also known as additive manufacturing, is a type of manufacturing whereby items are fabricated in consecutive layers with guidance from a computer-aided design (CAD) file[1]. Until recently, 3DP technology remained largely inaccessible to the general public, dominated primarily by prominent stakeholders[2]. Today, the applications of 3DP have expanded to the general market, from the commercial and academic environments to clinical settings as well[3].

The application of 3DP across healthcare domains is rapidly expanding, completely revolutionising traditional practices with the ability to create whilst ensuring personalisation, time efficiency and accuracy[4-5.] In occupational therapy practice specifically, 3DP is being explored as an alternative design and manufacturing technique to conventional processes within two areas of practice: assistive devices and splinting/orthotics[6]. Technology may present hurdles to current practices; however, it also provides new opportunities for enhancing and enabling patient engagement and meaning in life. For this reason, it is recommended that therapists engage beyond their typical practices to advocate for their patients[7].

Despite the rapid advancements in technology globally, acceptance and resultant use of advancements such as 3DP by individuals, in this case, occupational therapists, cannot be assumed and therefore, must be examined[8]. This study aimed to determine the perceived acceptance of 3DP technology by occupational therapists working in South Africa. The findings of this study are intended to provide a gateway to further research and advancements in occupational therapy practice and service delivery within the South African context.

LITERATURE REVIEW

The South African healthcare system and access to assistive technology

South Africa has a two-tiered healthcare system. The public sector is underfunded and services three-quarters of the population, whilst the private sector is grossly inaccessible to the majority due to the exorbitant cost of private care[9]. In South Africa, approximately 7.5% of the population lives with a disability[10]. Individuals living with disabilities require assistive technology (AT) that enables them to actively engage and complete a task that they would not otherwise be able to do[11]. Without access to the appropriate AT, an individual with a disability may be unable to access opportunities available to the able-bodied[12]. Equitable access for this population was documented in the South African National Development Plan (NDP)[13], this service however is fragmented and inaccessible. The government cannot meet between 35% and 85% of the total AT needs of the disabled population[12], and with the proposed implementation of National Health Insurance, the National Department of Health will be solely responsible for providing this essential service. The greatest challenge to provision of AT in South Africa is the financial constraints impacting on service delivery and availability of products. To bridge this gap, local innovation, product development, and manufacturing needs to be cultivated and supported[12].

3DP in the field of occupational therapy

Within the field of occupational therapy, 3DP is being explored as an alternative design and manufacturing technique to the conventional fabrication of orthotics and assistive devices (both of which fall within the domain of AT)[6]. An orthosis is a device applied externally to a body part to provide structural positioning or functional facilitation, referred to as 'splints' in the South African context. Fabricating orthoses requires clinical experience and can be labour-intensive[14]. 3DP may significantly reduce the equipment and materials required in the fabrication process of an orthotic. 3DP orthoses have also proven to be of lighter weight, better ventilated and more aesthetically pleasing compared to traditional thermoplastic orthoses[15]. Assistive devices are any item that enables an individual with a disability to complete a task that they would not otherwise be able to do[16]. 3DP has proven to be an effective method for designing, testing, and manufacturing unique assistive devices. The process has yielded greater patient satisfaction, functionality, and reduced cost[17].

Another advantage of 3DP is the availability of online open-source platforms. The digital blueprint designs are distributed and shared globally, with the end-user having the opportunity to customise the design for the specific needs of each patient[15]. Additionally, a potential benefit of using CAD is the opportunity for patient feedback during the design process prior to fabrication. This would cultivate a sense of ownership and improve patient satisfaction and subsequent compliance[14]. Input and feedback during the design process would also reduce unnecessary waste of materials, as adjustments can be made digitally before printing.

The gap in 3DP Research in occupational therapy

Limited research examines 3DP within healthcare and occupational therapy internationally, specifically in South Africa. This may be a barrier to potential advancements in therapy and technology integration for future practice. The Technology Acceptance Model (TAM) was developed in 1985, due to concern that employees were not using the Information Technology (IT) advancements made available to them. The original TAM consists of two major components: *perceived usefulness and perceived ease of use,* with the latter directly influencing the former. The model depicts that these two perceptions will influence the user's attitude towards the technology system, which will influence whether the user will accept or reject the technology. The two beliefs are directly influenced by the characteristics of the technology itself[8]. The TAM has become a leading model in explaining and predicting the acceptance and use of technology[18]. Previous empirical research studies have tested the TAM, and proven that tools based on this model have yielded results considered to be statistically reliable[19]. This study included questionnaires based on the TAM to determine therapists' perceived acceptance 3DP technology based on the following: usefulness, ease of use, attitude towards, and intention to use in future practice.

METHODOLOGY

Study design

The study used a multi- method design consisting of two distinct phases, outlined in Figure 1.

Phase 1
Intervention Development

The first phase used a Design-Based research methodological framework to develop an appropriate intervention to introduce the concept of 3DP to therapists.

Phase 2
Data Collection

This phase included the development of the data collection tool, running the pilot study, and data collection which consisted of three parts

Part I
Pretest Questionnaire

This questionnaire consisted of a demographic profile, 13 Technology Acceptance Model-based questions scored on a seven-point likert scale, and finally five open-ended questions

Part II
The Intervention

The therapists engaged in a 3DP introductory level workshop which consisted on a pre-recorded video presentation, followed by a practical demonstration of using the printer and its accompanying software.

Part III
Posttest Questionnaire

This questionnaire consisted of the same 13 Technology Acceptance Model - based questions scored on a seven-point likert scale and five open-ended questions.
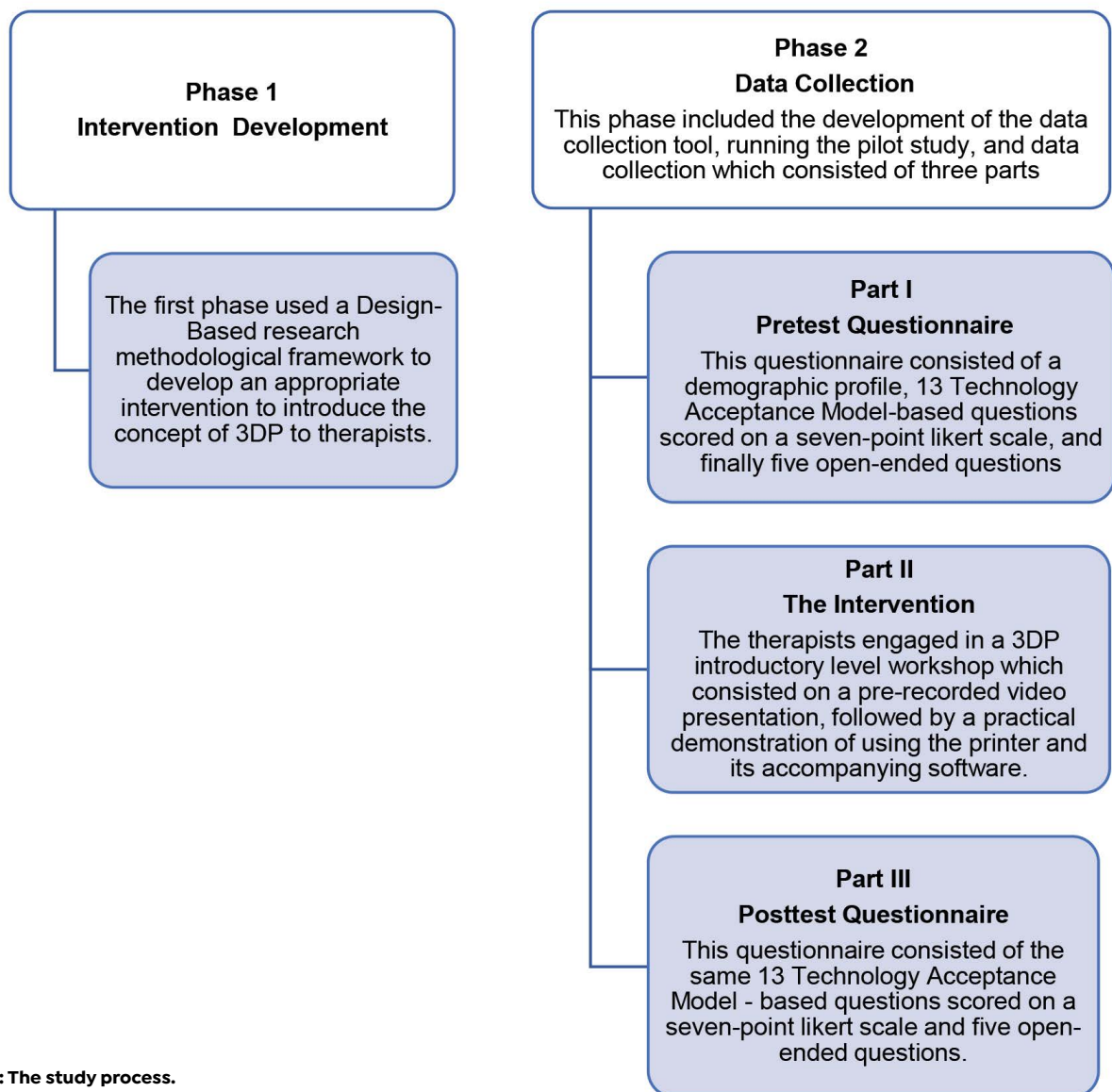
Figure 1: The study process.

Phase one: Intervention tool development

This phase was geared towards developing the intervention tool; the 3DP workshop and was guided by the Design-Based Research (DBR) process. The process begins with initially evaluating a problem within a specific context. Following this, a potential solution is designed – generally as an instructional tool. The researchers then test and develop the instructional tool through an iterative process, funnelling and refining the knowledge[20].

This research process is appropriate when the knowledge related to the problem is particularly new and when instructional material is lacking[21-23]. The DBR process is not a precise research methodology but rather a team collaboration engaged in a process of systematically examining, constructing, and evaluating information and tools for learning[22]. The DBR team consists of any stakeholder or collaborator whose expertise and knowledge contribute to development within the iterative cycle[21]. This team consisted of five co-authors. Three collaborators were clinicians with experience and published work in the field of splinting and rehabilitation in occupational therapy, and the other two are clinicians practicing in the field of physical rehabilitation in occupational therapy, with prior 3DP experience.

Phase two: Data collection

Phase two was geared towards developing the data collection tool, conducting the pilot study, and running the 3DP workshops and data collection process. Four workshops were run to cater to therapists in different areas in KwaZulu-Natal.

Study design: The second phase followed a quasi-experimental design consisting of a one-group pre-test, post-test design. In this study, the dependent variable was the therapists' perceived acceptance of 3DP technology, which was assessed before and after participating in a 3DP introductory workshop (independent variable).

Table I: The DBR process

Step
Step one: Evaluating the gap/need The identified problem defined the study's aims and objectives.
Step two: Developing the proposed intervention plan Initiating the development of an intervention to meet the objectives – introducing the therapists to 3DP technology. This step involved developing the intervention structure and mapping out potential content. Initially, the plan was to create a pre-recorded presentation for participants to be sent electronically. Following this initial plan, the structure of the presentation was outlined, mapping out areas of interest identified through the perusal of relevant literature. The structure included: • An introduction to 3DP • The history of 3DP • Orientation to the parts of the 3D printer • Materials used in 3DP and their properties • An introduction to CAD and open-source design sites • Applications in broader healthcare practice • Applications in occupational therapy practice Collaboration with relevant stakeholders determined that the presentation would be better delivered in-person, with a practical component, thus the plan for a 3DP introductory workshop.
Step three: Further developing the content of the presentation This involved the additional gathering of resources, such as journal articles, websites, reports, manuals, handouts, and video clips, to expand on each subsection of the abovementioned content. During this process, additional areas of interest were identified and included an introduction to various forms of manufacturing and different types of 3DP.
Step four: Collation and Synthesis This step aimed to funnel the acquired information, ensuring relevance and applicability. The information was synthesised and formatted in a handout and PowerPoint presentation. The feasibility and effectiveness of a PowerPoint presentation were then queried and altered. It was determined that a video presentation would be more appropriate to ensure consistency and standardisation across the various groups of participants. The actionable step was utilising available networks and sourcing a video creator and editor.
Step five: Creation and refinement of the video presentation and workshop content The video included animations, voiceovers, video clips, and music, to effectively present the information in a captivating and easy-to-understand manner. The first draft utilised the information synthesised in step four. The video presentation was divided into a theoretical section and a more practical one. The practical component included a combination of a pre-recorded presentation and real-time presentation, however, followed a structured format. This portion of the workshop included: • An introduction video. • A pre-recorded screen recording of the software and open-source websites in use. • Exposure to various examples of printed devices and splints. • Exposure to the types of materials used in printing. • Physical orientation to the parts of the printer. • Exposure to printers operating in real time. The video was then edited and formed the second draft, which was again critiqued and edited. The final video was utilised for each of the 4 workshops and pilot study. No alterations to the presentation were noted from the pilot study.

Setting: The study was located in KwaZulu-Natal, South Africa. South Africa has been described as both a developing and developed country, having high levels of inequality, juxtaposing wealthy neighbourhoods and poverty-stricken settlements[24-26]. South African healthcare expenditure aggregates to over R500 billion annually and is approximately evenly split between the public and private healthcare sectors, despite the former providing care for the large majority of the country[27]. Public facilities are, as a result, often overcrowded, have limited resources, long waiting times, and staff shortages[26]. A setting with two contrasting healthcare sectors required representation of both within the study.

The government is unable to meet a significant portion of the assistive technology needs within South Africa affecting the large majority accessing public healthcare, but in time also affecting the entire disabled population with the proposed implementation of National Health Insurance. One of the most significant challenges faced within this context, with the provision of products and services, is the financial constraints which directly impact resource availability, often resulting in extended waiting times. Waiting times of over two years have been reported, with devices no longer suitable to the patient's needs, size, environment, and life roles that have changed[12].

Participant selection and sampling: Participants included practising occupational therapists in physical or paediatric rehabilitation in either the public or private healthcare sectors in KwaZulu-Natal. The database of the Occupational Therapy Association of South Africa (OTASA) was accessed to attain membership figures; however, membership with OTASA is not mandatory, and it is therefore expected that not all therapists are registered with the association.

Therefore, the total number of potential participants in the target population was consequently unknown. However, the number of public sector hospital departments invited to participate in the study was 28, and the number of private sector practices invited was approximately 50. In total, 40 therapists consented to participation and were involved in the study. Non-probability convenience sampling was utilised. Public sector therapists were accessed via the chairperson of the KZN provincial forum, who aided in the distribution of the invitation and detailed explanation of the research study via email to each department. Private practice therapists were invited via networking, occupational therapy messenger groups and practice searchers were conducted via the internet to extend the invitation.

Research tools: The study included a pre-test, post-test questionnaire based on the TAM. A portion of the questionnaire was obtained, with permission, from a previous study conducted in the United States of America that successfully developed a TAM-based questionnaire and utilised it to determine occupational therapy students' attitudes and perceptions of 3DP technology[28]. The questionnaire included 12 biographical questions; 13 questions based on the TAM (scored on a seven-point Likert scale ranging from one (totally disagree) to seven (totally agree), and ended with five open-ended questions. The biographical questions were to determine the therapists' experience in the field and with 3DP, their practice habits, and their age – creating an opportunity to generate further discussions of potential influences. The open-ended questions were developed by looking at the TAM categories, and were phrased to create space for further perspectives and opinions to provide depth to the first 13 questions scored on a Likert scale. The pre-test and post-test questionnaires were administered directly before and after the therapists participated in an introductory workshop.

Research procedure: Four workshops were conducted with four different groups of therapists. The workshops were held at various settings (a public hospital, a private hospital, a private practice, and at a tertiary institution's occupational therapy department). Locations were chosen based on ease of access for therapists living in the Pietermaritzburg area, the Upper Highway area, North Coast and Westville Central area, and therapists were given a choice as to which workshop to attend. The workshops were run by the researcher and a co-facilitator and attended by the research supervisors (all of whom comprise the collaborators involved in the DBR process that produced the workshop content). Each workshop was 2.5 hours in length (including arrival and refreshments). The workshops spanned several weeks. At the start of the workshop, therapists completed the pre-test questionnaire; they then engaged in the presentation and practical components of learning before completing the post-test questionnaire. Questionnaires were collected at the end of the workshop, each therapist's pre and post-test responses were stapled together, enabling direct comparison of changes in responses.

Data analysis: The quantitative data collected from the pre- and post-test questionnaires were captured on a Microsoft Excel spreadsheet and were prepared for analysis using the IBM Statistical Package for Social Sciences (SPSS, Version 24.0). The data were analysed descriptively and collated using frequencies and means. The pre and post-test results from the 13 TAM-related questions were scored according to the four categories of the TAM including perceived usefulness, perceived ease of use, attitude towards use and intention to use. Paired t–tests were used to analyse the responses and compare the mean measurement taken from the pre- and post-test response[29]. Cohen's d was then used to calculate the effect sizes between the pre- and post-test responses[30]. The results were interpreted according to small, medium, and large effect. Results were then collated for representation in tabular format. Non-parametric tests could have been used and suitable, given the small sample size; however, a parametric test is often more likely to detect a significant difference when it exists and therefore paired t-tests were used[31]. The demographic questions were grouped, translated into quantifiable data, and represented in tabular format. The five open-ended questions in the survey were grouped by question and captured onto Microsoft Word.

The data were manually coded and thematically analysed using a deductive approach. The themes were predetermined and utilised in analysing both the pre- and post-test responses: 1) Perceived usefulness of the technology in practice, 2) Perceived ease of use of the technology system, 3) Attitude towards 3DP and the incorporation of the technology in practice, 4) Perceived accessibility of the technology system. The TAM informed the first three themes, whilst the last theme was informed by the review of literature throughout the research process, in combination with the experiential insight of living in a developing context. The specific subthemes were not determined deductively and were determined through the review, grouping and analysis of responses from the five open-ended questions.

Scientific rigour

Trustworthiness was ensured through replicability, transferability, confirmability, and triangulation. The detailed documentation of the following ensured replicability: the participants, the data collection tools and methods, the data collection process, and data analysis. The detailed record keeping of each step of the process will enable each step to be accurately repeated[32]. Transferability was ensured by providing sufficient detailed description of the study, so that readers can determine for themselves whether the findings are applicable to themselves in their own context[33]. Confirmability was established as three authors were privy to the raw data, were involved in the data analysis, and reviewed the discussions and conclusions drawn from this. Triangulation was achieved by converging multiple data sources, and the findings from this study are available for review by other professionals and experts in the field, enabling analyst triangulation[34].

Ethical considerations

Ethical clearance was obtained from the Biomedical Research Ethics Committee (BREC) prior to the commencement of

Table II: Demographics and practice/ experience profile of therapists

Characteristic		M (SD)
Age of Participants		31.63 (8.62)
Years of Experience		8. 22 (8.65)
Characteristic		**n (%)**
Gender	*Female* *Male*	38 (95.0) 2 (5.0)
Sector of Practice	*Public* *Private*	19 (47.5) 21 (52.5)
Computer Literacy		40 (100)
Experience with 3DP	*None* *Novice* *Intermediate* *Expert*	38 (95.0) 2 (5.0) 0 (0) 0 (0)
Frequency of Splinting	*Daily* *Several times a week* *Once a week* *Several times a month* *Seldom* *Never*	13 (32.5) 5 (12.5) 1 (2.5) 9 (22.5) 10 (25.0) 2 (5.0)
Tendency to Fabricate or Purchase Commercial Splints	*Fabricate Splints* *Commercial splints* *Both* *Neither – refer*	34 (85.0) 0 (0) 3 (7.5) 3 (7.5)
Frequency of issuing Assistive Devices	*Daily* *Several times a week* *Once a week* *Several times a month* *Seldom* *Never*	1 (2.5) 1 (2.5) 0 (0) 13 (32.5) 23 (57.5) 2 (5.0)
Tendency to Fabricate or Purchase Commercial Assistive Devices	*Fabricate* *Commercial assistive devices* *Both* *Refer on/ or no response*	18 (45.0) 18 (45.0) 2 (5.0) 5 (5.0)

the study (Reference number: BREC/00003938/2022). Gatekeeper permission was obtained from the Department of Health, for therapists working within the public sector (NHRD reference: KZ_202201_024). In order to ensure informed consent and confidentiality within the study, the following was ensured: Interested participants were provided with a written detailed description of the research purpose and process, prior to involvement in the study. Participants were informed of the research procedure, its purpose, possible risks and benefits, the selection process, the knowledge that they can withdraw from the study at any time, and additionally were given an opportunity to ask questions before accepting the invite to join the study. Throughout the research process, all information obtained from the data collection tools did not contain identifying data. 3D printers were used throughout this research study; the printers are the property of the University of KwaZulu-Natal, and permission to utilise the equipment as students was granted.

RESULTS

Quantitative results
Demographics
The demographic profile of the study participants is highlighted in Table II (above). The study included 40 occupational therapists, the majority of whom are females,

with the age of the participants ranging from 22 to 54 years, (M = 31.63; SD = 8.62). The experience amongst the therapists ranged from 0 years (currently completing community service) to 33 years (M =8.22, SD = 8.65). The study comprised a nearly equal distribution of therapists working within the public (47.5%,) and private (52.5%,) healthcare sectors. All participants were computer literate, and 95% had no prior experience with 3DP. The therapist's practice profiles indicated the majority (32.5%) splinted daily, 22.5% splinted several times a month, and 25.0% seldomly splinted. 85.0% of therapists manually fabricate splints/ orthotics, rather than purchasing a commercial product. Assistive devices are seldom issued by 57.5% of therapists while 32.5% issue them several times a month. The tendency to fabricate (45%) or purchase commercial (45%) assistive devices was equally distributed amongst the therapists.

Table III (page 9) highlights the changes between the pre- and post-intervention responses. The questionnaires consisted of 13 questions across the four categories of the TAM. Of the 13 questions, 11 depicted a significant change (p < 0.05) between the pre- and post-test responses. In terms of the magnitude of change, four questions depicted a small effect size ($0.2 \geq d \leq 0.5$), 7 depicted a medium effect size ($0.5 \geq d \leq 0.8$), and 2 depicted a large effect size ($d \geq 0.8$). The effect size is the most significant outcome of empirical studies, as it depicts whether an intervention has caused an effect, and the magnitude of the effect[35].

Table III: Significance and effect size of each question

TAM Category	Question	Response Mean (Standard Deviation)		p value	Cohen's d	Effect size
		Pre-test	**Post-test**			
Perceived usefulness	I think that using 3D printers would improve job quality for Occupational Therapists.	5.30 (1.159)	5.80 (0.791)	0.000	0.520	Medium
	I think that using 3D printers would improve the effectiveness of how Occupational Therapists deliver services to patients.	5.33 (1.118)	5.88 (0.883)	0.016	0.486	Small
	I think that the advantages of using 3D printers outweigh the disadvantages.	4.70 (0.992)	5.53 (1.037)	0.001	0.817	Large
	Overall, I think that using 3D printers is advantageous for Occupational Therapists.	5.05 (1.600)	5.78 (0.974)	0.582	0.403	Small
Perceived ease of use	Learning to work with 3D printers (will be/ is) easy.	4.05 (1.108)	5.00 (0.961)	0.005	0.857	Large
	I think that learning how to use the software and printers (will be/is) clear and understandable.	4.18 (0.984)	4.98 (0.947)	0.007	0.767	Medium
	I think it (will be/is) easy for Occupational Therapists to become skilful at using 3D printers.	4.80 (1.203)	5.20 (0.911)	0.065	0.313	Small
	I think that it is possible to use 3D printers without expert help.	3.83 (1.567)	4.75 (1.214)	0.003	0.628	Medium
	Overall, I think using 3D printers (will be/is) easy for Occupational Therapists.	4.43 (1.152)	5.15 (1.027)	0.001	0.654	Medium
Attitude toward using	I think that using 3D printers is a good idea for Occupational Therapists.	5.53 (0.933)	6.03 (0.698)	0.035	0.520	Medium
	As an Occupational Therapist, I like the idea of using 3D printers.	5.55 (1.037)	6.10 (0.778)	0.001	0.590	Medium
Intention to use	In the future, if 3D printer resources are available to me in my Occupational Therapy practice setting, I will probably use 3D printers.	5.68 (1.118)	6.10 (0.810)	0.000	0.504	Medium
	I will recommend the use of 3D printers to other Occupational Therapists.	5.30 (1.224)	5.73 (0.933)	0.000	0.411	Small

According to the TAM, the first three categories need to be favourable before the intention to use the technology is influenced.[8] The categories, perceived usefulness, perceived ease of use, and attitude toward using all presented with a significant difference of p<0.05 from pre-test to post-test, and medium effect sizes between 0.5 to 0.7. Therefore, the fourth category, intention to use, would also depict a significant change when comparing the pre and post-test responses. The score difference for intention to use was highly significant (p= 0.0), but the medium effect size (d= 0.518) was the lowest for all categories, indicating a lower clinical change.

Qualitative Findings: Pre-test
Participants answered five open-ended questions relating to 3DP technology and integrating the technology system into practice, in the pre and post-test questionnaires. Table V (page 10) shows a summary of the themes.

Pre-test Theme 1: Perceived usefulness of the technology in practice
Advantages
Some participants perceived the technology as being useful for its applications in splinting and assistive device production. Their perceptions were geared towards the customisation and individualisation of splints and assistive devices. Precision, accuracy and reduced human error were noted. Participants acknowledged that 3DP may produce neater, more aesthetically pleasing end products and promote time-efficiency in the fabrication process of assistive devices when compared to manual fabrication or procurement. Despite previous concerns regarding the expense and financial outlay for 3DP, several participants noted that it may be cost–effective in the long run.

"Allows OTs to make splints without hurting a patient or disrupting a repair, it is neater/cleaner, reduces stress on OTs to be perfect. (P19 - 28yrs, public practitioner)

"Better cosmetic outcome; possibly lower profile designs." (P27 – 36yrs, private practitioner)

Disadvantages
Participants perceived the technology as being disadvantageous for two primary reasons; the extended time required to print items and the perceived inability to

Table IV: TAM Category significance and effect size

| TAM Category	Response Mean (Standard Deviation)		Mean difference (MD)	Standard deviation (SD)	P Value (Significance)	Cohen's d	Effect size
	Pre– test	Post-test					
Perceived usefulness	20.38 (3.72)	22. 98 (6.06)	–2.60	3.73	0.011	0.693	Medium
Perceived Ease of use	21.28 (4.98)	25.08 (4.07)	–3.80	5.14	0.019	0.739	Medium
Attitude towards using	11.08 (1.89)	12.13 (1.40)	–1.05	1.83	0.008	0.574	Medium
Intention to use	10.98 (2.18)	11.82 (1.62)	–0.85	1.64	0.000	0.518	Medium
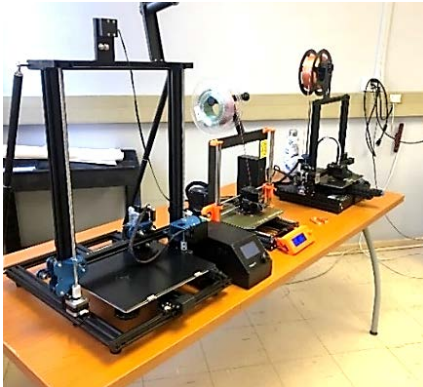
Figure 2: Printers setup for a workshop.

Figure 3: Splint printed from an open-source site.

Figure 4: One-handed shoe clip printed from an open-source site.

remould items. It was explicitly noted that a rapid turnaround time is essential in public settings with high patient loads. Participants also noted the concern regarding the ability to adjust and alter the items once printed, as in manual fabrication. The concern was centred around the need for alterations, specifically in the splinting process, to ensure comfort and to meet the patient's individualised needs with their specific condition/ diagnosis.

> "I feel that the time it takes to print objects may be a challenge as you may not be able to issue a device on the spot." (P14 – 36yrs, public practitioner).

> "Fabricating according to individual diagnosis/needs of patient /fit assists with comfort. Not sure if the 3D splint will be comfortable as it isn't individually moulded? Or is it?" (P24 – 31yrs, public practitioner).

Pre-test Theme 2: Perceived ease of use of the technology system
Simple/ easy
A minority of participants felt that operating the printer and its accompanying software would not be difficult despite the initial training requirement.

> "Ease of use might prove to be less of a problem specifically regarding younger occupational therapists familiar with newer technology." (P39 – 23yrs, public practitioner).

Difficult/ requires expertise
The majority of participants perceived the technology as requiring expert training to operate. Many indicated that they felt the technology would be complex, require expertise, and be time-consuming to learn how to use proficiently.

> "Probably needs a dedicated OT who can be consulted to assist." (P18 – 23yrs, private practitioner).

> "Training and understanding of staff, e.g., maybe one staff is trained but when he/ she leaves there is no handover to the next therapist." (P28 – 35yrs, public practitioner).

Willingness to learn and adopt a new skill
The willingness of therapists to learn a new skill was also queried by several participants, noting that therapists may be resistant to change.

> "New technology makes me slightly uneasy in terms of learning to use, therefore, I am sure others would be apprehensive but willing to learn to use it." (P21 – 31yrs, private practitioner).

Pre-test Theme 3: Attitude towards 3DP and the incorporation of the technology in practice
Novice
Many participants reported having limited to no prior knowledge or experience in 3DP technology, nor an

Table V: Summary of themes and subthemes

Pre-test Themes	Subthemes	Post-test Themes	Subthemes
Perceived usefulness of the technology in practice	Advantages Disadvantages	Perceived usefulness of the technology in practice	Advantages Disadvantages
Perceived ease of use of the technology system	Simple/ easy Difficult/ requires expertise Willingness to learn and adopt a new skill	Perceived ease of use of the technology system	Simple/ easy Difficult/ requires expertise Driving force; passionate therapists to drive 3DP forward in the profession
Attitude towards 3DP and the incorporation of the technology in practice	Novice Advancements Traditional practice, fear of automation and loss of scope of practice	Attitude towards 3DP and the incorporation of the technology in practice Following exposure to 3DP	Advancements Traditional practice and concern regarding gatekeeping
Perceived accessibility of the technology system	Expense Context Maintenance; updates, repairs, technical support, replacements	Perceived accessibility of the technology system	Expense Context Maintenance

understanding of how it works or could potentially be applied in practice settings. As a result of limited insight, several participants did not report strong opinions (or any opinion) of the technology system and waited until after the presentation to formulate an opinion.

> "I have very limited understanding. I had not heard of this concept prior. I only knew of commercial splints and assistive devices." (P40 – 27yrs, public practitioner).

Advancements

Certain participants acknowledged the technological direction in which the world is advancing and felt that 3DP would be a useful resource with an application in occupational therapy practice. They expressed excitement and optimism towards incorporating the technology in practice, perceiving it as a tool to enhance therapists' skills and remain relevant.

> "Think it should be part of therapeutic media in undergrad training. It's a no brainer." (P26 – 51yrs, private practitioner).

> "Occupational therapists are usually old school and not trend setters. It is important to stay up to date with technology relevant to our field. To incorporate technology in order not to become outdated". (P27).

Traditional practice, fear of automation and loss of scope of practice

Several participants raised concerns about job security; fear of automation and other disciplines encroaching on occupational therapy practice. They also raised concern of extracting from core occupational therapy skill sets and specialities; affecting the therapeutic relationship with a patient, and removing the ability to be hands-on with a patient.

> "I am concerned it may "rule out" the role of an OT in splinting as doctors may be able to 3D print splints themselves therefore reduce the no. of specialists required for an injury." (P31 – 27yrs, private practitioner).

Pre-test Theme 4 : Perceived accessibility of the technology system
Expense
A resounding perception of inaccessibility was evident, specifically due to the perception of the technology being highly costly to purchase. Participants noted that the technology would be especially inaccessible in the public healthcare sector, due to limited budgets and the structuring of the healthcare system.

> "I feel it does have a place and can be very beneficial, however it is probably something that you might only see in a tertiary hospital or private setting and not in other settings." (P38 – 23yrs, public practitioner).

Context
Participants were concerned about the practicality and effectiveness of operating a 3D printer instead of manual labour. The technology requires electricity, which raises concerns within South Africa, as all are accustomed to regular power outages and load-shedding.

> "In government settings we can barely access AFOs, wheelchairs, slings etcetera which are small things - the country does not even have electricity, so accessibility on technology within this setting is extremely limited". (P19).

Maintenance: updates, repairs, technical support, replacements
Repeatedly participants raised concerns regarding the practicality and feasibility of utilising a technology that will require maintenance, repairs, servicing and replacement of

broken parts. Regular updating of the software programme to operate the system was also reported, with the above concerns further highlighted as significantly problematic in the public healthcare sector due to limited funding and resources.

> "If it broke in the public sector, it wouldn't be serviced or repaired/replaced easily due to poor funding." (P24 – 31yrs, public practitioner).

Qualitative Findings: Post-test
Following exposure to 3DP participants reported having a clearer understanding of what 3DP is, what the technology system entails, the printing process and the actual and potential applications for practice.

Post-test Theme 1: Perceived usefulness of the technology in practice
Advantages
Participants' perceptions were geared towards the technology being beneficial in ensuring accuracy and exact specifications, individualisation, and producing aesthetically pleasing, durable and lightweight items. Participants noted that the benefits listed would cultivate patient compliance and satisfaction. Notably, the participants perceived the technology as being far more beneficial in the production of assistive devices than splints, specifically due to the extended time requirements for printing and patients generally requiring splints to be fitted and issued immediately. Participants appreciated the allowance for creativity, creating a wide variety of items, and especially manufacturing items that are not usually easily accessible.

> "It is a technology that our profession needs as we always make customised devices. Also beneficial to our patients who are more active and will require devices that will not limit them e.g. Weight." (P13 – 27yrs, public practitioner).

Disadvantages
Participants raised apprehension regarding the feasibility of using the 3D printer in practice due to the long print times, thus preventing fitting and issuing of splints and assistive devices during the session, delaying service delivery. Participants also noted, that even though open source design sites are available for use, they are not occupational therapy specific, and therefore may not be appropriate.

> "I think it has its role. However, when you are making 12 splints in a day that need to be individualised with tight time constraints, I don't think the printer would be easy to use under pressure." (P24).

Post-test Theme 2: Perceived ease of use of the technology system
Simple/ easy
The majority of participants reported a changed perception in admitting that operating the printer and its software seemed far less complex and daunting than they initially

thought. The participants agreed that training would be required but would be user-friendly and easy to grasp.

> "More accessible and a lot easier to use than I thought it would be. Would now definitely consider buying one in the future." (P34 – 32yrs, private practitioner).

Difficult/ requires expertise
Several participants felt that the technology system would be difficult to grasp even with training. They concluded that the ease of use would depend on the individual therapist's skills and technological proficiency. Some participants specifically felt that the designing process would prove to be difficult in learning how to operate the software, and specifically due to the perceptual demands of the design process.

> "I might struggle with CAD design as dimensions and shapes might get confusing." (P11 – 27yrs, private practitioner).

Driving force; passionate therapists to drive 3DP forwards in the profession
In their post-test responses, a few participants expressed the need for several therapists to take ownership and take charge of this potential 'field' to drive the process and avail themselves as consultants.

> "Need to actually have OTs working at designing and testing. Need OTs to actually put in the effort with development in order for it to be used successfully in the general OT practice/ setting in RSA." (P18).

Post-test Theme 3: Attitude towards 3DP and the incorporation of the technology in practice
Advancements
The majority of participants expressed excitement at the possibility of incorporating 3DP into practice, growing and evolving as a profession with technology. They viewed the technology system as something innovative with broad applications that will enhance intervention and complement the skills occupational therapists are equipped with.

> "Wow - the possibilities are endless!' Really, really interested! Can't believe all the options available." (P28). "The need for more education and research is apparent and I think it should be encouraged to help keep OTs on the forefront." (P36 – 36yrs, private practitioner).

Traditional practice and concern regarding gatekeeping
Several participants still raised concerns about job security. However, this time more also raised concerns about the technology, and specifically open-source platforms being available to other professions and the public – enabling anyone to print aids and splints, posing a serious safety concern as clinical reasoning will not be applied.

> "The disadvantage is that there is no clear sort of gatekeeping to protect our role and clearly define OTs

as key fabricators for assistive devices and splints, if the software can be used by anyone, which impacts our role in device/ splint fabrication." (P40).

Post-test Theme 4: Perceived accessibility of the technology system

Expense

Many participants admitted that the cost and accessibility were far less of a barrier than they assumed. Although an initial outlay is required to purchase the printer, they felt that it would result in cost-effectiveness in the long run as the materials are inexpensive.

> "More positive about the prospect now, the financial implications are not as daunting and the fact that open source provides so many options is encouraging." (P36).

Several participants expressed that the cost of the technology system would still be a barrier and result in reduced accessibility. Specifically, in the public sector, the outlay of finances for a printer would not take priority considering the lack of resources.

> "The accessibility problems within our context would still limit what types of facilities could use this technology." (P38).

Context

Participants perceived load-shedding and limited internet access in some areas as problematic, as electricity is required to operate the printer and the internet is necessary in utilising open-source sites or computer-aided design software.

> "Loadshedding is a nightmare! But we have generators in our hospital so that wouldn't be a problem for me personally." (P28).

Maintenance

Maintenance concerns did not surface as frequently compared to the pre-test responses. However, participants still raised concerns regarding repair, troubleshooting, technological support, and upgrading the technology system.

> "Technology becomes quickly outdated- constant need to upgrade printer." (P5 – 37yrs, public practitioner).

DISCUSSION

Within the field of occupational therapy, the global literature and applications of 3DP in practice are rapidly growing, revealing a paucity of South African-specific literature. This study, which is the first to the author's knowledge, aimed to determine the perceived acceptance of 3DP technology by occupational therapists, and to further determine whether the therapists' perception of the technology would be altered from exposure to the technology in the form of an introductory workshop.

A total of 40 therapists participated in the study, including male and female participants, with the age range spanning from 22 to 54 years, and their years of experience ranging from 0 years (currently completing community service) to 33 years. There was a balanced representation of therapists working in public and private practice. Therapists that were a part of the research study attended a 3DP workshop and completed a questionnaire based on the Technology Acceptance Model (TAM), before and after exposure to the technology during the workshop. The TAM portrays that a user's attitude towards a technology system is a pivotal determinant of whether the user will accept or reject the technology. The attitude is influenced by two crucial factors, 'perceived usefulness' and 'perceived ease of use'[8]. In addition to the categories of the original TAM, an additional dominant influential factor emerged; 'perceived accessibility'.

Perceived usefulness

Perceived usefulness is the extent to which an individual believes that their performance or role would be enhanced by using a specific technology[19]. The therapists held the perception that the technology cultivates therapist creativity, enables the broad creation of items, customisation, precision, reduced human error, and creation of an end product that is aesthetically pleasing; both prior to and post-exposure to the technology. However, although the therapists had positive perceptions of the technology prior to exposure, it was noted that the positive perceptions increased following exposure. Exposure to the technology caused a medium effect size, further solidifying their original perception of the usefulness of the technology system. A significant difference, however, between the pre- and post-exposure perception of usefulness was that most therapists felt that the technology would be better suited to producing assistive devices, rather than splints. Many of the therapists' splint on a daily/ weekly basis (47.5%). Unlike assistive devices with the primary goal of aiding function, splints can also be prescribed as an adjunct to medical intervention; they can be used to stabilise, immobilise and prevent injury or deformity[36]. As a result, a splint is generally issued within the session. For this reason, many therapists perceived the technology as inappropriate as a means of splint fabrication because 3DP can require extended printing times. An article by Willet[37] states that the printer's type or specification will also determine its use. For example, there are entry level, hobbyist, enthusiast, professional, and industrial–level printers, which will vary in printing speed, quality of printing and complexity. Printing times depend on the print settings, for example; print density, layer height, and the requirement for structural support. Therefore, suitability is more so task and item-specific.

Perceived ease of use

Perceived ease of use can be described as the degree to which an individual is of the opinion that using/ operating a specific technology system would not require significant mental effort or physical exertion[19]. Perceived ease of use was explored by looking at whether therapists perceived the technology system (hardware and software) as easy to learn, whether they felt they could become proficient and

skilful in using the technology, and whether they believed it would require expert training. This category displayed a medium effect size between pre and post-test responses. However, of significance was the large effect size in the change of perception as to whether the therapists perceived that learning to operate the technology proficiently would be easy. Initially, most therapists perceived the technology as requiring expert training, knowledge, and skill to operate. After exposure to the technology, there was a significant shift towards perceiving proficiency as attainable and within reach. Existing literature examining individuals' perceptions of ease of use of technology, shows that an individual's perceptions significantly depend on their perceived general technology self-efficacy[38]. Self-efficacy is a person's belief in his/ her capability to perform a particular task successfully and is one of the most powerful volitional predictors of how well a person performs[39]. Computer self-efficacy refers to one's confidence in learning, understanding and proficiently operating a new technology[40]. Research has shown that an individual's technological self-efficacy is a significant determinant of perceived ease of use[38]. All of the participants had minimal to no prior experience or knowledge of 3DP, after exposure, however, their perception of their ability to navigate and operate the technology was altered. These findings are validated by Research that has found that increased insight into a technology system correlates with reduced technology-related anxiety and increased interest in the technology[41].

Attitude

In the study, 38 of the 40 participants reported no prior experience with 3DP and two reported that they were novices. As a result, having limited to no prior knowledge or experience in 3DP technology, nor an understanding of how it works or could potentially be applied in practice settings, many therapists did not initially report strong opinions/ feelings (or any opinion/ feeling) towards the technology system. However, despite their lack of experience, others formulated an opinion and acknowledged the technological direction in which the world is advancing and felt that 3DP might be a useful resource in occupational therapy practice. Following exposure to the technology system, therapists reported having a clearer understanding of what 3DP is, what the technology system entails, the printing process and the actual and potential applications in practice. Afterwards, most therapists expressed positivity towards the technology system (not discounting their concerns), viewing it as something innovative with broad applications that will enhance intervention and complement the skills occupational therapists' are already equipped with. These findings corroborate with a study by Holzinger, Searle, and Wernbacher[42], where they depicted acceptance based on previous exposure to a technology system.

Several therapists raised concerns centred around job security, specifically due to the concern of automation. However, in an Oxford University study[43], 702 common occupations were examined, and their risk of automation was analysed and compared. Occupational therapy only scored 0.35% risk of automatic. Despite continual technological advancements, occupational therapy is not at risk of automation as it requires continual creativity, complex relational interactions and is highly unpredictable and vast. Technology can however change how therapists provide services[7]. A frequent concern was centred around losing or extracting from core occupational therapy skill sets and specialities; worrying that using a technology system instead of hands-on labour might affect the therapeutic relationship with the patient. An additional concern was centred around the open-source platforms. It was admitted that open-source platforms would prove to be highly advantageous in providing a global sharing of designs and knowledge; however, these resources would also be accessible to other professions and the general public. This raised the concern of other healthcare disciplines encroaching on occupational therapy practice, but even more so the concern of the general public accessing open-source sites, posing a serious safety risk because clinical reasoning would not be applied. These concerns corroborate with an article by Vogels, Rainie, and Anderson[44], which unpacks the uses of technology. The article states that the determinant of technology's impact, is how technology is used, who uses it, and what it is used for. Technology can be highly advantageous as easily as it can be detrimental to society; it depends entirely on the user.

Perceived accessibility

External variables are essentially a variety of variables that are expected to influence users' technology acceptance and adoption. These factors include environmental factors, political factors, personal characteristics, organisational factors, etcetera[45]. External variables emerged as a dominant feature, specifically accessibility and feasibility within the South African context. Initially, the majority therapists perceived the technology as being 'out of reach,' and financially inaccessible. Post-exposure, majority of therapists reported that the technology was far more financially accessible than they initially thought, and more accessible in the south African context than they originally thought. The feasibility, however, of procuring a printer in the public healthcare system was still raised as an apprehension due to the financial and resource constraints within the system.

Additionally, what did not change was the queried feasibility of the technology; using a system that requires electricity to perform an essential service in a country accustomed to frequent power outages. Eskom is South Africa's dominant electricity supplier but is frequently unable to meet the electrical demands of the country, resulting in the implementation of 'Loadshedding,' a staged approach to power outages with the purpose of conservation. While private facilities and frequently secondary/ tertiary-level public hospitals are equipped with generators, smaller hospitals and clinics are often left in the dark[46].

CONCLUSION

The study's findings reveal that engaging therapists in a workshop introducing them to the concept of 3DP at an introductory level, brings about a change in the therapists' perception of the technology system. Exposure to 3DP resulted in improved perception of the technology's

usefulness, ease of use and attitude towards it, impacting their reported intention to use the technology in future practice. Table VI (page 16) shows a summary of the advantages and disadvantages of 3DP in occupational therapy practice.

Apprehensions

Open source sites and technology system use cannot be monitored or controlled. This is true with everything. In an article by Vogels et al[44], the benefits and risks of technology advancements are discussed; what was noted is that from the beginning of time advancements have been two-fold. Fire, for example, can be used to cook just as easily as it can be used for destruction. The same is true for technology, it is neither inherently good nor bad, but entirely dependent on the user and how it is wielded. The occupational therapist's role is to ensure it is wielded for good. Several therapists have raised concerns about other disciplines encroaching on occupational therapy practice. However, despite the vast advancements in 3DP globally, South Africa is still at the exploratory phase, the profession therefore has the opportunity to take ownership and run with it, enabling the profession to evolve with technology and remain relevant, keeping occupational therapy at the forefront.

Recommendations

If the barriers to clinician uptake are overcome, the negative perceptions towards 3DP technology in occupational therapy practice may be mitigated, resulting in easier uptake and utility. The following recommendations would aid clinician uptake and overcoming of certain barriers.

3DP workshops

It is recommended that beginner, intermediate and advanced 3DP training courses are initiated, enabling upskilling of therapists. The courses should be geared towards incorporating theory and practice, enabling practical skills training.

Partnership and mentorship

It would benefit healthcare professionals to extend themselves beyond working in silos, and instead share resources, experience, and knowledge in 3DP. 3DP 'hubs' can be created for the sharing of resources. Smaller, poorly resourced clinics and hospitals should partner with better-resourced tertiary hospitals, and private practitioners should group together, pooling resources. To note, private and tertiary hospitals are equipped with generators[46]. Key therapists should be appointed as the point of call within each district, enabling mentorship and guidance.

Partnership with engineers utilising 3DP would be beneficial to enhance the applications and use of the technology system and guide troubleshooting, repairs, and maintenance.

Education

3DP should be incorporated into the occupational therapy undergraduate curriculum, together with continued studies on evolving technological advancements, ensuring the professions continual advancement is stimulated at a foundational level.

Resource pool

Occupational therapists need to be designing and uploading products onto open source sites such as Thingiverse, thus growing the profession-specific pool of resources.

During courses, therapists should be engaged in case studies that require practical designing of items, these can then be saved and uploaded to open source sites, contributing to resources.

Job security and conventional practices

As a profession, occupational therapists can also vouch for policy implementation, protecting the role of assistive devices and splint fabrication.

To combat the concern of extracting from core occupational therapy skill sets and specialities, coursework should include practical patient care, utilising the technology. This would enable therapists to determine whether the therapeutic relationship with a patient is affected due to the incorporation of the technology, and provide practice in navigating a new dynamic.

Limitations

Limitations to the study are multi-faceted. Firstly, the sample of participants was limited due to accessibility. For therapists to participate in the study they had to attend the in-person workshop, which limited the number of therapists as most of the therapists who did attend live in and around the eThekwini and uMgungundlovu districts, where the workshops were held. Secondly, the sample was also further limited by therapist's availability and willingness to participate in a two-hour in-person workshop. Although lack of interest cannot be assumed, the limited response and enthusiasm for the topic of 3DP may be indicative of such. Lastly, although the study is striving to ensure generalisability through the sample accurately portraying the population it represents, the study is limited to KwaZulu-Natal and therefore inevitably, it cannot be assumed that it will accurately represent the population outside of this region.

Author Contributions

Shelley Louise Barter was a Masters of Occupational Therapy student who contributed to the design, and was involved in the data collection, data analysis and writing up of this study. Alexander Jean Williams (Masters of Occupational Therapy candidate) and Pragashnie Govender were involved in the initial conceptualisation of the larger study on 3DP. Alexander Jean Williams assisted in the data collection for this study. Pragashnie Govender, Gina Rencken and Nonjabulo Ndaba were supervisors of the study and contributed to the design, provided supervision during the data collection process, and provided critique of the manuscript and assisted in revision of the manuscript for publication.

Conflicts of Interest

The authors have no conflict of interest to declare.

Table VI: Summary of 3DP advantages and disadvantages in occupational therapy practice

Advantages	Disadvantages
• Ensuring the profession evolves with technology and remains relevant, keeping occupational therapy at the forefront. • Allows for creativity and the production of innovative items. • Enables accuracy and precision of items fabricated. • Enables customisation and individualisation to the exact specifications of the patient and opens doors to vast problem- solving to meet each patient's specific needs. • The material is more cost effective than conventional materials, and provides increased variety of materials. • Products are aesthetically pleasing, can be lower profile and lighter weight, ultimately improving patient compliance. • A broad spectrum of items that are not easily accessible, affordable, or not even available can be fabricated - the convenience of being able to make rather than having to source. • Access to open-source sites allows access to ideas and blueprints globally, enabling a vast pool of resources. • Ability to design and fabricate without touching the patient; reducing pain, and preventing disruption of a repair etcetera. • The patient can see and visualise the end product during the design process, allowing opportunity for input prior to printing, contributing to reduced wastage. • Reduced manual labour.	• The printer's initial cost would make it especially difficult to procure in a public setting. • Extended print times (Depending on the size, complexity, and density of the item being printed). • Requirement for electricity to operate, in a country accustomed to loadshedding/ power outages. • Need for training and continuous upskilling of new staff. • Concern regarding the availability of maintenance, repairs, assistance with troubleshooting, specifically in the public sector. • Technology will continue to evolve; therefore, the system and printers will require continual upgrading which requires continual financial outlay. • Due to the availability of open- source sites, correct, therapeutic use of the technology system is not guaranteed. • Occupational therapists' role of being the key fabricators of assistive devices and splints cannot be protected. • If there is an error or the machine malfunctions, printing might need to start from the beginning. • The design process requires perceptual proficiency, making designing difficult for those who struggle to work between 2D and 3D designs.

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