Cape Peninsula
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The integration of digital technologies into fashion product development education

By

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ABSTRACT

This study explores the integration of digital technologies into fashion product development education to address the challenges of the fourth industrial revolution in the apparel industry. Historically, the fashion industry has favoured traditional methods and physical artefacts for design and production, but recent technological advances have disrupted this practice, raising questions about the relevance of current teaching methods used by the University of Technologies that offer fashion design programs. This research aims to bridge the gap between traditional and modern teaching approaches in product development education in the fashion industry. The research questions underlying this study are twofold: (1) What is the relationship between current design technology and fashion product development? (2) How does technological change affect teaching and learning in fashion product development? To answer these questions, the study compares the teaching practices of the different fashion design programmes being offered by universities of technology (UoT) in South Africa**,** and the apparel industry, and finally develop a framework for adapting teaching methods. Through a qualitative research method influenced by posthumanism and actor-network theories, the study explores the relevance of current educational approaches for 21st century students and their alignment with industry practices. It looks at 21st century education and its alignment with industry practices. It recognizes the continuing importance of conventional methods as a foundation for digital systems and explores how teaching and learning must evolve to harness the potential of technology. Through a systems-analytic analysis approach and benchmarking at two UoT offering fashion design programs, this study identifies opportunities to bridge the digital-physical divide and align education with industry needs. By providing a comprehensive impact overview of how digital technologies are being used in the apparel industry and at Universities of technology that offers programs of study in fashion design and product development, the study uncovers research gaps, underscores the need for further studies and provides recommendations for policy and practice. The study contributes to the ongoing dialogue on transforming fashion product development education and highlights the need for innovative teaching approaches that combine digital and traditional learning experiences to prepare students for successful careers in the evolving fashion industry through a conceptual framework. The dynamic nature of the fashion industry is highlighted, and the findings aim to foster a deeper understanding of digital technology integration for informed decision-making in curriculum development. The research ultimately suggests that digital technologies and conventional production methods must co-exist.

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DEDICATION

I humbly dedicate this PhD study to the cherished memories of my late mother, Nondumiso Kolisi, and my esteemed former lecturer and mentor, Bryan Ramkilawan. May their souls continue to rest in eternal peace.

To my beloved father, Siphelo Kolisi, I express my deepest gratitude for your unwavering upbringing, your inspiring motivation, your profound wisdom, and the love you have showered upon us, your children. Enkosi Dongo.

LIST OF DEFINED ACRONYMS

ACRONYM	DEFINITION
2D	Two-Dimensional
3D	Three-Dimensional
3DP	Three-Dimensional Printing
ANT	Actor Network Theory
CAD	Computer-Aided Design
CPUT	Cape Peninsula University of Technology
DT	Digital technology
FIR	Fourth Industrial Revolution
POPIA	Protection of Personal Information Act
RQ1 & RQ2	Research Question One and Research Question Two
TCF	Textile, clothing, and footwear
UoT	University of Technology

CLARIFICATION OF TECHNICAL TERMS

TERMS	CLARIFICATION
Anthropometry	A practice of measuring the human body, has been performed for centuries by artists, scientists, anthropometrists, and tailors using traditional tools such as tape measures (Glock & Kunz, 2005).
Apparel product development	"A process that facilitates the transformation of a market opportunity and a set of assumptions about a product's technology into a product that is available for sale, and that includes planning, design, sampling, manufacturing, and retailing" (Fung et al., 2021, p. 6).
Blocks	Consists of two-dimensional templates that form the basis for creating three-dimensional garments (Lim & Cassidy, 2017).
Basic block	Basic block patterns are developed using body measurements and allow for allowance to ensure movability (Lim & Cassidy, 2017).
Curriculum	As defined by (Van Den Akker et al., 2009, p. 9) "The word curriculum is derived from the Latin verb currere, meaning to run, and is further defined as a plan for learning".
Design	"An act of describing an object's structural features, either in a plan or in the object itself. Because design is an activity rather than a stage in a process, it may not have a clear endpoint" (Ralph & Wand, 2009, p. 3).
Educational Technology	"The use of various modern methods, media, and materials to enhance the learning and teaching experience" (Shah & Murtaza, 2012, p. 1).
Fashion	"A current style that is followed by many people at any one time. It is about promoting the new and is concerned with constantly changing aesthetics" (Burke, 2011:11).
Fashion Design	Fashion design stands for the integration of material and ideas (Lu, 2018).
Fashion product development	Encompasses the design and engineering necessary to create marketable and profitable production measures (Glock & Kunz, 2005).
Fit	"How the garment conforms to or differs from the body. Sometimes described as garment cut" (Glock & Kunz, 2005:141).

TERMS	CLARIFICATION
Fashion Education	A comprehensive system that includes education at different levels, continuous retraining, and lifelong learning to train professionals in the fashion industry, including fashion designers, manufacturers of consumer goods and footwear, and creators and promoters of fashion brands (Yezhova et al., 2018).
Manufacturing	A process that turns a design concept into an actual product (Fung et al., 2021, p. 9).
Online Learning	"An innovative educational approach where instruction and content are focused on interactivity, design, learner-centred approaches, and facilitated learning experiences which are primarily delivered through open, flexible, and distributed learning environments" (Madathil et al., 2017).
Pattern	A guide for cutting the fabric which can be sewn together to form a garment (Datta & Seal, 2018).
Pattern Making	"The art of designing patterns by making templates from which clothing and craft items can be sewn. A pattern making process helps to come out with the imagination of the designer from the sketching to a real product. Pattern making is considered the first step in garment production" (Datta & Seal, 2018, p. 29).
Pattern Grading	A gradual adjustment of base size or sample size in accordance with specific instructions, utilizing a size specification sheet based on measurements. This adjustment can involve both increases and decreases as directed (Datta & Seal, 2018 p. 32).
Product Development	"The design and engineering required to make products serviceable, saleable, producible, and profitable" (Glock & Kunz, 2005:p. 85).
Mock-Up	"A sample garment, usually made of translucent cotton or linen fabric, that is not perfectly completed or hemmed like the genuine garment and is used to test and perfect the design" (Datta & Seal, 2018:p. 30).
New Product Development	The process of translating market opportunities and technological assumptions into saleable products through planning, design, sampling, manufacturing, and retailing. As a result, this study discusses the processes involved in new product development, (Fung et al., 2021).
Technical Design	"A process that includes perfecting styling and fit, engineering production patterns, testing materials, and assembly methods, developing style and quality specifications, developing detailed costs and grading patterns" (Glock & Kunz, 2005:p. 86).

TERMS	CLARIFICATION
Zero-waste fashion design	A process that aims to eliminate production waste and traditionally uses 2D digital tools such as Gerber pattern software, Adobe Illustrator, and Photoshop to develop zero-waste patterns, (McQuillan, 2020).

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CHAPTER ONE: INTRODUCTION

In the past, the development of tangible artefacts was seen as the most effective method for teaching fashion design since they facilitated experiential learning and the acquisition of fundamental skills. This thesis presents a study conducted to aid contemporary students in the 21st century and address the need for adapting existing academic methodologies in fashion product development courses.

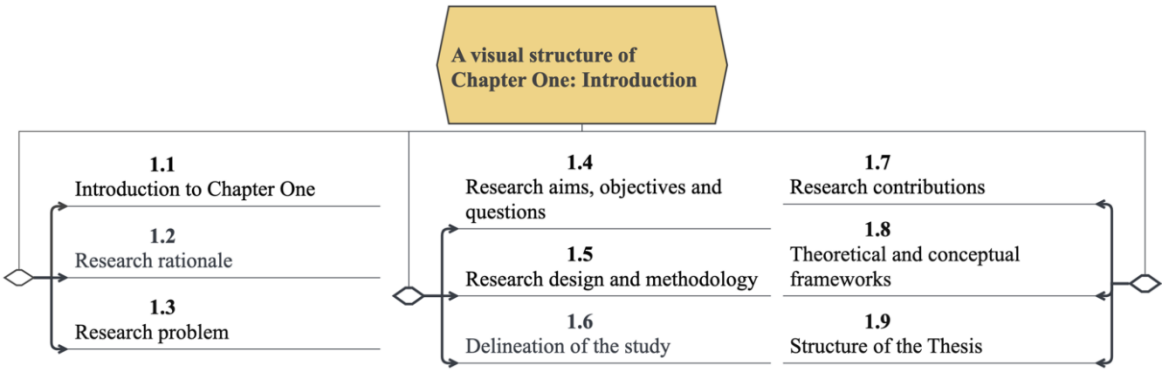


Figure 1.1: Visual structure of Chapter One

This chapter provides an overview of the key dimensions and fundamental elements of the research study. To provide an overview of the key areas covered in this chapter, Figure 1.1 above lists the key headings and subheadings. The diagram serves as a visual structure as well as a guide through the different dimensions of the research and summarises the fundamental elements of the research.

1.1 Introduction to Chapter One

In the realm of fashion design education there is a dearth of research literature on learning design experiments that explore the application of online teaching and learning for subjects that involve practical applications. This lack of attention can be attributed to the prevailing assumption that practice-based subjects primarily revolve around physical activity and necessitate students' physical collaboration in on-campus workshops and groups (Nortvig et al., 2020).

The purpose of this research was to explore the dynamics between design technology, pattern making, and garment construction and their implications for teaching and learning. This results from the fact that evidently, general design education was transitioned to digital blended learning, while teaching methods in apparel product development remained hands-on. This was more evident during the outbreak of COVID-19 in the year 2020. Consequently, this study was conducted to discover how the physical learning spaces of apparel product development can be digitally enhanced. Additionally, this study explored ways to improve traditional fashion education and manufacturing methodologies, as well as how the incorporation of digital technology into fashion design education can be promoted.

This study explores the factors driving current change in fashion education while providing an overview of the design field and its educational landscape. It also examines the fashion design technologies available. To emphasize the importance of a basic understanding of design and fashion education, it is important to note that this study focuses specifically on fashion product development, particularly in the area of apparel manufacturing.

In the next section of the thesis, I provide a basic overview of the field of design and fashion education, focusing on the development of fashion products, particularly in the area of apparel manufacturing. Factors driving change in fashion education are discussed, as well as available design technologies. As a result, an assumption was drawn and is discussed.

1.2 Research Rationale

To gain a better understanding of current teaching practices in fashion design schools, the literature review focused on fashion pedagogy and current product development technologies used by both the apparel industry and fashion schools. It explored the methods used by the apparel industry and their changing trends. A similar study by Faerm and Campbell (2012, p. 1) explored the future of fashion design education by examining current practices and assumptions about professional practice and design pedagogy.

This study was motivated by changing expectations of designers, changes in design and production methods, and evolving design education philosophies in schools, all of which impact how designers are taught. Higher education is changing responding to cultural, technological, and economic needs, with some countries moving from standardised approaches to personalised learning models that prioritise what students learn over time spent in the classroom (Pontis & van der Waarde, 2020).

This study focused on technology with an aim of understanding the technologies currently used in fashion design schools and the apparel industry, as technology has a significant impact on global change. This research also explored the role and the impact of technology in product development and compared production methods in the apparel industry and in fashion design education. This approach was guided by the idea that intense competition in the industry necessitates staying current with new technologies and modernising manufacturing methods (Fung et al., 2021) an idea echoed by Surani *et al.*, (2021) regarding the impact of technological advances in the current industry training and practices.

The research involved benchmarking various apparel manufacturing companies and the (UoT), using a design-based approach. The objective was to assess the product development approaches and methods used by the apparel industry and compare them to those used by the fashion schools, as well as their

relevance of approaches and methods used by apparel design educational institutions for 21st century students.

The use of this benchmarking method was influenced by Yezhova et al, (2018) who used a benchmarking method during the process of conducting a comparative systemic analysis of personnel preparation models in fashion education, examining the European Union, Ukraine, the USA, Canada, China, and Japan. The benchmarking process enabled me to identify the possible gaps in the clothing design course offering within the South African fashion design schools. The gaps unveiled in this study are discussed in Chapter Five.

1.2.1 Basic assumption

The assumption underlying this study is that fashion product development teaching needs to change and that the current method of teaching needs to be adapted in a more technology-integrated approach that caters to the current students to better prepare them for the fast-changing clothing industry. This stems from the observations that, as the general design education became more transformed to digital blended learning, the practice-based fashion clothing product development teaching methodology is not transformed accordingly.

This assumption was supported by the results of a study conducted by Han *et al.*, (2020), which revealed that 3D is gaining traction. Further stating that, adopters in the sector, including Adidas, Nike, Under Armour, Target, Coach, and many more, have been experimenting with 3D for years and are putting pressure on vendors to deliver solutions that work, according to their findings. It has been determined that 3D technology is already available, (Han et al., 2020). To confirm this assumption, it was crucial to conduct research and answer the research questions. Further details about the focus of the study are explained in the following sections.

1.2.2 Research focus

Design education is a broad field that includes both practical and academic disciplines. Each category comprises various specialized disciplines characterized by fluid, indeterminate parameters that are subject to constant change. Various design societies are involved in these disciplines (Meyer & Norman, 2020). Fashion design courses include both practical and theoretical elements.

One of the objectives of this study was to examine the product development methods employed in fashion design courses, specifically focusing on the *manufacturing processes* within fashion design studies. *Manufacturing* is a process that adapts a design idea into an actual product, (Fung et al., 2021, p. 9). The study placed particular emphasis on the incorporation of technology into various aspects of fashion product development, exclusively on pattern making and garment construction.

Fashion product development encompasses the design and engineering necessary to create marketable and profitable products (Glock & Kunz, 2005). Given the rapid pace of the design industry, Fung, and Chan (2021) introduced the concept of new product development and defined it as the process of translating market opportunities and technological assumptions into saleable products through planning, design, sampling, manufacturing, and retailing. As a result, this study discusses the processes involved in new product development.

Although the focus of the study is on fashion education, garment industry practices are also explored to assess their consistency with those used in universities and technical schools. The study also examines the conventional and digital methods used in this context. Thus, the dynamic nature of the apparel industry requires constant adaptation of education models in the teaching and preparation of future fashion designers.

1.3 Research Problem

Due to the changing ways in which garments are produced in professional practice, Fashion design UoT should explore new methods of teaching product development that relate to garment construction and pattern making. The research problem is outlined in Figure 1.2 below, which considers the practical problem, academic problem, and theoretical problems.

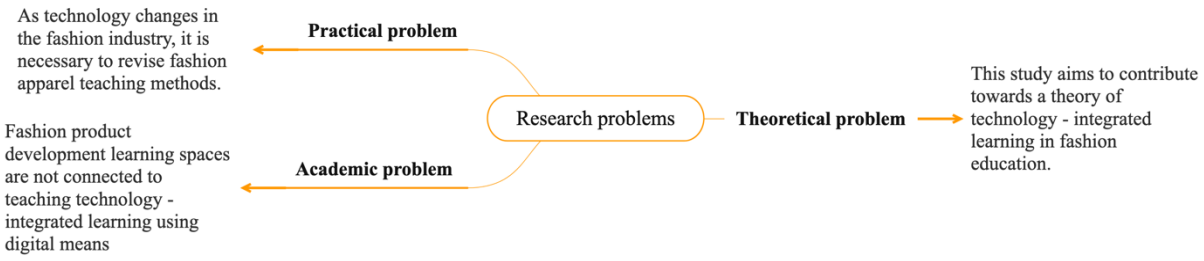


Figure 1.2: An outline of the research problem

A practical problem identified is that, as technology changes in the fashion industry, it is necessary to revise fashion apparel teaching methods. An academic problem is that fashion product development learning spaces are not connected to teaching technology-integrated learning using digital means. Lastly, a theoretical problem is that this study aims to contribute towards a theory of technology-integrated learning in fashion education. The next section outlines the research problems, which include practical, academic, and theoretical dimensions. The rationale for this research is explained in the forthcoming section and is discussed in detail.

1.3.1 What prompted the study?

Due to the implementation of hands-on methodologies in fashion education, the practical component of fashion design encountered challenges throughout the COVID-19 pandemic. Consequently, the delivery of practical courses necessitated a shift towards theoretical instruction and online platforms. Students may find it difficult to understand course material as a result of this integration gap, for example, if they use 2D software (CAD) rather than the conventional pencil and paper method for creating patterns (Gu & Liu, 2019).

My interest in exploring this field stems from the observation that despite the existence of pattern making technologies such as 2D computer-aided design software (CAD) and 3D body scanners, my teaching experience in fashion design suggests that apparel manufacturing technology is not seamlessly integrated into pattern making and garment construction processes. Palaskas (2002) concurs with this opinion, noting that many teachers are sceptical of, and sometimes even resistant to the introduction of new learning technologies into the classroom. In addition, Palaskas mentions that teachers' negative attitudes toward integrating technology into the classroom may be due to non-educational factors such as commercial interests, organisational politics, cost considerations, and enrolment goals.

In addition, there are concerns about the inclusivity of the fashion design course for people with disabilities who are interested in studying fashion design and pattern making as a career and who may have difficulty using the equipment used in the course. Equipment such as high pattern making tables and pedal-controlled sewing machines and other equipment, due to their height or other form of disability. In my experience as a university lecturer, there were people with disabilities who enrolled in the course but were unable to complete it due to the hands-on nature of the disciplines, particularly garment and pattern making. The subsequent section of this study introduces a research gap.

1.3.2 Research gap

Research indicates that traditional teaching methods are no longer suitable because technology has changed. Thus, how should teaching and learning be adapted to harness technology? In fashion product development education, hands-on subjects with an emphasis on physical interaction create a gap between digital and physical experiences for students.

This gap stems from the dynamic and constantly evolving nature of digital technology, as well as diverse options of digital technology application within the education and apparel sectors. This was echoed by Arribas and Alfaro (2018) who alluded that, to date, there is a gap in research regarding the impact of digital transformation on industries whose primary products are physical, such as the fashion industry. A similar gap was identified in a study by Han *et al.* (2020, p. 379), which examined the efficient

integration of digital prototypes into the textile, clothing, and footwear (TCF) industry's product development process and the adoption of new digital technologies. The study examined the use of 3D visualisation and virtualisation and the scepticism and cautious optimism of technology providers, experienced users, and academic researchers in the apparel and fashion industry.

Their study found that there is a lack of dimensional digital prototypes of apparel in the product development phase. As a result of the identified gap, my goal was to explore how, and which new teaching approaches may be adopted through the integration of technology. The next section outlines the aims of the research, objectives as well as the discussion of the research questions on which the study is based.

1.4 Research Aim, Objectives, and Questions

1.4.1 Aim

The overall aim of this research is to explore the dynamics between design technology, pattern making, and garment construction and their implications for teaching and learning.

1.4.2 Objectives

To achieve the research aim, the following objectives refer to:

- Determine how the physical learning spaces of apparel product development can be digitally enhanced; and
- Identify ways to improve traditional fashion education and manufacturing methodologies, as well as
- Promote the incorporation of digital technology into fashion design education.

The next section addresses the basic assumption upon which this study is based.

1.4.3 Research questions

Table 1.1 provides a visual representation of the research questions underpinning this study, while a more detailed explanation follows.

The research questions of the study aimed to find out:

- What is the relationship between current design technology and fashion product development?
- How does a change in technology affect teaching and learning in product development?

Table 1:1: A visual structure of the research questions

1.5 Research Design and Methodology

Motivated by the pursuit of insightful and comprehensible insights, I opted for a qualitative research methodology. The associated resource requirements were critically scrutinised and considered.

1.5.1 Methodological cost

This study intentionally chooses a qualitative research design to prioritize the capture of rich, contextualized meaning and explore underlying narratives. While a mixed methods approach could offer complementary dimensions, the scope of this investigation necessitates a focused exploration, making efficient use of the available sample size. The sample consisted of approximately twenty-five carefully selected participants. The methods used for sample selection are briefly highlighted.

1.5.2 Data collection methods and technique

Given the specific focus and context of this study, a purposive or judgmental sampling technique was used to select participants because it is cost-effective, convenient, and saves time. This decision was guided by the findings of Taherdoost (2016, p. 23), who emphasized that purposive or judgmental sampling deliberately targets individuals in certain situations to obtain specific information.

Consequently, the study aimed to capture the perspectives of a specific population in a specific setting, which included industry practitioners, lecturers at selected Universities of technologies (UoT1 and UoT2), alumni, and final-year students (third and fourth year), with the assumption that they could provide first-hand insights.

It is important to note that no statistical inferences were made about the overall population in this study, and there was a clearly defined rationale for including the participants (Taherdoost, 2016). The data gathering approaches used consisted of focus group interviews with UoT1 and UoT2 students and UoT2 faculty members. In addition, confirmatory interviews were conducted with two apparel industry practitioners, which were considered the optimal approach for data collection. Sources such as books, journals, and the Internet were used for secondary data collection.

Contextual analysis was considered relevant to identify the methods used in product development for both pattern making and garment construction. In addition, it was used to assess the awareness and knowledge of current digital technologies used in fashion product development. Finally, the study aimed to improve the understanding of the conceptualization of methods used in apparel production in both traditional and digital contexts.

1.6 Literature surveys

An ongoing literature review was conducted to stay current with the research supporting this study and to understand the prevailing techniques and resources used in the apparel industry and in fashion product development education. This review included an examination of books, journals, and online sources, with particular attention to identifying current trends in fashion product development and education.

1.7 Delineations of the Study

Because I wanted to get the views from the people who could share their views and experience in the apparel industry and UoT offering fashion design programmes, the study referred exclusively to individuals working in the apparel industry and is limited to fashion South African UoT and practice. It considers only lecturers involved in pattern and garment construction courses in the final year of study and the practitioners who are directly involved in apparel manufacturing.

In the UoT, only final year students were considered, not first or second year students, as it is assumed that they do not have the necessary experience to participate in the study. Small, medium, and large apparel manufacturers were considered for data collection. Although preliminary data suggested that small companies may not have access to technology, they were considered for data collection because their views on integrating technology into product development are of high value, and an introduction to the research methodology used for data collection is outlined below.

1.8 Research Contributions

This exploratory study helps to identify the need for change in product development education in fashion design, especially in pattern making and garment construction. It contributes to the body of knowledge in fashion design education and focuses on integrating technology into teaching methods to improve learning.

This study's contribution to the body of knowledge is presented via a conceptual diagram of theory of change for integrating digital technologies into fashion product development education and is presented in Figure. 5.3 in Chapter Five. The contribution lies in its vision for the future of fashion education,

where tradition and technology coexist harmoniously to prepare fashion students for the challenges of the future.

Additionally, the research enhances our comprehension of the dynamics involved in integrating digital technologies into fashion education. It offers insights into the complexities and challenges associated with this integration process, drawing from the perspectives of students, graduates, and industry professionals. It also underscores the importance of early adoption and the balance required between traditional craftsmanship and modern innovation.

This study encompasses different chapters and are outlined below. In the next section, I provide an overview of the thesis and give insight into the various chapters that make up this research, all of which contribute to a holistic understanding of the topic. This thesis encompasses a multi-faceted exploration that should provide insights and knowledge to the field.

1.9 Theoretical and Conceptual Frameworks

This study incorporates posthumanism and actor-network theory by linking the human and nonhuman aspects and examining how technological advances can change, transcend, or even eliminate humanity (Forlano, 2017). Cennet Ceren Çavuş (2021) emphasizes that post humanists embrace technological development and aim to improve it.

As mentioned earlier in this chapter, this study is about the incorporation of digital technologies into fashion product development education. Understanding the complexities of this integration requires an approach that considers the interplay between human and non-human actors. During the process of data collection, an Actor Network Theory (ANT) provided a perspective through which to explore the complex and dynamic interactions between human and non-human actors in the context of teaching fashion product development.

ANT was used to consider both human and non-human entities as active participants, which yielded additional insights into how digital technologies are integrated in the apparel industry and in the teaching and learning processes. Throughout the study, I was able to recognize the variety of actors participating and their individual skills and interests.

ANT appeared as a valuable framework for such investigations, offering a lens to explore the dynamic relationships between various entities involved in the integration process. The use of ANT allowed for an exploration of how digital technologies influence change in the curriculum and pedagogy of fashion product development education, as well as how the roles of lecturers, students and technology are changing in the context of digital fashion education as a result of the use of digital technologies. The ways in which the classroom environments influence the use of digital technologies were looked into.

This decision was drawn from Wright and Parchoma (2011) who employed ANT in their study of learning technologies, particularly mobile learning, and considered it a valuable perspective for their research (Wright & Parchoma, 2011, p. 247). ANT provides researchers with a method to challenge commonly accepted assumptions and offers a new perspective on the study of technology, making it relevant to this study.

Lastly, ANT provided me with an opportunity to challenge the commonly accepted assumptions about the role of technology in fashion education by offering new perspectives on the study of integrating digital technologies into fashion education.

1.10 Outline of the Thesis

This study aims to contribute to the body of knowledge in the field of fashion design education by looking at the processes involved in fashion product development, focusing on pattern making and garment construction. Through investigation and analysis, this study seeks to shed light on key aspects of integrating digital technology into fashion product development education, addressing fundamental research questions and objectives. The subsequent chapters of this thesis are organized as visually outlined in Figure 1.3 and summarised below.

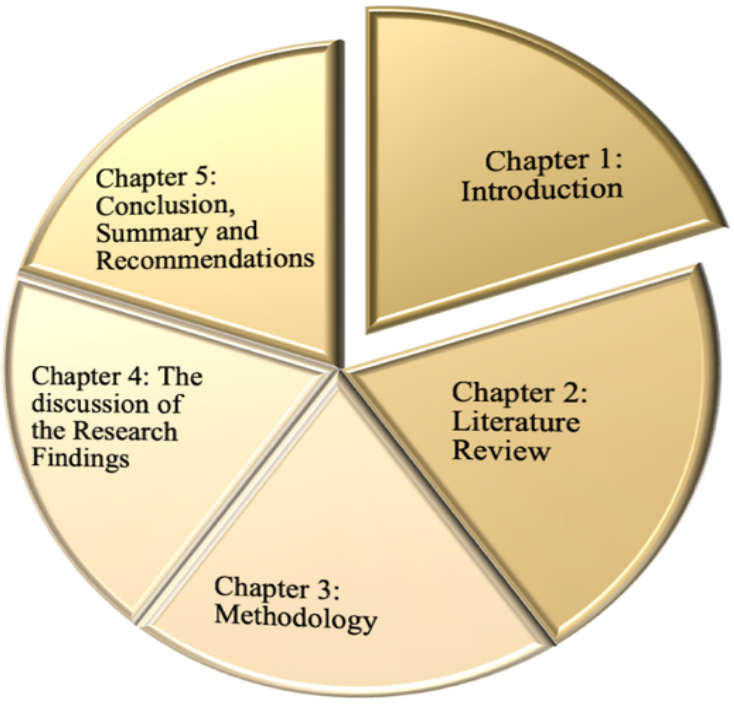


Figure 1.3: A visual structure of the thesis

The thesis consists of five distinct chapters that collectively aim to explore the dynamics between design technology, pattern making, and garment construction and their implications for teaching and learning. The following chapters of this thesis are organized as follows:

- Chapter One is an introduction of the thesis, and it provides an overview of the key dimensions and fundamental elements of the research study, as discussed above. The subsequent chapters of this thesis are organized as outlined in Figure 1.3;
- Chapter Two, the literature review, addresses the existing knowledge on this integration and provides a thorough understanding of the theoretical and practical principles in the field of fashion;
- Chapter Three describes the research methodology, explaining the research framework, data collection techniques, and analytical tools used to investigate the incorporation of digital technologies into fashion product education. It illustrates the sourcing and interviewing of a group of twenty-five (25) participants. It also explains the analysis of qualitative data collected through the use of ATLAS.ti in conjunction with a custom-developed Microsoft Excel spreadsheet (Appendix F); and
- Chapter Four discusses the research findings and presents the insights gained through data analysis and interpretation. Key trends, challenges, and opportunities in integrating digital technologies into fashion education are highlighted.

Chapter Five is the culmination of the research, drawing conclusions from the findings in Chapter Four, summarizing the results, and exploring their implications for digital technologies in fashion education and the apparel industry in general. In addition, Chapter Five provides recommendations for educational practice, policy, and future studies to advance digital technology initiatives while identifying gaps in the current understanding of this transformative potential. This thesis contributes to the ongoing dialog about the transformative impact of digital technologies in fashion education, with each chapter playing a unique and essential role in this scholarly endeavour.

CHAPTER TWO: LITERATURE REVIEW

In response to a rapidly evolving landscape of cultural, technological, and economic change, higher education is undergoing a transformation that is also impacting fashion design education. As design issues shift to new digital technologies, today's curricula have evolved to emphasize problem-solving methods that focus less on tangible artefacts (Pontis & van der Waarde, 2020).

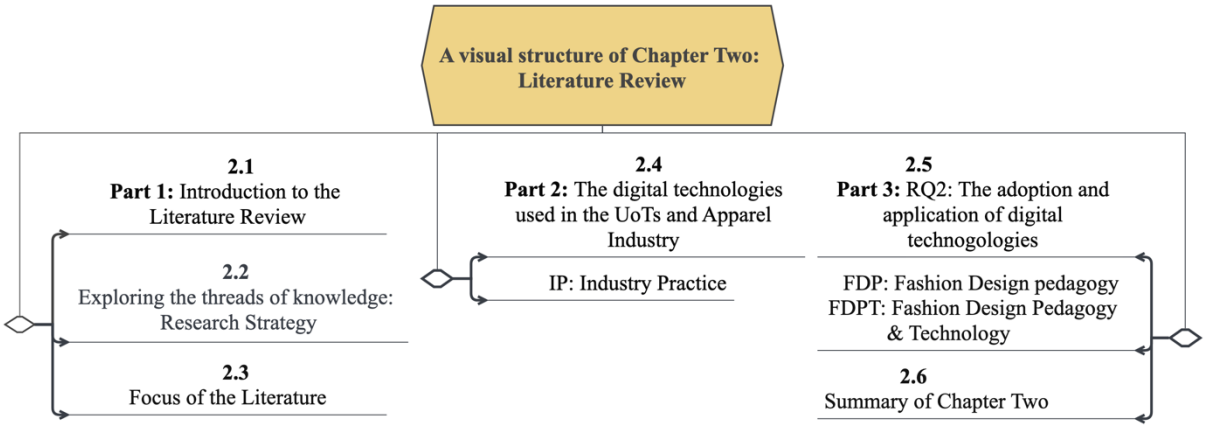


Figure 2.1: Visual structure of Chapter Two

This section, summarised above as Figure 2.1, deals with the literature review for this study, which is divided into three parts. The first part discusses the research strategy that was followed in the literature review. The second part deals with aspects related to the first research question, which relates to digital technologies used in the UoT and Apparel Industry. The third part deals with all aspects related to the second research question, which examines the adoption and application of digital technologies, focusing on the two areas of fashion design education and the aspects of fashion design pedagogy and technology. The summary of Chapter Two is also discussed in this section.

2.1 Part 1: Introduction to the Literature Review

Before delving into the multifaceted world of design technology and its impact on fashion product development, it is important to establish the framework for the review.

This literature review is divided into three main parts. The first part introduces the literature review and its methodology, while the second and third parts address the two research questions and sub-sections as outlined in Figure 2.2.

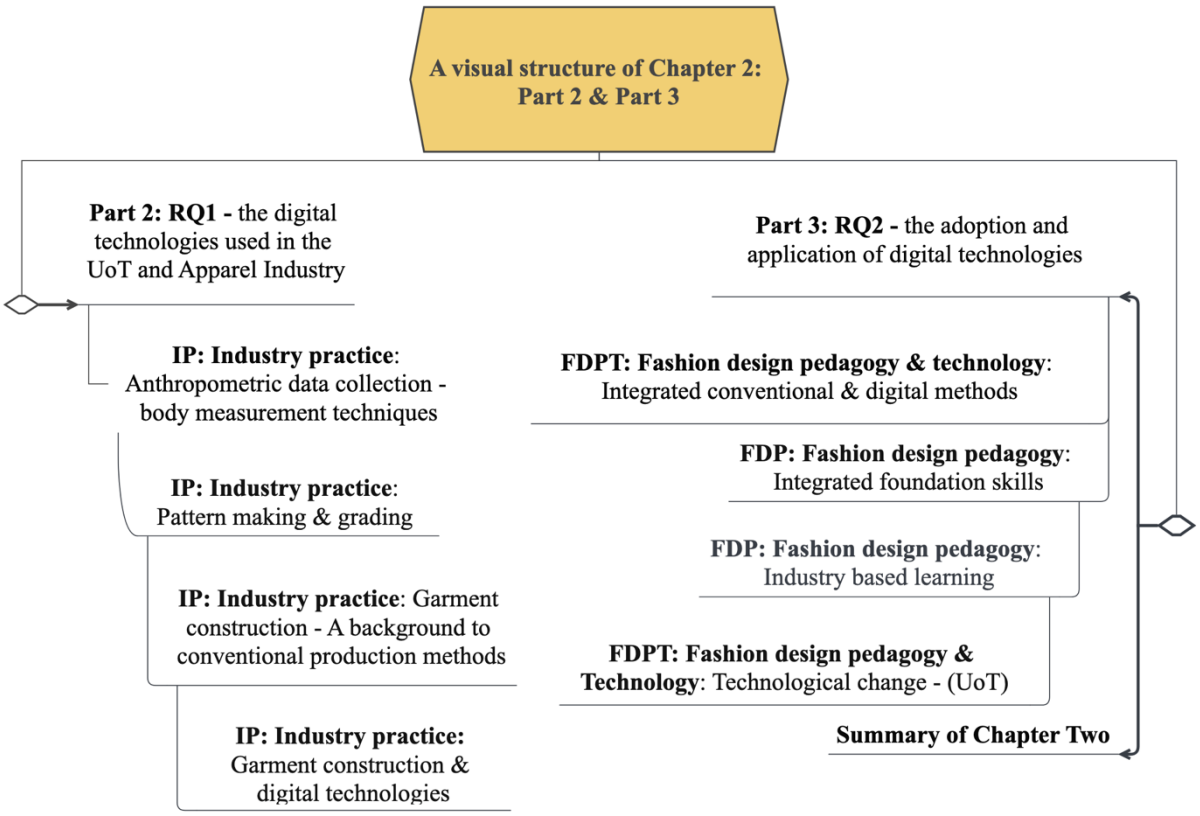


Figure 2.2: A visual structure of part two and part three of Chapter Two

Internationally, many countries are actively reforming their educational paradigms and moving away from one-size-fits-all approaches to adopt innovative and personalized learning models that prioritize quality over quantity in education (Pontis & van der Waarde, 2020). This change is not limited to conventional academic education, but also impacts design education. Through this literature review, the impact of technological advancement and digital transformation on apparel development and production processes in the apparel industry and in UoTs is explored. This is in response to the fact that the fourth industrial revolution has brought about technological advances that are altering old educational and industrial procedures (Surani et al., 2021).

This thesis explores the evolving landscape of design education and investigates the implications, challenges, and opportunities that arise as it responds to the dynamic changes in higher education and the design industry. It is motivated by the increasing pressure on designers to adapt their design and production methods to this changing environment, as well as the growing number of design schools revisiting their established educational philosophies to respond to these changes.

To determine whether the methods used in fashion design education are consistent with industry practices, the study evaluates the production techniques used in the apparel industry. This approach is

supported by Fung *et al.* (2021) who argue that companies need to adapt to new technologies and modernize their apparel manufacturing methods in response to intense competition.

The literature is primarily concerned with describing the main subject, namely product development, and its phases, such as pattern making and garment construction. In addition, the function of digital technologies, their advantages, and their efficiency in this specific context are examined. The integration of technology into fashion design education is explored, and its efficiencies and benefits. The final section addresses underutilized product development technologies in fashion education. This section aims to highlight technological opportunities and advances that have not been fully exploited in fashion education.

In addition to the introductory part of the literature review, the review itself consists of two main parts.

Part Two: This section provides a concise overview of the main research question (RQ1) of the study. and its related probing questions. The main research question is:

- What is the relationship between current design technology and fashion product development?

To answer this question, industry practices related to anthropometric data collection and body measurement techniques are explored. The purpose of this research is to give an understanding of the anthropometric data collection methods (body measurement techniques), commonly used in the apparel industry and the benefits related with them. This information was collected to allow for comparison with study participant responses presented in Chapter Four and to provide practical recommendations (Chapter Five) for fashion schools. In addition, this section addresses, patternmaking and grading methods used in the apparel industry. Insights into the background of conventional and digital production methods in garment manufacturing are also provided.

Part Three: In this section, I address Research Question Two which seeks to understand,

- How the change in technology affect teaching and learning in fashion product development.

The main objective of this question was to identify the aspects to be considered in the redevelopment of a curriculum for pattern making and garment construction. It also sought to identify the digital technologies used for product development by both the apparel industry and fashion design universities.

The literature review begins with an overview of the integrated conventional and digital product development methods used in fashion education, highlighting the levels at which the apparel industry and UoT are evolving and the transformative role of digital technology. It explores the nature of

technology and looks at how the industry has evolved, adapted, and adopted new approaches, providing insights into its development and technological advances.

The importance of conventional skills as a foundation for digital skills, which can serve as a way to teach students industry-related knowledge and skills is looked into as well as the extent to which UoT are embracing digital technological transformation. This decision was influenced by a study conducted by Pontis and Waarde (2020) which identified that "design education has broadened and diversified and can be grouped into at least four interrelated dimensions" (Figure 2.3) such as:

- Professional practice "Any major changes in professional practice will automatically require changes to what and how design is taught, because "curricular decisions determine the entry employment qualifications of new practitioners" and "designers' abilities to evolve as professionals and informed citizens across careers that last fifty years or more";
- Teaching arena, "The increasing complexity in the scope and scale of new types of design problems, and the need for multidisciplinary responses has triggered a wave of interest in design skills acquisition";
- Students, "The third group of changes that are influencing design education is related to the nature of today's students, their motivations, and their interests"; and
- The teaching approach, "As the student population becomes more diverse, new approaches, strategies and skills are needed to equip future designers, and so different approaches to teaching are needed too". This literature review is an attempt to identify, summarize, and evaluate the existing knowledge base, thus laying the foundation for subsequent chapters in which this study will contribute to this growing body of knowledge.

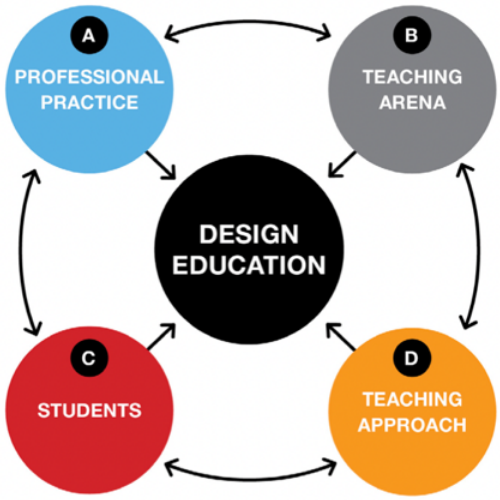


Figure 2.3: Changes that influence design education can be grouped into at least four interrelated dimensions, (Pontis & van der Waarde, 2020)

2.2 Exploring the Threads of Knowledge: Research Strategy

This study involves a systematic literature review, and the process is depicted in Table 2.1.

Table 2:1 Systematic review process

SYSTEMATIC LITERATURE REVIEW PROCESS						
Academic databases	**Research areas/inclusion and exclusion criteria**					
1) Google Scholar 2) Berg Fashion Library 3) Ebscohost 4) Scopus	**Search method**: Backward and forward snowballing method.		**Disadvantages of the search method** The constant influx of new articles in the rapidly evolving fields of apparel industry and fashion education.			
Total number of articles identified = 119	Included Articles = 49	Excluded articles = 70	**Key cited authors** (Arribas & Alfaro, 2018; Cukurova & Luckin, 2018; Da Silva et al., 2019; Datta & Seal, 2018; Faerm, 2012; Fung et al., 2021; Gu & Liu, 2019; Han et al., 2020; McQuillan, 2020; Spahiu et al., 2021; Sun & Zhao, 2017; Wijewardhana et al., 2021; Wohlin et al., 2022).			
Key Themes/Research areas: FDP: Fashion design pedagogy; FDPT: Fashion design pedagogy & technology; FPD: Fashion product development; Fashion product development & technology; IP: Industry practice.		**Total number of included literature = 49**		**Inclusion criteria**	**Data search criteria**	**Exclusion criteria**
1) Fashion product development & technology		5	**1**	English	**Language**	All languages either than English
2) Fashion design pedagogy		9	**2**	Academic databases & Grey literature - Open access & via library	**Source**	Sources not peer reviewed
3) Fashion design pedagogy & technology		11	**3**	Open access & via library	**Access**	No access to full text
4) Fashion practice		14	**4**	2001 - 2023	**Dates**	Prior 2001
5) Research thories		4	**5**	Consistency with research objectives	**Consistency**	Inconsistency with research objectives
6) Research methodology		6	**6**	Relevance to the research problem	**Relevance**	Irrelevance to the research problem
2001 to 2016 - *Objective*: To examine traditional approaches to product development at both the University of Technology (UoT) and the apparel industry.	**2017 to 2023 -** *Objective* : To gain a comprehensive understanding of current methods and practices, with a particular focus on evaluating the current state of incorporating digital technologies into the product development field.		**7**	Relevance to the research areas	**Relevance**	Irrelevance to the research area
			8	Insights into manufacturing methods	**Relevance**	No insights into manufacturing methods

The use of a systematic literature review was to identify all empirical evidence that fits the pre-specified inclusion criteria to answer a particular research question (Snyder, 2019). The search process began with a careful review of digital databases and indexing services, supplemented by a bibliographic snowballing technique to find relevant articles, as suggested by Wohlin (2022).

The goal was to gather information that was specific to the research problem, consistent with the research objectives, and illuminated the integration of digital technologies into fashion product development education. In addition, the study further aimed to address the challenges posed by the increasing complexity and systematic changes in design education. While general design education was transitioning to digital blended learning, teaching methods in apparel product development remained hands-on.

To gather information on the relationship between design techniques, pattern making, and garment construction, along with their impact on education through interviews with the fashion UoT students, and lecturers and alumni and the apparel industry practitioners, various academic databases, including 1) Google Scholar; 2) Berg Fashion Library; 3) EBSCOhost, and 4) Scopus, were carefully searched for relevant articles.

The initial search yielded a number of specific articles, including work by Arribas & Alfaro, 2018; Cukurova & Luckin, 2018; Da Silva *et al.*, 2019; Datta & Seal, 2018; Faerm, 2012; Fung *et al.*, 2021; Gu & Liu, 2019; Han *et al.*, 2020; McQuillan, 2020; Spahiu *et al.*, 2021; Sun & Zhao, 2017; Wijewardhana *et al.*, 2021; and Wohlin *et al.*, 2022.

The period from 2001 to 2016 was studied to examine traditional approaches to product development at both the University of Technology (UoT) and the apparel industry. Studies published between 2017 to 2023 were examined to gain a comprehensive understanding of contemporary methods and practices, with a particular focus on evaluating the current state of incorporating digital technologies into the product development field.

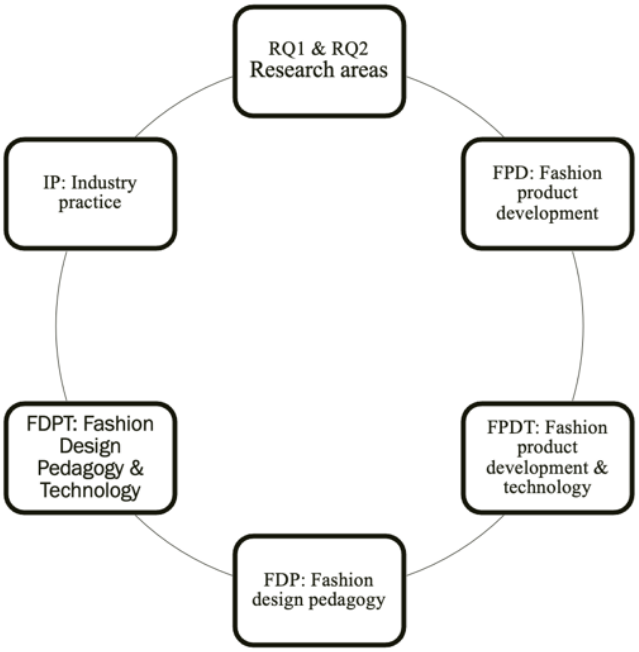


Figure 2.4 The research areas that led the systematic review process

The following research areas (Figure 2.4) led the systematic review process, and the selection inclusion and exclusion process were used based on the research areas, FPD (Fashion Product Development), FPDT (Fashion Product Development and Technology), FDP (Fashion Design Pedagogy), FDPT (Fashion Design Pedagogy & Technology) and IP (Industry Practice). To broaden the scope of the search, a bibliographic snowball approach was adopted. This method included both "backward snowballing," i.e., a thorough review of the reference lists, and "forward snowballing," i.e., searching for more recent papers in which the original papers were cited, according to the framework suggested by Wohlin *et al.* (2022).

The search process was to continue until a saturation point was reached, i.e., until no more relevant articles could be found. However, it must be acknowledged that this approach has its limitations,

primarily due to the constant influx of new articles in the rapidly evolving fields of apparel and fashion education. Therefore, inclusion and exclusion criteria were applied to the search during this process, as explained below.

2.2.1 Inclusion criteria

In conducting this systematic review, adherence to a set of predefined criteria for the selection of eligible articles was essential. The first inclusion criterion was that all articles had to be in English, excluding articles in languages other than English. The evaluation of articles went beyond linguistic aspects and included an assessment of their relevance to the research problem, consistency with the research objectives, and the presence of valuable findings related to manufacturing. Articles that did not meet these specific criteria were subsequently excluded.

Of utmost importance, the search process was guided by the delineated research areas, as shown in Figure 2.5.

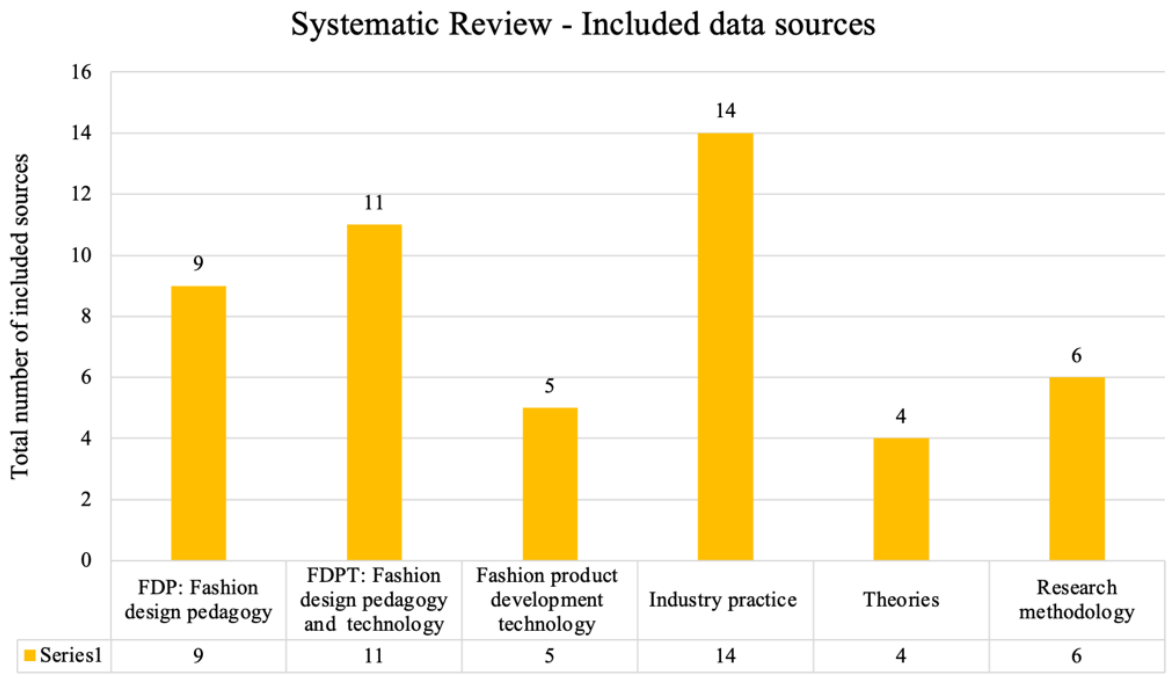


Figure 2.5: Delineated research areas

In the systematic review process, I applied several inclusion criteria, including:

- Relevance to the research problem;
- Consistency with research objectives; and
- Insights into manufacturing methods.

The listed criteria for inclusion are outlined in more detail in the following discussion.

Relevance to the research problem

Articles that specifically address the research problem and focus on the integration of digital technologies into fashion product development education and as well as the product development practices used by the apparel industry.

Consistency with research objectives

Inclusion of articles that are consistent with the research objectives and provide a deeper understanding of the established research goals.

Insights into manufacturing methods

Inclusion of articles that provide insights into manufacturing methods used by the apparel industry and UoT.

2.2.2 Exclusion criteria

The study applied the following exclusion criteria:

- Irrelevance to the research problem; and
- Lack of insight.

Irrelevance to the research problem

Exclusion of articles that do not address the research problem or that do not align with the research objectives.

Lack of insight

Exclusion of articles that do not provide insight into the integration of digital technologies into product development education in the fashion industry or manufacturing methods in the apparel industry and universities.

2.2.3 Exploration of emerging themes through coding and analysis of articles

The literature review process included article selection, coding, and development of a thematic framework. The research areas that the research uncovered are coded as FPD (Fashion Product Development), FPDT (Fashion Product Development and technology), FDP (Fashion Design Pedagogy), IP (Industry practice) and digital technology applications were identified and guided the research. These themes played a key role in structuring the findings in Chapter Four and helped identify similarities and discrepancies in the data and literature.

The study focused on specific aspects of fashion product development within the broader fashion industry. In addition, several new topics emerged from this process that focus on the application of digital technologies in the apparel industry and UoT, with an emphasis on pattern making and garment construction.

These established themes played a central role in guiding the coding process and ensuring that it ran smoothly. These themes were particularly important in structuring the findings presented in Chapter Four. They serve the dual purpose of highlighting the consistency between the research findings and identifying where the data and literature review don't fully align. After conducting the process of article inclusion and exclusion, the retrieved articles were uploaded to ATLAS.ti for further reading, further inclusion and exclusion process and coding.

The emerging themes, sub-codes, and keywords were then used as headings and subheadings when writing this literature review chapter and are illustrated in the diagram below and used to address both Research Question One and Research Question Two. As mentioned earlier in this chapter, the fashion industry includes several stages that contribute to successful apparel production. However, this study focused on product development in a specific area of interest. Therefore, it is important to highlight the specific areas covered in this literature review.

2.3 Focus of the Literature

In this section, I review the product development process in the fashion industry and briefly discuss important preliminary phases such as market analysis, design and concept development, material sourcing and draping which is another method pattern making. Because pattern making and garment construction are the key research areas of product development, they will be discussed in detail including. Garment construction is discussed as a stage of sample development and prototyping.

These stages play a critical role in bringing creative concepts to life while overcoming the challenges of waste reduction and garment fit. I also address the evolving role of digital technology in transforming

traditional methods. The production process in the fashion industry is multi-layered and influenced by factors such as the complexity of garments and the different roles within the industry (Fung et al., 2021). In the digital age, the study highlights the importance of integrating technology into the development of fashion product development education. The literature review addresses apparel manufacturing methods, particularly in fashion education, and compares industry practices. It also examines traditional and digital approaches to product development. Additional details are discussed here.

The fashion industry follows a complex development process with several stages that contribute to the production of garments. These stages vary from company to company and are influenced by factors such as the complexity of the garment, while those involved in the process are responsible for different functions (Fung et al., 2021). As the industry undergoes rapid digital transformation, it is becoming increasingly important to explore the potential benefits and advantages of incorporating technology into fashion product development.

Based on this background, the study recognizes that product development involves various processes. Therefore, the literature review focuses on the product development processes, particularly the manufacturing methods used in the apparel industry and fashion design schools (UoT), which include pattern making and garment construction. Although the focus of the study is on fashion education, garment industry practices are also explored to assess their consistency with those used in universities and technical schools. The literature review also examines the conventional and digital methods used in this context.

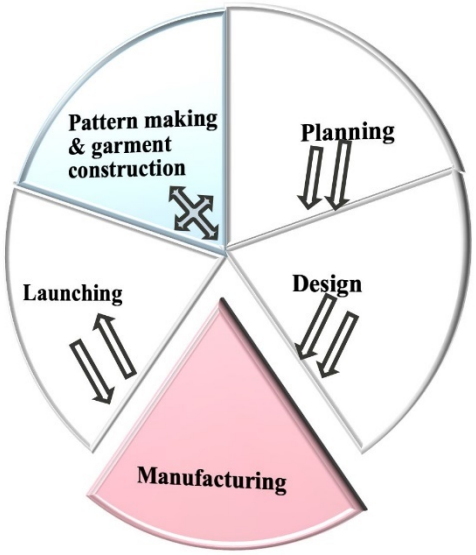


Figure 2.6 Evolution of fashion product development process (Adapted from Fung *et al.*, 2021)

The concept of manufacturing is consistent with the perspective of Fung *et al.* (2021, p. 9) who define it as "the process that transforms a design concept into an actual product". Figure. 2.6, adapted from

Fung *et al.* (2021), provides an overview of the phases of product development, namely planning, design, manufacturing, and launching. Other aspects of fashion product development are briefly mentioned and explained but are not discussed in detail in this study.

The main focus of this study is on apparel manufacturing, which includes techniques used in taking body measurements, quality control methods, and production steps such pattern making (conventional and digital), draping technique, sample development for testing purposes, and prototyping. Garment complexity affects each fashion development stage.

The traditional design approach involves iterative sample creation, fittings, and alterations to realize the designer's concept, relying on their and the product development team's (Fung et al., 2021; Wijewardhana et al., 2021). As mentioned earlier, it is becoming increasingly important to explore the potential benefits and advantages of incorporating technology into fashion product development, therefore, the aspects of fashion product development are discussed below.

2.3.1 A basic overview of the design field and fashion education

This section explores how design concepts are transformed into tangible products through manufacturing processes, considering both educational practices and industry standards. It also evaluates the coexistence of conventional and digital methods in this context. Design is a broad field that encompasses both practical and academic disciplines. Each category encompasses numerous specialised disciplines whose parameters are fluid, ill-defined, and constantly changing, and to which different design societies are dedicated (Meyer & Norman, 2020).

Fashion design courses include both practical and theoretical elements. However, this study focused on product development methods, exclusively on the manufacturing processes of fashion design studies, with an emphasis on the integration of technology into fashion product development processes, such as pattern making and garment construction.

2.3.2 Reasons for transformation in fashion education

As professional practice and society's relationship to design have changed significantly, the methods utilised for fashion education must be reconsidered. In their research Pontis and van der Waarde (2020) found that changes in the world of design have impacted on design education in four main areas:

- Design practice;
- Teaching field;
- Students; and

- Pedagogy in response to the evolution of socioeconomic, technological, and other global changes.

These developments have required the development of an educational paradigm that teaches young designers how to deal with global change.

Due to these changes, the teaching methods employed for fashion education had to be adapted to the circumstances. National and international academic institutions questioned their long-standing philosophies in art and design education and had to evolve the product and strengthen failing systems (Faerm & Campbell, 2012). However, a study conducted by Meyer and Norman (2020) cited that, design education has lagged behind 21st century requirements, necessitating the acquisition of additional information and technical skills. These studies indicates that further research is needed to identify the specific areas where design education needs to improve and to develop new methods of teaching that will better prepare students for the challenges of the 21st century.

Various fashion design programmes adopted diverse strategies, with certain institutions opting to maintain their existing methodology, while others concentrated on particular facets of the upcoming generation (Meyer & Norman, 2020). The importance of acquiring a more comprehensive grasp of the present teaching practises was underscored by these findings. This chapter presents the rationale and background for the study, and the following section elaborates on these aspects.

2.3.3 Product development

The product development process plays a critical role in transforming market opportunities and technological assumptions into tangible products. Traditional product development requires a comprehensive understanding of various tools and versatility in learning and working across relevant domains (Sun & Zhao, 2017).

Consequently, the conventional product design and development involves a costly and time-consuming iterative process that includes multiple rounds of creating samples, fitting, and design alterations. The goal is to bring the designer's original concept ideas to life as a final physical product, requiring the knowledge and skills of the designer and product development team (Arribas & Alfaro, 2018).

Current methods present challenges for waste elimination, especially in the critical design phase when working with sketches or existing garments. Traditional product development requires a comprehensive understanding of different tools and versatility in learning and working in relevant areas (Sun & Zhao, 2018). Most manufacturers start the design phase in a traditional way, where designers' creative ideas essentially start from a 3D shape (a 3D concept idea in mind or an existing finished garment), from

which 2D information such as 2D sketches, 2D patterns with corresponding fabric layers are extracted (3D-to-2D phase).

Some designers still use pen and paper as design tools. The introduction of powerful and relatively inexpensive computers, systems, and graphics software such as Photoshop, Illustrator, and CorelDraw has encouraged the textile and apparel industry to use this versatile medium to create and develop their designs (technical illustrations and visual representations), presentations, and apparel series, and to manage their workflows (Papahristou & Bilalis, 2017a).

New Product Development (NPD) has significantly changed the apparel market and created new opportunities. It plays a central role in translating market opportunities and technological assumptions into tangible, saleable products (Fung et al., 2021). This overview traces the evolution of the fashion industry, focusing on the transformative impact of digital technology. It examines the advances, benefits, and limitations of digital technology compared to traditional methods and highlights its potential value and influence.

Globalization and the NPD process have led to geographically dispersed participants in the apparel market, resulting in significant changes and new opportunities (Fung et al., 2021). The NPD process has become a critical factor in apparel manufacturing strategies due to changing customer demand for customised fashion (Wijewardhana et al., 2021). This research focuses on the role of manufacturing, including production techniques, quality control, and steps such as pattern making, draping, sample development, and prototyping.

The fashion industry encompasses various stages. The goal is to bring the initial concept ideas envisioned by the designer to life in the form of the final physical product, depending on the know-how and skills of the designer and the product development team, and it can take up to 70 percent of an ordinary product lifecycle (Arribas & Alfaro, 2018). Because the study’s focus is on pattern making which includes draping; and garment construction, it is necessary to discuss the two stages in detail.

2.3.4 Pattern making and draping

Pattern making is the art of designing templates that serve as the foundation for sewing clothing and craft items, acting as a link between a designer's vision and the final products (McQuillan, 2020). These patterns, also known as blocks, slopers, or master patterns, consist of two-dimensional templates that form the basis for creating three-dimensional garments (Lim & Cassidy, 2017). Flat pattern techniques involve creating a draft on paper using various tools and measurements, while draping is a modelling process (Datta & Seal, 2018). While making patterns using the flat pattern method is relatively straightforward, the challenge lies in manually creating the templates or using pattern making software.

In the apparel industry, two manual pattern production techniques are commonly used: flat pattern generation and draping. Draping involves cutting a garment directly from a fabric piece fitted to a figure form of the correct size (Gu & Liu, 2019, p. 575).

Clothing patterns need to be adaptable to different body sizes and types. They are classified into three main types: basic block patterns, style block patterns, and production patterns. Basic block patterns are constructed using body measurements and allow enough allowance to ensure movability (Lim & Cassidy, 2017).

Designers and pattern makers manipulate, mark, and adjust the three-dimensional mock-up (creating many variations of style) until they are satisfied with the shape and fit (Datta & Seal, 2018, p.30; Gu & Liu, 2019, p. 575). However, traditional pattern making methods based on standard human body models often result in poor fit due to variations in body shapes. To address this problem, companies are trying to develop items tailored to their target audience by updating size charts based on their measurements and using garment simulation techniques (Spahiu et al., 2021).

2.3.5 Garment construction – sample development and prototyping stages

In the production process, pattern development and prototyping involve pattern makers/designers and sample sewers/machinists. In this phase, real sample garments are created to evaluate fit, construction and overall design. Prototypes are made from engineering drawings and then modified to achieve the desired fit, and to address comfort and aesthetics. To verify the design and aesthetic details of the products before production, it is important to have a physical prototype that closely resembles the final garment. This provides the opportunity to view the prototype in real space and directly experience the final design through touch, allowing for a comprehensive evaluation of the "look and feel" (Arribas & Alfaro, 2018).

During the clothing production process, generally, garment sewing is the final step in the production process, which involves the creation of patterns and prototypes to evaluate fit. While manual methods were traditionally used, pattern making software and 3D visualization tools are now being integrated into the process. In preparation for prototyping, marker making is an important phase in the manufacturing process that occurs after a garment pattern is created. It involves the arrangement and positioning of pattern pieces on a length of fabric to optimise fabric utilisation and minimise waste in the pattern phase of garment production.

In this process, a layout or marker is created to indicate the placement of each pattern piece on the fabric (Spahiu et al., 2021). In traditional garment manufacturing, this process is time-consuming and involves many errors, resulting in higher costs in terms of wasted materials and labour. However, advances in

computer graphics have led to a more reliable virtual garment manufacturing process. Therefore, it is important to explore the essence of digital technology and its advantages.

2.3.6 The nature of digital technology and its benefits

This section addresses the transformative impact of digital technology on apparel manufacturing during the Fourth Industrial Revolution (FIR). It highlights the use of 3D (Three Dimensional) technology, Computer Aided Design (CAD) software, and 3D printing in fashion design, discussing how these advances can potentially reduce costs, provide customization options, and promote sustainable fashion.

The integration of virtual and physical manufacturing systems, driven by the focus on digitalization during the FIR, has transformed garment manufacturing. 3D technology and computer graphics have emerged as powerful tools throughout the manufacturing process, offering cost reductions and customization options (Wijewardhana et al., 2021). The fashion industry has embraced Computer-Aided Design (CAD) software and 3D printing (3DP) to promote innovation and create prototypes, customized products, and artistic fashion items (Sun & Zhao, 2017; Kwon et al., 2017). CAD software, including popular systems like Gerber and Lectra, enables pattern grading and design simulation, while CLO 3D software is used for garment design and simulation (Datta & Seal, 2018; Spahiu et al., 2021). These advancements also aim to simulate the entire garment production process in a virtual environment.

Garment simulation is a process used to create virtual replicas of models and assess the garment fit before creating the physical sample. It provides an ability to assess garment drape and fit over 3D avatars or personalized body models realized simultaneously within the 3D window (Spahiu et al., 2021). These technological advancements in virtual garment simulation offer insights into design choices, enabling designers to make informed decisions and refine their designs for optimal fit and aesthetics.

In addition, these tools provide the capability to simulate, assess, and make alterations to garments within a unified environment, effectively meeting customer demands and reducing overall time consumption. The utilization of 3D software in presenting virtual garment prototypes, from the initial concept to a fully actualized design draped over a 3D body model, makes a significant contribution to sustainable fashion. This is especially evident in the capacity to adjust and modify, evaluating the drape and fit of the garment on a 3D avatar instead of a physical sample. Consequently, this approach reduces the need for evaluating numerous unappealing prototypes (Spahiu et al., 2021).

Furthermore, advances such as digital prototyping minimizes waste and allows for direct ordering from a digital render, revolutionizing the design process (McQuillan, 2020). However, there is a need for fashion designers to acquire specific 3D software skills and for software companies to simplify their solutions for broader usage (Arribas & Alfaro, 2018). The use of novel technologies enables designers

to better understand manufacturing capabilities and foster closer relationships with the factory floor (Sun & Zhao, 2018).

Largely, the efficient and fruitful customized production of a garment is dependent upon the technological facts interpreted into the pattern making. A pattern maker should have a technological mindset and should understand the production implementations of each detail in the relevant pattern. Pattern making and grading software still present a substantial cost investment, limiting their widespread usability (Datta & Seal, 2018, pp. 30 & 32).

Despite this limitation, many emerging design entrepreneurs are embracing digital applications and virtual design software as a means to streamline the development process of new styles. These changes are driven by the high consumer demand for fashion products, highlighting the industry's significant impact on global economic growth. Consequently, companies are continuously investing in new technologies to enhance various production processes (Spahiu et al., 2021).

The study conducted by Arribas and Alfaro (2018, p. 8,10) highlighted the advantages of using 3D technology, as depicted in Figure. 2.7 shows the efficiency of digital technologies.

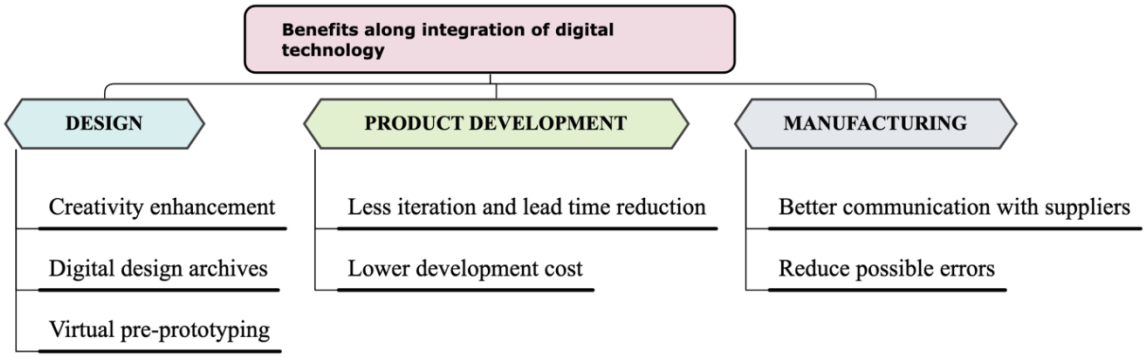


Figure 2.7: Benefits along the process of integrating digital technology (Adapted from Arribas & Alfaro, 2018)

The advent of digital technology has led to numerous advancements and various aspects. According to Arribas and Alfaro (2018), design stages have greatly improved, resulting in enhanced creativity. Additionally, there are now opportunities to archive work for future reference and engage in virtual pre-prototyping. In the area of product development, there are fewer iterations and reduced lead times, leading to lower development costs. Moreover, in manufacturing, there is improved communication with suppliers, which minimizes the likelihood of errors (Arribas & Alfaro, 2018), and speedy processes. The use of technology for greater efficiency is discussed below.

2.3.7 Use of technology for greater efficiency

Incorporating advanced digital technologies into fashion product development can lead to cost savings, less waste, and more inclusion for people with disabilities (Datta & Seal, 2018). It also improves hands-on learning and streamlines repetitive tasks. There are 3D body scanners and CAD software systems that are used for pattern making and grading. These technologies improve pattern accuracy and efficiency as well as trying to eliminate waste that is associated with clothing product development.

The impact of new technologies is evident in some areas of production, as they speed up production time, reduce material waste, and increase the quality of products or systems through process shortening and automation simulation. Although these attempts are not very advanced yet, they show that there is an increased awareness of sustainable fashion industry among companies and stakeholders, and the role of designers in designing sustainable fashion products is mainly in the selection of sustainable materials (Spahiu et al., 2021).

The use of 3D technology in product development offers the possibility to track any change made to the 3D design and go back very easily, as well as to keep each design in a digital archive that can be “saved" at any time or used as a carryover for future collections (Arribas & Alfaro, 2018). The rapidly growing and advancing 3D printing market reflects the need for a new design approach to product customization and personalization, as well as the integration of sustainable methods or systems in the 3DP (3D Printing) era. Consequently, this technology is expected to provide alternative ways for sustainable manufacturing from environmental, social, and economic perspectives (Sun & Zhao, 2017). Product evaluation in the early stages of manufacturing contributes to sustainability in the fashion industry.

The virtual process of garment production contributes to time and cost reduction by avoiding the production of physical garments and the waste they generate, while contributing to sustainability (Spahiu et al., 2021). 3D printing technology offers other interesting advantages for the customization of the final product, as it enables the production of small quantities of customized goods at a relatively low cost. Important product decisions regarding design and aesthetic details are made at an early stage of the process called the “virtual 3D pre-prototyping” phase" and directly referred to as virtual 3D prototyping by other authors on this topic (Arribas & Alfaro, 2018). These processes are useful in the process of striving to eliminate production waste that appear in the process of product development.

3D software plays a role in the quest for zero-waste fashion design. Product development teams should continuously look for and implement methods to avoid production waste, as it can be a major environmental problem. Zero-waste fashion design is a process that aims to eliminate production waste and traditionally uses 2D digital tools such as Gerber pattern software, Adobe Illustrator, and Photoshop to develop zero-waste patterns, (McQuillan, 2020). McQuillan further defines zero-waste design as the

process of designing garments that aims to avoid creating waste when cutting and sewing the garment (McQuillan, 2020).

These digital systems enable the creation of virtual prototypes and strive to minimize the need for physical prototypes in the early stages of product development in an aid to minimise unnecessary waste. Figure 2.8 shows the differences between a basic fashion design process, a basic zero-waste design process without 3D tools, and the changes introduced by incorporating 3D software into zero waste design.

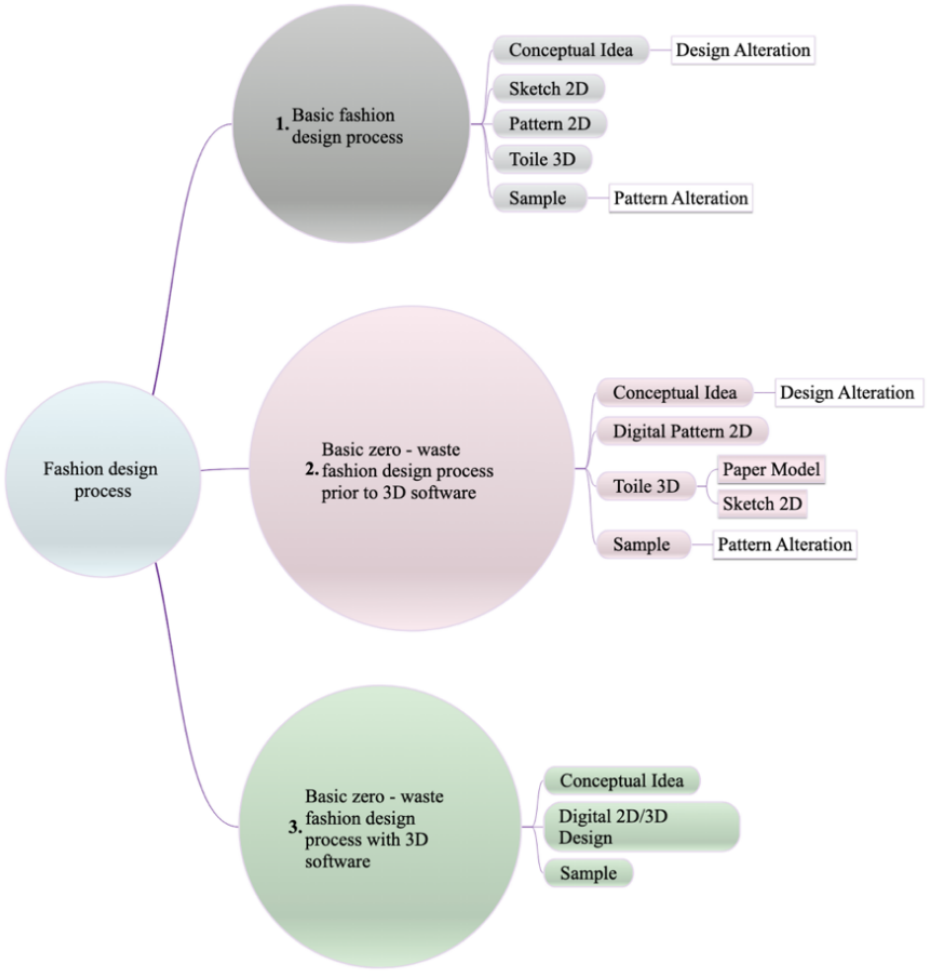


Figure 2.8: Zero-waste fashion design: a comparison of traditional and 3D-enabled processes (Adapted from McQuillan, 2020)

McQuillan (2020) echoes this sentiment, arguing that 3D software is often used by industry primarily as a visualization tool for promoting and marketing, and that the benefits of using 3D software to improve apparel design are mainly evident in zero-waste fashion design. This is one of the methods that

strives to help save time and costs associated with traditional prototyping methods. To achieve sustainable fashion, the process of sustainable development of fashion products is one of the key areas that all fashion apparel supply chains should be aware of (Fung et al., 2021). Figure 2.6 illustrates the differences between a basic fashion design process, a basic zero-waste design process without 3D tools, and how the use of 3D software changes zero-waste design.

The initial steps of the basic zero-waste design process (number 3) replace the "ideation/sketch" process of traditional fashion design, while the rest follows more traditional fashion development practices and attempts to test the pattern. The process of new product development is of importance across industries and impacts various aspects such as quality, cost, and time throughout the value chain. In apparel product development, revisions and changes are often made even after the final product is ready to sell, requiring adjustments based on customer demand, such as changing the colour of a model (Wijewardhana et al., 2021). Consequently, it is empirical that this study explores the practices of design education.

2.3.8 Background information on fashion design education and programs

The landscape of fashion design education is evolving toward technology, reflecting advances in the industry, and targeting a new generation of digitally savvy students. In the following sections, I address key aspects of this shift, from integrating technology into fashion education to exploring underutilized product development technologies and highlight the need for change and adaptation. These sections provide the foundation for a comprehensive examination of fashion design education and the central role technology plays in shaping its future.

Design education encompasses a variety of subjects and requires close communication between students and instructors. Atkinson's study provides a clear distinction between design and related courses, including design management, design theory, and various design disciplines (Atkinson, 2017). This study focuses specifically on the fashion design course, which includes the combination of materials and concepts (Lu, 2018). It prepares students for professional apparel design by teaching practical creative skills. Students can enter directly into a three- or four-year fashion design program or finalise a groundwork year before entering the regular program.

Fashion design programs often include site visits to supplement contextual learning and provide insight into professional practice. These courses typically offer theoretical and craft subjects as well as hands-on product development. In this study, the focus is on practical product development. This results from the fact that, previously, the apparel industry has favoured traditional manufacturing methods and prioritized physical artefacts for design, development, and production (Arribas & Alfaro, 2018, p. 2). Therefore, to prepare students for a career in the apparel industry, hands-on activities such as laboratory exercises are critical to help them gain fundamental skills and knowledge.

Recent technological advances have indeed disrupted this long-standing practice. In its traditional form, the product development process is time consuming and characterized by trial and error, resulting in increased material waste and labour costs. However, progress in computer graphics has resulted in a virtual garment design process that is more dependable (Spahiu et al., 2021). To support 21st century students, product development courses in the fashion industry must incorporate current academic techniques and methodological advances. This is necessary due to changing circumstances, including the characteristics of today's generation of students and technological trends in professional practice.

Thus, how must teaching and learning need to change to accommodate and take advantage of technology? An important part of fashion product development education is the hands-on subjects that focus on physical interaction leading to a barrier for students between digital and physical experiences. The study aims to explore how and what new approaches to teaching can be adopted through the integration of technology.

2.3.9 Integration of technology in fashion education

The integration of technology into fashion design education is essential due to advances in technology. Many educational institutions have transitioned from traditional laboratory exercises to online or digital formats. Pontis and Waarde (2020) emphasized the need to explore changes in design education and practice for the future. New teaching models, especially those that focus on technology, can better serve technologically oriented students, and prepare them for professional practice (Papahristou & Bilalis, 2017a).

Production techniques used in the apparel industry are examined to determine if the methods used in fashion design education are comparable to those used in industry. This approach is influenced by (Fung et al., 2021) when suggesting that companies need to keep up with new technologies and modernize their apparel manufacturing methods due to intense competition in the industry. An introduction of new approaches can adequately accommodate current technologically oriented students and prepare them for professional practice. Notwithstanding all the technological progressions happening in the world outside of fashion and apparel, Papahristou and Bilalis (2017a) alluded that “Design, Development, and Production have largely relied on the same often manual methods”.

2.3.10 Under-utilized product development technologies in fashion education

Educational technology uses various modern methods, media, and materials to improve the experience of both teaching and learning (Shah & Murtaza, 2012). The rising complexity and systematic shifts have also prompted changes in design education. As design issues have moved to a new digital technology capability, modern curricula contain fewer artifact-driven problem-solving methodologies (Pontis & van

der Waarde, 2020). Fashion design software such as 3D Body Scanners, CAD applications, 3D software, is available for use globally.

As described in Taylor and Unver (2005, p. 3) “body scanning is a process used to build a digital 3D copy of a physical surface to assist the analysis of clothing appearance, body measurements and fit”. CAD applications originally appeared in the cutting industry in the 1970s, and computers are useful for creating repeated garment patterns to speed up the pattern making process and enhance accuracy (Datta & Seal, 2018).

Clothing manufacturers keep up with new technologies and enhance their production techniques, according to (Fung et al., 2021). As a result, it is argued that incorporating technology into fashion product development education will be beneficial to the apparel industry's future. It is therefore necessary to explore the digital technologies used in the UoT and apparel industry.

2.4 Part 2: The Digital Technologies used in the UoT and Apparel Industry (RQ1)

In this section, the focus is on addressing the themes related to Research Question One (RQ1), which asks the question, “What is the relationship between current design technology and fashion product development”? The codes that emerged from the research areas such as FPD: Fashion product development; FPDT: Fashion product development and technology; FDP: Fashion design pedagogy; FDPT: Fashion design pedagogy & technology; and IP: Industry practice guided the research, with the first topic being body measurement techniques used in the apparel industry.

2.4.1 Industry practice: anthropometric data collection – body measurements techniques

Simmons (2001, p. 14) suggests:

> *No two people are ever alike in all of their measurable characteristics. This uniqueness has been the object of curiosity and research for over 200 years. In the past, different individuals have set out to express quantitatively the form of the body. This technique was termed anthropometry.*

Body measurements are the first steps that take place in product development. Accurate body measurements are critical in apparel design, especially in the early stages of product development. As a result, anthropometry, the practice of measuring the human body, has been performed for centuries by artists, scientists, anthropometrists, and tailors using traditional tools such as tape measures (Glock & Kunz, 2005).

When taking body measurements with large-scale motion, the first priority is recovering accurate pose parameters (Xu et al., 2013). This was echoed by Smith (2009), "who mentioned that body measurements are needed to determine the correct pattern size to use and if any alterations are required".

Table 2:2 Summary of the anthropometric tools and usage (Adapted from Simmons, 2001)

Anthropometric data	Usage
Weight scale	For determining weight.
Camera	For photographing subjects.
Measuring tape	**For measuring circumferences and curvatures**.
Anthropometer	For measuring height and various traverse diameters of the body.
Spreading caliper	For measuring diameters.
Sliding compass	For measuring shirt diameters such as those of the nose, ears, hand, etc.
Head spanner	For determining the height of the head.

Traditionally, there are a few body measurement tools available. Adapted from Simmons, (2001), Table 2.2 provides a summary of the manual anthropometric tools and their usage. Out of the above-mentioned tools, the focus of the study is on measuring tape (only) which is used for measuring circumference and curvature and is commonly used in apparel manufacturing.

Figure 2.9 An image of a traditional tape measure (Pinterest.com)

With the advent of digital technology, 3D body scanners (Figure.2.9) have been introduced as an alternative method. The TC^2 body scanner was the first digital scanner to be developed with the initial focus for the clothing industry. For the American apparel industry to be more competitive, TC^2 service provider saw the need for the drive toward mass customisation (Simmons, 2001).

Figure 2.10: Stage one of body scanning process (Techmed 3D.com, 2023)

Simmons, (2001), further mentioned that the advancement of three-dimensional body scanning enables the extraction of body measurements within seconds using this technology. It also allows consistent measurements. This was echoed by Tailor and Unver (2005), who in their study mentioned that body measurements must be taken with manual or computerized devices. This underscores the availability of digital technologies.

These scanners provide multi-dimensional anthropometric data and enable the creation of more reliable standard measurements that support the development of size categories and fit patterns (Forster & Ampong, 2012). “When measuring many locations on the human body, the most desirable method would be one of non-contact” (Simmons, 2001). Figure 2.11 shows the last phase of the body scanning process.

3D programs CAD model real product representations in conjunction with 3D scanning technology, resulting in cost reductions, especially for customized products (Sun & Zhao, 2018). In addition, Modern 3D body scanning has expanded the scope by providing sophisticated 3D shape data that include thousands of data points that can be altered to create static or active shapes (Gómez Chova et al., 2019b).

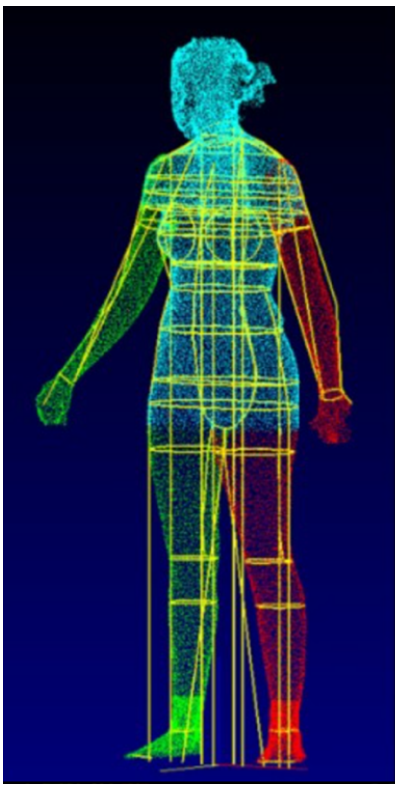


Figure 2.11 An image of the final 3D Body scan (TC2.com)

Further to these advantages, a recent study conducted by Youn *et al.* (2023) suggests that "accurate body measurement data drawn from 3D Body scanning technologies will help designers and retailers develop garments for inclusive consumers, such as plus size, older, and consumers with disabilities". It further alluded that, varied customers, including people with physical difficulties and aging adults represent an increasing consumer market segment with special needs for personalized clothing.

In the field of fashion education, the incorporation of 3D body scanning technology in the curriculum is critical to creating targeted and inclusive apparel designs that appeal to a wide range of people. Studies show that this innovative tool can play a critical role in educating aspiring designers with the skills and knowledge necessary to shape the future of fashion by ensuring that their creations not only follow current trends but also adhere to the principles of inclusivity and functionality.

Designers can use 3D scanning technologies to eliminate the need for physical prototyping. By entering precise body measurements into CAD programs, they can design garments and accessories that fit perfectly, minimizing the need for physical alterations, which is a common practice today, (Pasricha & Greeninger, 2018). Simmons, (2001) further highlighted that, "the data capture process of specific body measurements can be standardized or communicated among scanning systems". 3D body scanning is capable of extracting an immeasurable number of types of data. However, a problem exists in the consistency of measuring techniques between scanners.

In contrast, in recent years, 3D scanning technology has played a critical role in obtaining accurate body measurements and fit data, from research projects to commercial applications for customized clothing, prosthetics, and ergonomic devices (Taylor & Unver, 2005). This is an indication that there are improvements in this technology that can be beneficial to the apparel industry.

Although the technology is available worldwide, there are differences in measurement practices. A vital step in promoting the open use of 3D body scanning for experimental 3D learning and teaching is the consideration of practicing a discreet and respectful use of 3D body data for academic purposes, especially in light of the improvements in body measurement techniques. A study by Tylor and Unver (2005), found that the use of 3D scanners for 3D modelling in education is not as widespread as the use of 3D modelling and animation software. The differences in practices were further interrogated during fieldwork data collection and is reported in the findings Chapter Four.

2.4.2 Industry practice: pattern making, and grading

In the apparel industry, two manual pattern production techniques are commonly used: flat pattern generation and draping. Flat pattern techniques involve creating a draft on paper using various tools and measurements, while draping is a modelling process (Datta & Seal, 2018).

Draping involves cutting a garment directly from a fabric piece fitted to a figure form of the correct size, incorporating body measurements that are crucial for achieving the right fit. It is often called ‘draping on the stand’ and is a pattern making method that involves muslin fabric for fitting of block garment generally on a designated dummy body of appropriate size.

The pattern makers draft, mark, and adjust the 3D mock-up (creating many variations in style) until they are satisfied with the form and fitness (Datta & Seal, 2018, p.30; Gu & Liu, 2019, p. 575). However, standard pattern making methods based on standard human body models often result in a poor fit due to variations in body shapes. To address this, companies aim to create items tailored to their target group by updating sizing tables based on their measurements and using garment simulation techniques (Spahiu et al., 2021). Digital design tools that integrate 3D designs, 2D patterns, and 3D samples provide a broad approach to garment creation and enable waste reduction (McQuillan, 2020).

2.4.3 Industry practice: garment construction – conventional production methods

Conventional product design and development is a costly and time-consuming iterative process that involves multiple rounds of creating samples, fittings, and design changes. The goal is to bring the designer's original concept ideas to life as the final physical product, relying on the knowledge and skills of the designer and product development team (Arribas & Alfaro, 2018). Most producers start the design

phase in a conventional way, where designers' creative ideas essentially start from a 3D shape (a 3D concept idea in mind or an existing finished garment), from which two-dimensional (2D) information such as 2D sketches, 2D patterns with corresponding fabric layers are extracted (3D-to-2D phase).

The manual production of garments takes time because if the first sample does not fit properly, the design must be modified and updated to prepare for the second fitting, where the mock-up/prototype is tested. There is a need for tools that can easily automate repetitive, time-consuming operations, as time, fabric and pattern paper are wasted in this process. In the production process, sample development and prototyping involve pattern makers/designers and sample sewers/machinists. Real sample garments are created in this stage to assess fit, construction, and overall design.

Prototypes are made based on technical drawings and then modified to achieve the desired fit, as well as considerations for comfort and aesthetics. To validate the design and aesthetic details of the products before production, it is crucial to possess a physical prototype that closely resembles the final garment. This enables the opportunity to observe the prototype in real space and directly experience the final design through touch, allowing for a comprehensive "look and feel" assessment (Arribas & Alfaro, 2018).

In preparation for prototyping, marker making is an important stage in the manufacturing process that occurs after creating a garment pattern. It involves arranging and positioning pattern pieces on a length of fabric to optimize fabric utilization and lessen waste during the pattern stage of garment production. This process includes creating a layout or marker that indicates the placement of each pattern piece on the fabric, considering factors such as grainlines, fabric width, pattern repeats, and cutting constraints (Spahiu et al., 2021).

In summary, the conventional production methods present challenges for waste elimination, especially in the critical design phase when working with sketches or existing garments. In its conventional way of garment construction, it requires time and trial and error that are part of this process leading to higher costs related to material waste and labour. As a result, there is a need for tools that can easily automate repetitive, time-consuming operations, as time, fabric and pattern paper are wasted in this process.

2.4.4 Industry practice: garment construction & digital technologies

In the apparel industry, 3D software serves as an important visualization tool for marketing and merchandising purposes, which is beneficial for zero-waste fashion design. The focus of waste reduction is often on the pattern making stage, although a significant amount of waste is also generated in the design stage. McQuillan, (2020) sees this as a design-led solution to waste generation that impacts production costs, lead times and quality control.

This paradigm shift improves product innovation, cost efficiency, and speed-to-market for apparel companies, and promotes sustainability through improved flexibility in responding to change (Sun & Zhao, 2018). This technology improves communication between designers and suppliers through the sharing of 3D files and prototypes, eliminating potential manufacturing errors (Pasricha & Greeninger, 2018).

Technological aspects include:

- Virtual 3D prototyping of garments; and
- 3D visualization.

Virtual 3D prototyping of garments

Using a 3D virtual garment prototyping scheme to facilitate product design and manufacturing, new technologies and electronic tools to enhance the design aesthetic, are all ways to improve their competitive advantages. As a result of the growing popularity of 3D technology, leading companies in the industry, such as Adidas, Nike, Under Armour, Target, and Coach, have been actively exploring and utilizing 3D technology, pushing vendors to provide effective solutions. The study concluded that 3D technology is no longer a prospect but a present reality, (Han et al., 2020, p. 380).

Advances aim to simulate the entire apparel manufacturing process in a virtual environment, using apparel simulation to create virtual models and assess fit before physical sampling. The 3D window enables simultaneous garment and fit evaluation using 3D avatars or personalized body models, (Spahiu *et al.*, 2021). These technological advances in virtual garment simulation provide invaluable insights and enable informed design decisions for optimal fit and aesthetics.

3D visualization

As mentioned by Pasricha and Greeninger (2018) 3D visualization enables designers to digitally refine designs, assess fit and purpose, examine materials and colours, and enable collaboration and interaction, reducing the cost and time of prototyping and physical production. Pasricha and Greeninger, (2018), further alluded that, 3D technology provides customization capabilities, eliminating the need for fittings and simplifying the design process, especially for wearable technologies and smart textiles.

The integration of digital technologies into product development has shortened development time and significantly reduced costs because the sampling phase is the most expensive aspect of product and collection design (Arribas & Alfaro, 2018). According to Sun and Zhao (2017) digital technologies, especially 3D printing, offer advantages such as shorter lead times, reduced errors in prototypes, and the

ability to produce small quantities of customized goods at a relatively low cost, allowing for greater flexibility and mass production.

It is evident that, computer-aided design (CAD) and computer technologies have traditionally existed separately in the apparel industry, creating a gap between design and apparel manufacturing. Virtual simulation software can bridge this gap and potentially minimize bulk sampling phases by providing a sample of the product without the prototyping phase (Gómez Chova et al., 2019b). Gomez *et al.*, (2019b) cited that CAD enables the entire design, sampling, and testing process in a single environment.

2.5 Part 3: The Adoption and Application of Digital Technologies (RQ2)

This section of the literature review addresses issues related to Research Question Two and explores how technological advances impact teaching and learning in fashion product development. It is divided into the following sections, each exploring different aspects:

- Fashion design pedagogy and technology: integrated conventional and digital methods;
- Fashion design pedagogy: integrated foundation skills;
- Fashion design pedagogy: industry-based learning; and
- Fashion design pedagogy and technology: technological change (UoT).

Each of these sections explores different dimensions of the effect of digital technologies on fashion design pedagogy and industry, offering insights and implications for education, students, and the broader field of design. Further details are presented in each section. A summary of this chapter is also included.

2.5.1 Fashion design pedagogy & technology: integrated conventional and digital methods

Conventional procedures are being overturned by technology, and new software tools are being implemented, as is the case in the garment business. New software tools with 3D visualisation capabilities are being used in the apparel industry's product development process, promising a more creative, innovation-based approach. Because of technological developments and advance, pattern making systems have become more complex and modified, allowing them to better suit the demands of the apparel industry (Datta & Seal, 2018).

The electronic prototype is at the centre of this change because fashion companies are under pressure to go to market rapidly. Even though technological solutions such as 3D and virtual prototypes have been around for a while, the industry has been slow to accept them. However, it has only recently become

popular and well-established in the fashion industry (Papahristou & Bilalis, 2017a). Computer-Aided Design (CAD) software is accessible in some garment industries and fashion design colleges for the creation of electronic patterns.

According to Datta and Seal (2018, p. 30), CAD software first appeared in the clothing cutting rooms in the 1970s, and while computers have gotten more accessible in recent years, pattern making and grading software remain a costly venture that may impair usability. Pattern design systems improve pattern accuracy while speeding up the pattern making process (Datta & Seal, 2018).

2.5.2 Fashion design pedagogy: integrated foundation skill

While design schools are implementing new techniques of skill development, it is critical to examine the methods used by industry professionals to guarantee that students are trained in a way that ensures they are industry ready. Despite all the technology improvements outside of fashion and apparel, design, development, and manufacture have mostly trusted the same, often manual producers (Gill et al., 2020). Traditional product development requires a broad understanding of diverse tools and versatility in learning and working across relevant fields (Sun & Zhao, 2017).

National and international academic institutions are challenging their long-lasting viewpoints in art and design education to advance the product and strengthen missing systems (Faerm, 2012). Introducing new teaching models that are technologically oriented into studio-based core fashion product development courses can improve current teaching practices that require face-to-face contact.

Knowledge and technical skills are two very important mechanisms in the apparel industry.

To produce beautiful and high-quality designs, precise skills in pattern making and intricate sewing are required, the lack of which has led to ideas being stolen and imitated by other designers (Maryam et al., 2019). The changes in the world of design affect design education in four main areas: Practice, academic institutions, student profiles , and pedagogy, in response to evolving socioeconomic, technological, and other global changes (Pontis & van der Waarde, 2020).

These developments necessitate the development of an educational paradigm that teaches young designers how to cope with global change. As a result of the current changes, the current teaching method needs to be adapted to the current realities. According to Norman and Meyer (2020), design education has lagged the demands of the twenty-first century, necessitating the acquisition of additional information and technical skills. Individual schools may also employ different tactics, with some refusing to change their methods and others focusing on specific aspects of emerging talent.

2.5.3 Fashion design pedagogy: industry-based learning

The upcoming fashion designers will be expected to have a good understanding of software design and physical computing in the digital era, as the fashion industry has seen substantial changes because of recent advancements and the commercialisation of wearable computing technologies (Han et al., 2020). They often struggle with the pattern cutting process due to knowledge gaps or the perceived role of pattern cutting as simply a tool for manifesting pre-existing designs (McQuillan, 2020).

In the digital era, designers need comprehensive understanding of programming and physical computing, with technology and wearable computing transforming the apparel industry (Han et al., 2020). The adoption of technology has revolutionised communication and information retrieval processes, emphasising the need for a collaborative approach in executing creative pattern cutting (McQuillan, 2020). This calls for an improvement in fashion education for the benefit of students who are the future of the industry to be able to meet the expectations of the workplace.

It is crucial to find new fashionable educational options that are both efficient and provide students with the benefits of traditional learning experiences. Educational technology is the use of various modern methods, media, and materials to enhance the learning and teaching experience (Shah & Murtaza, 2012, p. 1). It is crucial to find new fashionable educational options that are both efficient and provide students with the benefits of traditional learning experiences. This sentiment was echoed by Pontis and Waarde (2020, p. 31) in stating that shifts in design education and practice systems should be examined in terms of the future of design education.

There is a need to update knowledge in a variety of areas of ongoing professional development by incorporating new methods of evaluating efficiency and production (Poplavska et al., 2021). Rapid technological progress requires continuous renewal of educational content to prepare professionals for modern requirements while developing the industry in which a graduate is expected to work (Yezhova et al., 2018).

2.5.4 Fashion design pedagogy and technology: technological change (UoT)

Technology advancement has a role in the adoption of digital manufacturing; however, it also includes key organizational issues that managers overlook (Da Silva et al., 2019). Industries need to understand how to use emerging technologies to generate new goods and/or process innovations in high-tech sectors, which are environments characterized by fast technological development (Wijewardhana et al., 2021). When simply defined, particularly within the context of education, “emerging technologies are the technologies that have the potential to change the current state of affairs in education” (Cukurova & Luckin, 2018).

Cukurova and Luckin, (2018) further mentioned there is a shift in the educational technology that is intended to be assessed as well as in how the interventions affect the learners, which will be used to assess the technology's impact. In the process of navigating the way towards change, Figure. 2.12 outlines the innovation cycle as presented in the Cukurova and Luckin, (2018) study.

In their research, Cukurova and Luckin realised that different stages of change and innovation would require different types of evidence, such as:

- Exploring opportunities and challenges that emerge during the implementation of the change;
- Generation of ideas around the implementations;
- Developing and testing;
- Making the case;
- Delivering and implementing;
- Growing and scaling; and lastly
- Changing the systems.

These are important stages to consider when implementing new changes.

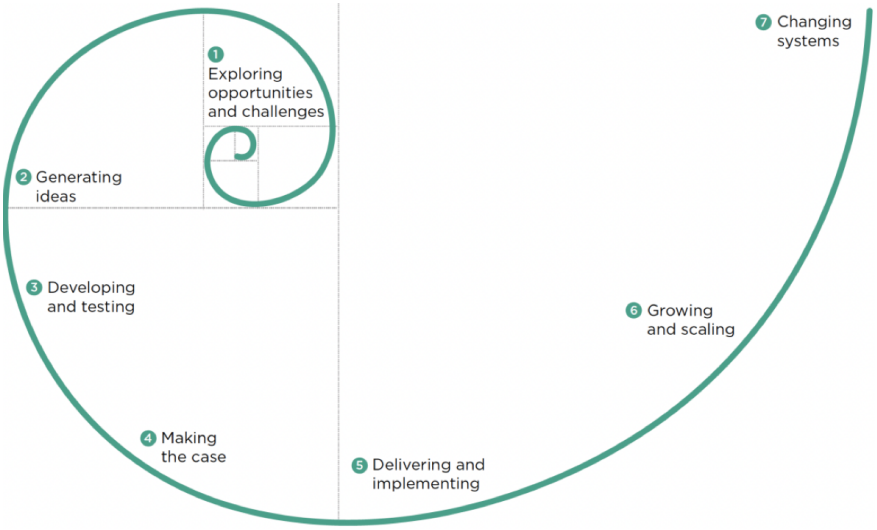


Figure 2.12 Innovation cycle as presented in using research evidence: a practical guide (Cukurova & Luckin, 2018)

In the apparel industry, it is evident that digital technology is making its way to bring about a change in the way we work through the use of CAD. According to Datta and Seal (2018, p. 30), CAD software first appeared in the clothing cutting rooms in the 1970s, and while computers have gotten more accessible in recent years, pattern making and grading software remain a costly investment that may impair usability. They further mention that many educators and professionals in the apparel industry

have limited experience with digital tools and techniques for pattern making. This is because for a long time, only conventional methods were available and taught (Datta & Seal, 2018).

Consequently, the fundamental studio courses in fashion design and garment production that are taught at the undergraduate levels usually serve as the foundation for fashion design curricula. Having said that, the establishment of a graduate portfolio and fashion collection that highlights the student's skills and introduces them to the market is the experience of the undergraduate program. Therefore, it is advised that design schools teach a foundational set of concepts before providing advanced courses that could lead to one of the school's few design specializations or that might be exclusive to the school's specific abilities (Meyer & Norman, 2020b).

However, according to Palaskas, (2002, p. 49) teachers' negative views toward the integration of learning technologies into the curriculum are exacerbated by the fact that technology adoption in education is sometimes influenced by non-pedagogical factors such as commercial interest, organizational politics, anticipated cost savings, and the need to increase enrolment (Palaskas, 2002, p. 49). Furthermore, they show scepticism and, on occasion, outright resentment when it comes to adopting new learning technology into the classroom.

Nevertheless, a study conducted by Maryam *et al.*, (2019) highlights that, many people think that the design industries are transitioning from "knowledge-based economies" to "product-centered practices." It goes on to say that some adjustments must be done in order for students to fulfil the evolving technological, knowledge, and technical demands of the business, particularly in higher education institutions' curriculums, training programs, and educational systems (Maryam et al., 2019).

This sentiment was echoed by Faerm and Campbell who alluded that, our design processes' next step is to "produce ideas and design solutions that demand a high level of education, skills, and creativity, (Faerm & Campbell, 2012). Other forms of design emerge in response to new developments, new tools, new situations, and new technologies (Meyer & Norman, 2020).

2.6 Summary of Chapter Two

This chapter provided an important bridge between basic knowledge and the specific objectives of this study. It began by outlining the evolving landscape of design education, underscored by the global shift toward the integration of digital technologies. The shift in higher education coupled with the changing dynamics of the fashion industry formed the basis for examining the impact of technology on fashion product development education.

This study sheds light on the changing landscape of fashion design education in response to dynamic changes in the fashion industry, highlighting that, in the past, the industry favoured manual production

and physical artefacts, which influenced teaching methods in fashion design courses. However, the advent of technological advances has disrupted this traditional approach. The need for educational institutions to adapt to the changing needs of 21st century students and align their methods with current apparel industry practices is evident. Technological trends in professional fashion design, such as virtual garment design, have led to more efficient processes and less waste.

In the previous sections, I have explored the landscape of fashion product development in the fashion industry and the transformative impact of technology in this industry. The literature review has provided insights into key aspects of product development, pattern making, and garment construction and has highlighted the challenges and opportunities of digitization. This chapter has also underscored the critical role of technology in improving efficiency, sustainability, and customization in the fashion industry. In the process of literature review, the study identified gaps in the literature and are outlined below.

The chapter provided an overview of the product development process in the fashion industry, highlighting the stages of market analysis, design, material sourcing, pattern making, draping, sample development, and prototyping, as well as the complexity of the development process in the fashion industry and the importance of incorporating technology into fashion product development education. The literature review has provided a comprehensive understanding of the fashion product development process and highlighted the transition from traditional methods to technology-driven approaches. It has highlighted the importance of this change and its impact on the various stages of product development.

One of the key findings from the literature is the change in product development brought about by digital technology, which is considered critical to understanding the fashion industry today. The literature shows that this change has shortened iteration cycles, reduced lead times, and improved communication with suppliers, all of which contribute to cost reductions and more efficient production. This will be interrogated further in the data collection chapter.

It has recognized the importance of technology in reducing waste, especially in the critical design phase. Digital prototyping and the integration of 3D technologies have significantly streamlined the design process and have the potential to revolutionize the industry by enabling customization, reducing waste, and promoting sustainable fashion.

The exploration of zero-waste fashion design is another notable aspect, with digital tools playing a critical role in minimizing the most difficult aspect of product development; waste and promoting sustainable practices. This represents a significant paradigm shift in design, with 3D software proving to be an effective tool for improving garment design, particularly in a zero-waste fashion. In addition,

the incorporation of technology into fashion design education has been deemed necessary given the rapid technological advances in the industry.

The literature further highlighted the need for teaching models that better support technologically oriented students and prepare them for professional practice. This is because, the fashion industry is undergoing a significant transformation driven by digital technology, necessitating a corresponding shift in education. However, there is a gap in the research that presents practical strategies to bridge the gap between traditional methods and technology-driven processes, especially in fashion education.

Faerm and Campbell (2012), emphasize the increasing demand for well-educated, creative, and capable designers in an ever-evolving field. This is also echoed by Norman (2020b), who states that the ever-changing landscape of design requires the exploration of new tools, techniques, and technologies.

Datta and Seal (2018), further highlight the high cost and limited accessibility of pattern making and grading software, which have discouraged many educators and professionals from adopting digital techniques due to the long-standing dominance of conventional methods.

In education, the integration of learning technologies clearly faces resistance, largely due to negative attitudes posed by teachers and various non-educational factors, as noted by Palaskas (2002). Scepticism and resistance persist even as Maryam *et al.* (2019), argue that the design industry is becoming a "knowledge economy". In response to this shift, the study suggests that educational systems, training programs, and curricula in universities need to be adapted.

In summary, this literature review highlights the complex interplay between digital transformation, education, and the evolution of the apparel industry and UoT, stressing the dynamic nature of the field and the need for adaptation and innovation in fashion education. It emphasizes the central role of technology in reshaping fashion product development, curriculum design, and industry practices.

In the course of the literature research, gaps were identified. These included:

- Integrating new technologies into fashion design education;
- Empirical studies on the impact of 3D technology in fashion design;
- Sustainable fashion and zero-waste design;
- The role of new technologies in transforming apparel manufacturing; and
- Comparing educational approaches to industry practices.

Integrating new technologies into fashion design education

While the literature highlights the need for a shift toward technology-integrated learning in fashion design education, there is a lack of in-depth exploration of specific strategies and best practices for incorporating these new technologies into curricula.

Empirical studies on the impact of 3D technology in fashion design

The use of 3D technology is addressed in the literature, but there is a lack of empirical research on its practical impact on fashion design and designers' ability to explore new creative scenarios.

Sustainable fashion and zero-waste design

While the literature mentions the concept of zero-waste fashion design, it does not elaborate on the challenges and opportunities associated with implementing these strategies in the fashion industry, particularly with regard to teaching and learning.

The role of new technologies in transforming apparel manufacturing

While the potential of new technologies to revolutionize the manufacturing process is highlighted, how these technologies impact design education practices is not fully explored. Measuring the impact on educational outcomes is certainly a necessity if we are to increase our confidence in our educational technologies for their potential to meet, their expected outcomes. However, particularly in the case of emerging technologies, the evidence generated from impact evaluations might rather be used to provide ‘informed change’ instead of a justification for standardized practice and manuals for implementations, (Cukurova & Luckin, 2018).

Comparing educational approaches to industry practices

Given the rapid pace of technological change, there is a need to examine more closely whether the methods used in fashion design education are consistent with those used in industry. This literature review has paved the way for a thorough exploration of the impact of technology on fashion product development education. The potential benefits, challenges, and opportunities associated with the integration of digital technologies is highlighted. In the upcoming chapters, the empirical evidence to inform and enrich the understanding of technology-integrated learning in fashion product development is gathered. Chapter Three presents the methodology used in the data collection, the results of which are presented in Chapter Four.

CHAPTER THREE: METHODOLOGY

The study employs qualitative methods to uncover the details of technological development in the fashion industry and its impact on education. Actor-network theory (ANT) guides the investigation of these relationships, while the study involves universities that offer fashion design courses and industry practitioners. Additional information on data collection, sampling procedures, participant recruitment, and theoretical and field research frameworks used for data collection are discussed in more detail in the following sections.

This chapter outlines the research methodology used in this study. It uses Mouton's (2009) research design approach (Figure. 3.2) to investigate the relationship between design technology, pattern making, and garment construction in fashion product development education and its impact on teaching and learning. In this section I report on the methodologies used in data collection following the topics highlighted in Figure. 3.1.

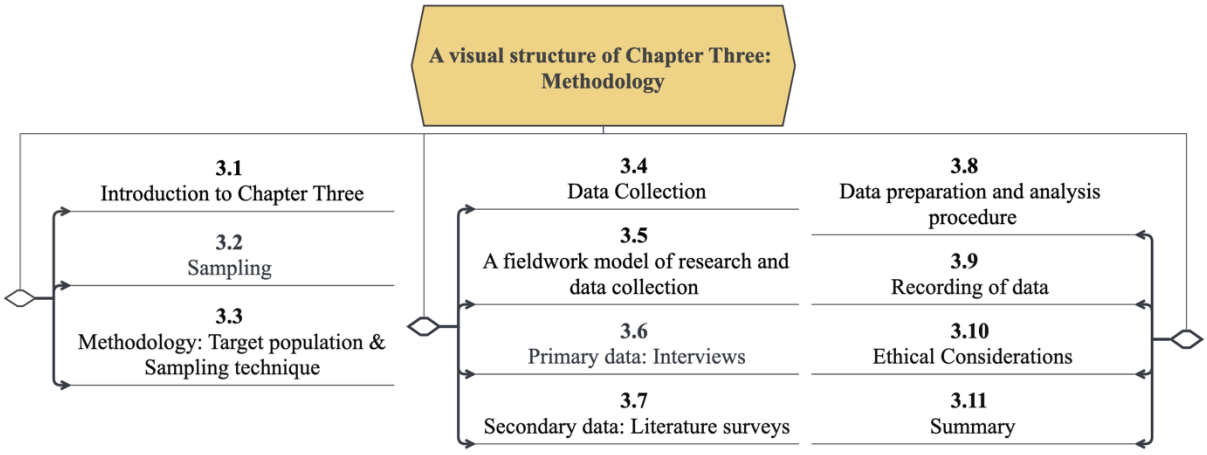


Figure 3.1: Visual structure of Chapter Three

The study employs qualitative methods to uncover the details of technological development in the fashion industry and its impact on education. ANT guides the investigation of these relationships, while the study involves universities that offer fashion design courses and industry practitioners. Additional information on data collection, sampling procedures, participant recruitment, and theoretical and field research frameworks used for data collection are discussed in more detail in the following sections.

3.1 Introduction to Chapter Three

In this section, I present the methodological strategy and data collection techniques and emphasize the importance of using a qualitative research methodology to explore the ever-evolving convergence of technology, fashion product development, and education. This research study applied a research

methodology following the procedure outlined in Mouton, (2009, p. 56) which served as a roadmap for answering the research questions. In preparation for data collection, I focused on the research process, the kind of tools and procedures to be used. Data collection and sampling methodology is outlined, and the focus is on the individual steps of the research process and its objective.

Figure 3.2: A research methodology procedure, (Adapted from, Mouton, 2009)

As noted earlier, the purpose of this research is to investigate the relationship between design technology, pattern making, and garment construction in fashion product development education and its impact on teaching and learning. The main objective is to explore the dynamics within the manufacturing process, focusing on pattern making and garment construction, and how technological advances have influenced teaching methods.

The following section of the study describes the methodology used to select participants and define the target population. It provides a comprehensive overview of the participant sample size and offers insights into the roles and responsibilities that contribute to the broader understanding of fashion product development in the apparel industry and academic institutions.

3.2 Methodology: Target Population and Sampling Technique

In conducting this exploratory qualitative study, the use of a judgmental or purposive sampling method resulted in the selection of participants with unique insights, including:

- Lecturers who are involved in teaching pattern making and garment construction;
- Final year fashion students;
- Industry practitioners such as:
    - Pattern designers
    - Fashion designers
    - Garment and fabric technologists
    - Project managers

The selected population inclusion was based on their assumed first-hand experience and expertise related to the research topic and provided insight from their own experiences. As a result, a non-probability sampling technique was considered, and it allowed for the deliberate selection of individuals with certain characteristics or expertise not easily obtained through other sampling methods. The use of this technique was cost effective and efficient in collecting relevant data from the target population (Taherdoost, 2016).

To answer the research questions, a sample was drawn from the population using a sampling technique and sampling steps to reduce the number of cases as suggested in Taherdoost (2016, p. 19) and illustrated in Figure 3.3 below.

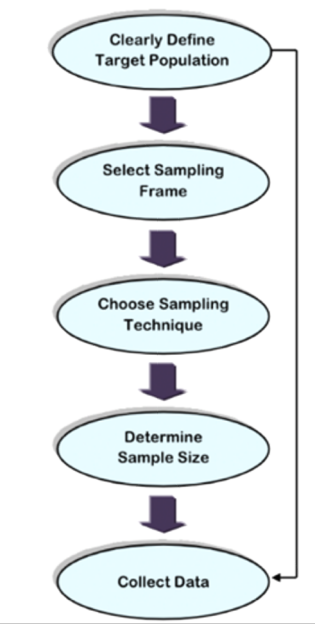


Figure 3.3: Sampling process steps (Taherdoost, 2016)

These sampling process steps were considered because the study has a clear rationale for the inclusion of participants, which is to get the views directly from the persons with experience and expertise in the research area. Therefore, the following steps occurred prior to data collection:

A targeted population was identified; a sampling frame was chosen; a sampling procedure was selected; and finally; a sample size was established.

3.2.1 Target population

Study participants were carefully selected from a pool of individuals representing the universities of technology and the apparel industry. The selection criteria focused on participants who had a deep understanding of product development processes in the apparel industry, the ability to provide first-hand insights, and active involvement in the fashion design program at the universities of technology. The participants' expertise in the research area and their diverse perspectives from both the South African University of Technology and the apparel industry were considered.

3.2.2 Sampling frame and procedure

This section describes the methodology used to select participants to ensure that the research sample was selected for a specific purpose and with expertise that matched the research objectives. Further findings and details are presented in this section. A non-probability sampling method used to recruit participants with relevant expertise in the field (Taherdoost, 2016).

3.2.3 Sample size

Participants were carefully selected to have an in-depth understanding of product development processes in the apparel industry and the ability to express first-hand opinions, as well as those who are actively involved and have good study and teaching experience in the fashion design programme at UoT. To accomplish this, systematic sampling was used to select participants with expertise in the research area and to bring diverse perspectives from the South African universities of technology and the apparel industry. It was important to ensure that all participants were eligible for the study, which allowed for practicality and the ability to collect the useful and necessary data for the study.

The sample included about twenty-five (25) participants from both the apparel industry and the two universities of technologies (UoT). Ethical considerations were observed by obtaining written consent from all relevant parties (Appendix D), including organizations and participants, prior to data collection; this is discussed below.

The following participants were included:

- Lecturers from both UoT1 and UoT2 who are engaged in teaching final-year courses on conventional and digital patterns and garment construction, (x5);
- Alumni of different universities of technology (UoT). Small, medium, and large companies in the apparel industry, (x6);
- Only students in their final year of study were eligible for participation, as this ensured a sufficient level of study experience, (x8). To ensure that data were collected from individuals with sufficient study experience, first- and second-year students were excluded; and
- Only apparel industry participants who are actively involved in the process of product development, with some alumni's playing a dual role of both UoT alumni and apparel industry practitioners, (x6).

Figure 3.4 shows the demographics or the total number of participants in the study as a percentage. Therefore, the answers are outlined using the percentages given.

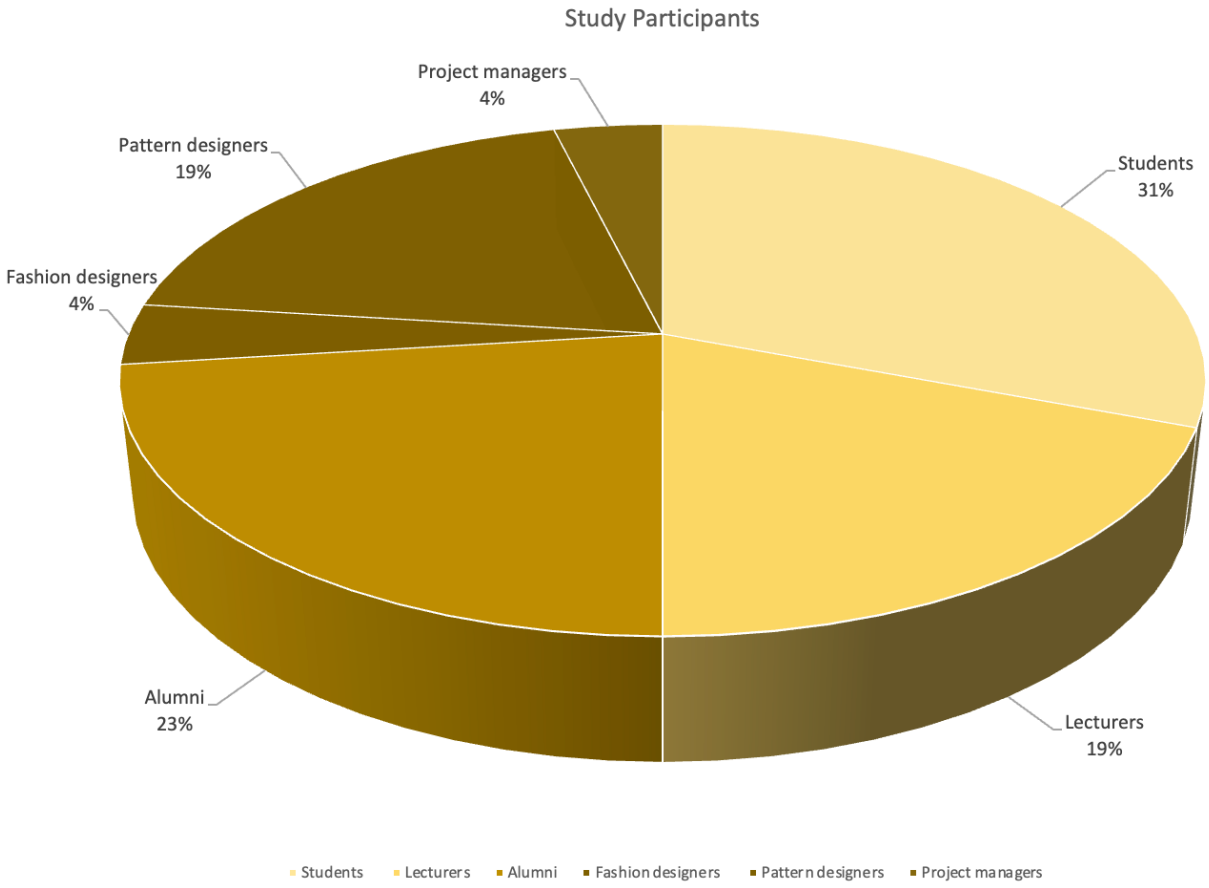


Figure 3.4: Demographics of participants

Tables 3.1 to 3.3 visualise the sample of the study, detailing purposively selected UoT participants, alumni, and industry practitioners. Ensuring the eligibility of all participants was paramount to the study's practicality and the collection of valuable and necessary data. As shown in Tables 3.1 to 3.3, pseudonyms and codes were used. There were two participating UoTs, and they are referred to UoT 1 and UoT 2. Where applicable, participants identities have been anonymised. Additionally, they have been encoded as follows:

- Lecturers – L1 and L2;
- Alumni – A1 to A6;
- Fashion designer – FD;
- Pattern designers – PD; and
- Project manager – PM.

There were two participating UoT, and they are referred to UoT 1 and UoT 2 in this study (Table 3.1). Participants included students and lecturers.

Table 3:1 UoT participants: students and lecturers

UoT Participants				
UoT 1			UoT 2	
Focus group	Individual interviews		Focus group	Individual interviews
Students	Lecturers		Students	Lecturers
Focus group (x3 third years)	L1:Akha	L2:Stella	Focus group (x5 advanced diploma students)	Focus group (x3)

While Table 3.1 above sets out UoT student and lecturer participants, Table 3.2 below outlines the participants who contributed as UoT alumni. For confidentiality purposes, the names and codes given to participants that appear in all the tables are not their real names.

Table 3.2 shows the participants who participated as UoT alumni. For confidentiality purposes, the names and codes given to participants that appear in all the tables are not their real names.

Table 3:2 Alumni participants

Alumni					
A1:Nesi	A2:Asi	A3:Oko	A4:Sihle	A5:Lukho	A6:Ruth

Table 3.3 shows the industry practitioners who participated in the study. The participants were a fashion designer (FD), pattern designers (PD1 to PD4) and a project manager (PM). Their roles are outlined in figure 3.4 below.

Table 3:3 Industry practitioner participants: fashion designer, pattern designers and project manager

Industry practitioners				
Medium Company: Fashion Designer	Medium Company: Pattern Designers	Big Company: Pattern designers		Big company: Project Manager
Face - Face interview	Online confirmatory interviews	Telephone interviews		Online interview
FD:Lizelle	PD1:Faeeze PD2:Janet	PD3:Yushaa	PD4: John	PM:Anneline

Figure 3.4 shows a visual structure of the apparel industry participants of the study.

3.3 Unpacking the Key Roles of Study Participants from the Apparel Industry

Figure 3.5 sets put the roles of carefully selected participants in the apparel industry. In this section the roles of practitioners in the apparel industry are explained, as mentioned in Glock & Kunz.(2005).

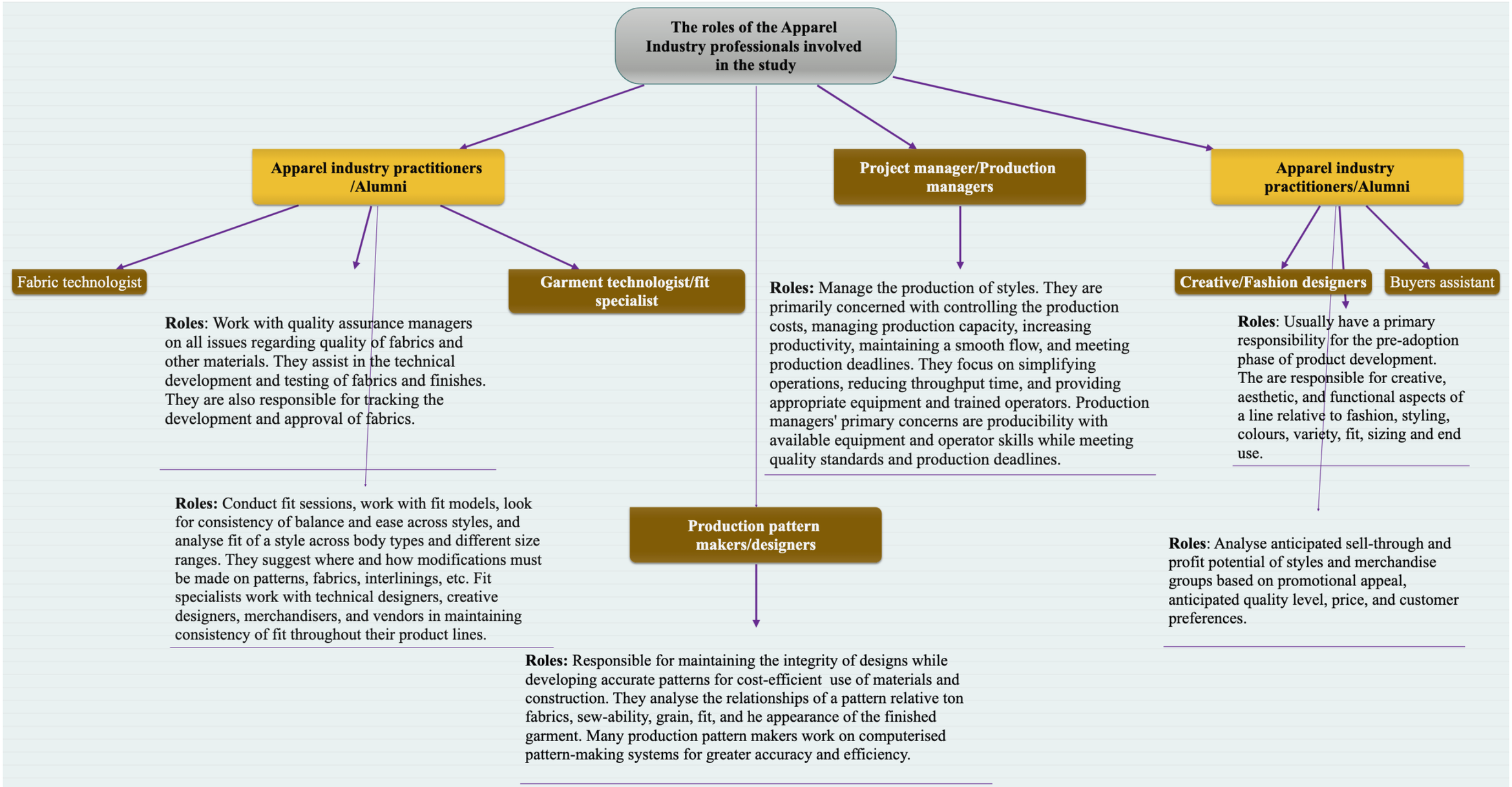


Figure 3.5: An outline of the roles played by participants in the apparel industry

As highlighted earlier in the study, the study sample focused on diverse individuals both in the apparel industry and at UoTs. Consequently, the importance of the roles of industry participants was paramount, as it was critical to gain insight from those directly involved in the product development process.

3.4 Data collection

In this section, the research study enters the phase of data collection to understand the impact of new technologies on the apparel industry and higher education institutions. The study focuses on assessing technology change readiness and resource needs, with an emphasis on the impact of technology on curriculum design. In this section, I present the methods and approaches used to gather insights and expand my understanding of the technological landscape in the field of fashion. It prepares for the analysis and findings that follow (Chapter Four) and lays the foundation for an in-depth examination of the impact of technology in this dynamic and evolving field.

The study also examined the outcomes of new technologies and the planning required to implement them following a theory of change steps. A theory of change steps is very useful in impact evaluations as it enables one to identify the steps that are necessary to take in order to reach the expected educational outcomes as well as the assumptions taken for granted between those steps (Cukurova & Luckin, 2018).

3.4.1 Data collection methods

Data collection included the use of benchmarking and a systems analysis at two universities that offer fashion design courses. The selection of the Universities of technology (UoTs) was based on the availability of fashion design courses, without any specific criteria. Both in-person and online data collection methods were used, and participants were given the opportunity to choose their preferred method of participation. Individual and focus group interviews were conducted in person, when possible, supplemented by online sessions via Microsoft Teams and phone chats.

Data collection combined primary and secondary sources, using Actor Network Theory (ANT) as an interview framework to analyse the interaction between design technology, pattern making, and garment construction in fashion product development education. Further information about the use of ANT is further discussed below. This approach highlighted the influence of technology and the interconnections within the fashion industry and academia.

3.4.2 A theoretical model of data collection: literature reviews and contextual analysis

Two phases or models of data collection were used to determine the generally accepted findings about the study, namely literature review and contextual analysis. Various tools are used as part of qualitative

data collection and analysis to uncover underlying meanings providing an overview of the field research, highlighting the tools and models used for data collection (Figure 3.6). Tools also apply to data analysis using a range of methods, and the individuals involved in the process.

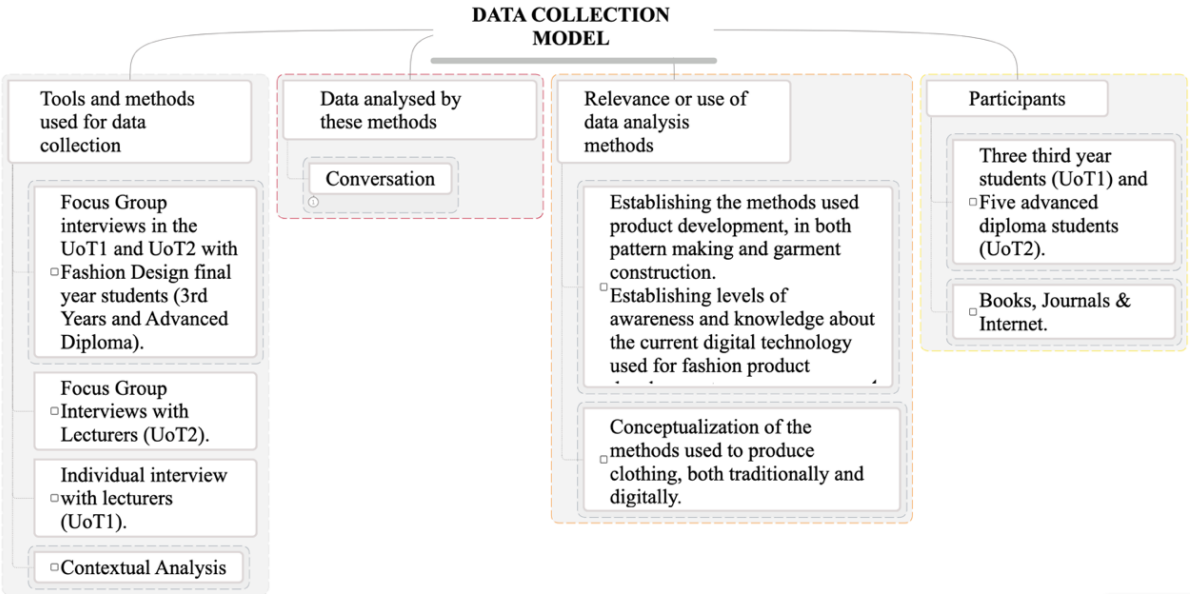


Figure 3.6 A theoretical model of data collection

Two phases or models of data collection were used to determine the generally accepted findings about the study, namely literature review and contextual analysis, and from both primary and secondary sources. The data collection process included a structured interview approach based on the five steps of theory of change described by Cukurova and Luckin (2018, p. 7). This approach helped identify the actions needed to achieve the desired educational outcomes and understand the assumptions between these steps. These theoretical data collection methods are important to evaluate the approaches of the apparel industry and Fashion design UoT in developing fashion products and to collect relevant data. Sources used for this purpose include books, trade journals, and the Internet. The use of literature is critical to this study as it allows me to identify previous research and gaps that need to be addressed, as well as relevant variables and connections between theory and practice (Onwuegbuzie et al., 2012, p. 1).

3.4.3 Methodological cost

A mixed data collection method was not considered because the use of statistics would not reveal the underlying story and meaning I wish to uncover. In addition, the scope of the study would be too large, and the research sample is not overly large. In order to achieve the study objectives, it will be outlined how the research was conducted.

3.5 Fieldwork Model of Research and Data Collection

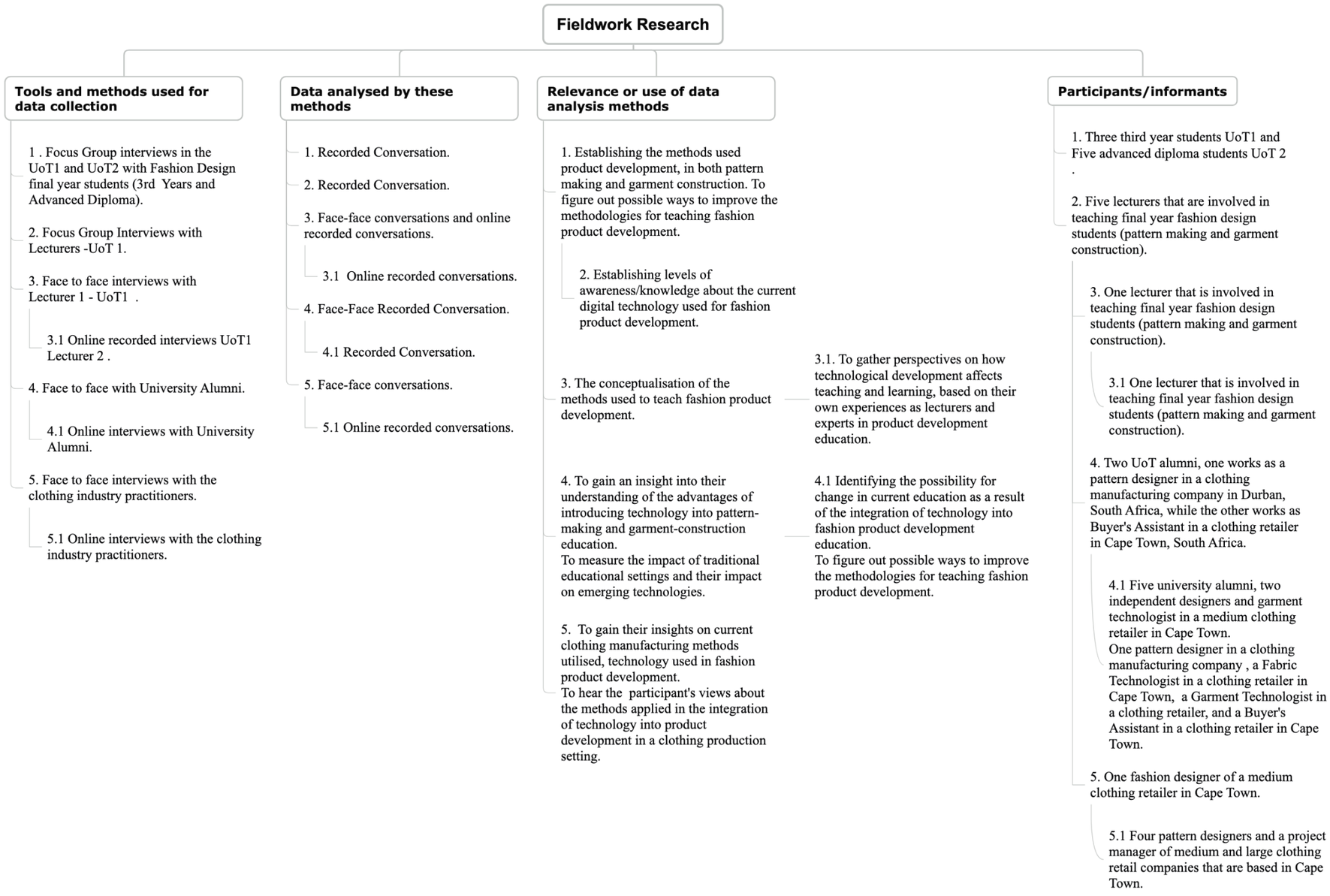


Figure 3.7: Fieldwork-research data collection

Figure 3.7 provides an overview of the field research, highlighting the tools and methods used for data collection, the data analysed using these methods, the importance of these data analysis techniques, and the individuals involved in the process

Qualitative fieldwork was an essential component of the study. In this approach, I immersed myself in the research setting to gather context-specific data through interviews and focus groups. The interaction with participants allowed for a deeper understanding of the topic and helped to deepen scientific knowledge and answer the research questions. This method played a critical role in capturing the nuances of the human experience and underscored the importance of direct interaction with research participants to achieve meaningful and contextual results. It also highlights the relevance of data analysis methods and emphasizes the involvement of research participants in the data collection process.

3.6 Primary Data: Interviews

To gain insight into the perceptions and experiences of undergraduate students, university alumni, and industry practitioners, data was collected through primary data through in-depth online and in-person interviews (open-ended) and focus groups. Because this study employed a qualitative research methodology to examine the impact of technology on fashion product development, semi-structured interviews were conducted. Group interviews were conducted to avoid interrupting workers in their work, and participants could choose to be interviewed in person or online.

The interviews and focus groups were structured to clearly define the purpose of the study and the expertise of the researcher. I also paid attention to the atmosphere created during the meeting and ethical procedures. In the focus groups, the group dynamics determined the direction of the discussion and the way in which the participants responded to the group leader and to each other. This was an advantage, as the interaction between the participants encouraged them to share their opinions and formulate contributions to the research problem.

The face-to-face meetings and online conversations with all participants were essential to gain a full understanding of the complicated dynamics and procedures used in both the apparel and education sectors. During the in-person interviews at UoTs, the process with conversations the student focus groups before speaking to the lecturers. The reason behind this approach was to gain an understanding of the students' experiences, challenges, and views of the research topic. This approach provided a foundation for understanding student views and the impact of digital technology on their learning. In addition, the insights gained from the students played a critical role in shaping the subsequent interviews with the lecturers.

These findings provided clues for the formulation of targeted questions aimed at exploring the lecturers' viewpoints on the issues raised by the students. Through this approach, deeper insights into specific areas, such as teaching methods for pattern making and garment construction were gained, while also enriching data through extensive interviews with lecturers.

In this study, the narrative inquiry approach is used for data analysis because it focuses on collecting data that comes from participants' personal experiences. This decision is consistent with the perception of Butina (2015) who considers narrative inquiry as an approach that involves exploring narratives about human experiences or generating data in narrative form. This approach is useful for this study because it allows for the analysis of information shared by participants during data collection, contributing to the findings of the study.

To answer the second research question, a thematic analysis method was used, which, as recommended by Ibrahim (2012, p. 40) enables the identification of relationships between concepts and their comparison with replicated data. Using a thematic analysis approach, the collected data from the interviews and focus groups were systematically examined and the responses of all participants were characterised in order to gain meaningful insights.

3.6.1 Tailored approaches for different groups

The interviews were structured differently for the different participant groups to ensure that the interview process was sensitive, engaging, and allowed for an in-depth exploration of the research topic from different perspectives. Lecturers were asked primarily about the theoretical impact of technology on fashion product development. Alumni, on the other hand, provided practical insights based on their experiences as students and in their professional environments.

Industry practitioners discussed challenges, opportunities, and their use of digital technology systems in the fashion industry. This tailored approach made participants feel comfortable and confident in sharing their insights and experiences. It also allowed for a deeper understanding of the impact of technology on fashion product development from different perspectives.

3.6.2 Interview process

To gain insight into the views and experiences of students, university alumni, and industry practitioners, primary data was collected through in-depth online and face to face (open-ended) interviews and focus groups. Group interviews were conducted to avoid disturbing employees at work, and most importantly, to gain insights from a group perspective. Participants could choose whether they wanted to be interviewed in person or online.

The interviews and focus groups were structured to clearly define the purpose of the study and the expertise of the researcher. Paying attention to the environment created during the meeting and ethical procedures was important. In the focus groups, the group dynamics determined the direction of the discussion and how the participants responded to the group leader and to each other. This was an

advantage because the interaction between participants encouraged them to share their opinions and formulate contributions to the research problem.

The face-to-face meetings and online conversations with all participants were essential to gain a full understanding of the complicated dynamics and procedures used in both the apparel and education sectors. During the in-person interviews at UoT, it was decided to begin the interviews with the student focus groups before approaching the lecturers. The reason behind this approach was to gain a deeper understanding of the students' experiences, challenges, and views on the study. This sequence provided a foundation for understanding student views and the impact of digital technology on their learning. In addition, the insights gained from the students played a critical role in shaping the interviews with the lecturers.

These insights provided guidance for formulating targeted questions aimed to explore the lecturers' viewpoints on the issues raised by students. Finally, this approach allowed for a more in-depth exploration of specific areas and facilitated the collection of data during the interviews with the lecturers. It is worth noting that this procedure was successfully employed at one of the participating universities, while it could not be used at the second university due to the absence of students.

3.6.3 Participants: informed consent

During data collection, students, lecturers, or industry personnel were not compelled to participate. Signed consent forms were used as requirements for participation and all participants signed the forms voluntarily, without excessive influence. Students who are currently enrolled at one of the partnering institutions were eligible to participate. In the consent forms as well as during the interview sessions, it was clearly stated that participants who prefer to withdraw from the study and revoke the information they provided to me will be able to do so without consequence. Further details on the ethical considerations that were used during data collection are presented below.

3.6.4 Question types and grouping strategies in individual and focus group interviews

The study aimed to validate the assumption that students can be exposed to the need to integrate digital technologies into fashion product development education through hands-on experience with digital design tools, virtual prototyping, 3D technologies, and other technologies that are widely used in the apparel industry. To assess readiness for change and resource needs, questions were asked to understand the resources needed and to assess participants' readiness to implement new systems. The interview questions were designed to explore the impact of technology on the apparel industry and higher education institutions, as well as its impact on curriculum design (Taherdoost, 2016), and to answer the research questions.

As highlighted earlier in this study, the research problem revolves around understanding the relationship between current design technology and fashion product development. In the planning stage of this study, it was recognized that there are different groups of participants and may require different approaches to question structuring. This decision was based on the difference in the participants' backgrounds, expertise as well as research objectives, as a result, different interview schedules were developed and shared with the participants before embarking on the interview process.

As previously stated, there was no need to scale the questions because they were all open-ended. Through the use of open-ended questions, the respondent made his or her suggestions or comments without being restricted by a predetermined set of questions. In certain cases, closed-ended questions were taken into consideration; these questions could only have one of a restricted number of possible solutions, like "Yes" or "No." For more information on the questions asked in the interviews and a graphical representation of the answers in chat format, see the next chapter.

The line of questioning mainly focused on:

- Determining the categories of digital technology utilized to improve learning;
- Knowing how to improve the methodologies for teaching fashion product development;
- Identifying the potential for change because of the integration of technology into fashion product development; and
- Determining the effect that technological advancement has on teaching and learning.

To gather insights into implementation planning and resource requirements, questions were structured to understand the additional resources or input needed for successful change plans. Additionally, questions were designed to assess the preparedness for change, as it plays a crucial role in facilitating or hindering the implementation of new systems. Uniform, and systematic questions were posed during both individual and focus group interviews to ensure consistency across participants.

During the initial phase of the interviews, oriented/open-ended questions were asked to familiarize participants with the subject under question and respondents made suggestions without being constrained by a fixed set of possible responses. Administering interview questions. Interview questions were carefully designed and distributed to all potential participants, who were given the freedom to decide whether to participate voluntarily.

Through interviews with fashion design universities and apparel industry practitioners, the study sought to gather information on what production methods are being used in apparel manufacturing, both in production and education. Whether digital technologies are used in apparel manufacturing. What methods are used to integrate digital technologies into training for fashion product development.

Informed consent forms were prepared and distributed to all participating technical universities and apparel manufacturers, and all individual research participants willingly signed the forms. Ethical review and approval were obtained from the appropriate ethics committees and review boards before data collection began to ensure that the research met the required standards (Appendix A). Gatekeeper consent letters are listed as Appendices B and C.

Key questions formed the basis for the survey, justifying reasons for asking them. Questions were directed at specific participants. Various methods were used for data collection, the types of questions asked, detailed explanations of why these questions were asked, and how the approaches chosen contributed to the study. These questions served as a framework for further investigation, focusing on the use of technology. A coherent line of questioning was used to identify areas of agreement and reveal differences in responses.

The questions were arranged into sets based on specific objectives. Each set of questions aimed to validate the assumption regarding the lack of integration of digital technology in fashion product development education. These question types allowed for in-depth and detailed responses, and additional further probing was done to gain specific information and understand participants' perspectives.

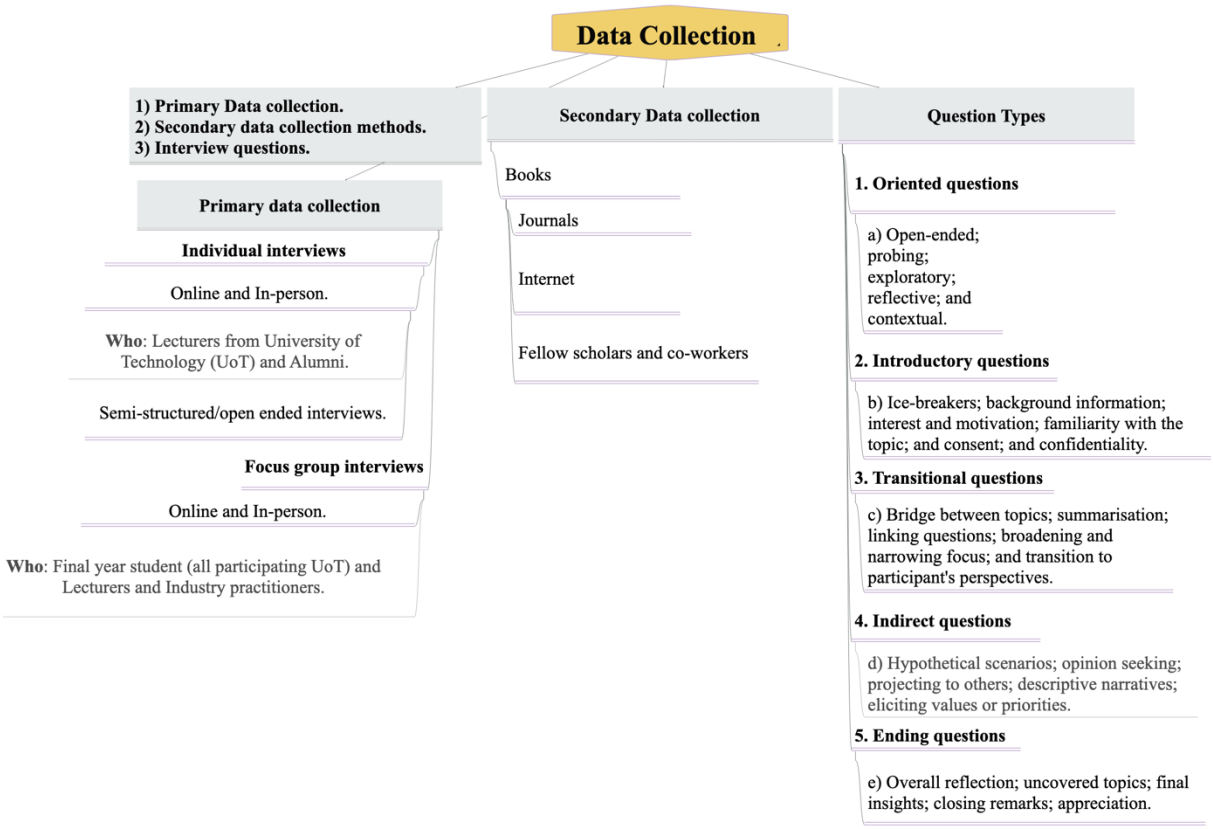


Figure 3.8: Data collection methods and question types

Exploratory questions were presented to encourage participants to respond honestly and without prior ideas or assumptions. This approach facilitated reflection on past experiences for students, alumni, lecturers, and business professionals. It was particularly insightful to hear from practitioners who transitioned from conventional to digital production processes, providing a comprehensive understanding of the research topic. Participants contextualized certain aspects of the research in their answers, drawing from their experiences, background knowledge, and viewpoints. This enriched the comprehension of the subject matter, and the questions posed were structured accordingly.

3.6.5 Questions prepared for participants

In this study, it was important to ask questions that would be helpful in gathering information to answer the research questions and achieve the objectives of the study, however, it must be noted that these questions were drawn to guide the questioning, otherwise the questions were open-ended and relied on the answers given.

The questions asked are related to the following areas:

- What are the different categories of digital technologies used in fashion product development?
- How has the use of technology changed the way fashion products are developed?
- What are the benefits and challenges of using technology in fashion product development?
- How can technology be used to improve the sustainability of fashion product development?
- How does technology encourage collaboration?
- What are the ethical implications of using technology in fashion product development?

Further details on the research findings will be discussed in the subsequent chapter.

3.6.6 Conducting the interviews

The study was conducted using a systems analysis approach through benchmarking at two different UoT offering fashion design in two different provinces. This approach was influenced by Yezhova et al, (2018) who used a benchmarking method in conducting a comparative systemic analysis of staff preparation models in fashion education in the European Union, Ukraine, the United States, Canada, China, and Japan. With reference to the data presented visually above in Figure 3.7 the following methods were used to collect data:

- Focus group interviews with, lecturers, students in their final year of study;
- In-person and online interviews with lecturers and alumni;
- Online recorded interviews with apparel industry practitioners; and
- Online focus group interviews with pattern designers.

3.6.7 Interviews with final year students

Focus group interviews were conducted with final-year students (third and fourth-year students) at two UoTs in 2022 and 2023. The students were selected because they had extensive experience in the fashion industry and were likely to have completed a large portion of their fashion education, which included both traditional and digital techniques. Their experience provided a comprehensive view of the research study. Focus group interviews were considered for the students to provide them with a comfortable environment where I could gather information while they spoke freely around their peers.

3.6.8 Interviews with lecturers

Interviews with the lecturers were conducted in person and online. The lecturers were selected because they teach pattern and garment construction courses to third- and fourth-year students. The goal of the interviews was to gain insight into their approach to fashion product development education and the impact of digital tools on course design, content creation, and adaptation to industry needs.

3.6.9 Interviews with alumni and apparel industry practitioners

Apparel industry practitioners, including alumni who have moved into professional roles, were selected because they have first-hand experience with digital technologies in product development. The purpose of these interviews was to explore industry expectations for fashion students and to improve their preparation, particularly with regard to product development education and the integration of digital technologies into fashion education. Most participants were former students who now work as independent designers, apparel technologists, fabric technologists, pattern designers, and buyer's assistants. Their dual roles as alumni and industry professionals brought perspectives to the research.

3.6.10 Using Actor Network Theory (ANT)

In the data collection phase, a purposive sampling technique was used to identify actors (both human and non-human) for the interviews. This included human participants, namely, students, alumni from universities, clothing industry practitioners, and non-human participants, such as, computers. Interview questions were developed under the guidance of an ANT to explore the perspectives, functions, and influences of the different network actors.

This approach provided a detailed understanding of the collaborations, connections, and relationships between participants and other actors. As a result, the interviews provided insights into the ways in which particular actors might help or hinder the integration of technology into fashion product production and the teaching and learning curriculum. During the interviews, particular attention was paid to how different actors behaved, interacted, and influenced each other. This was evident during the

interviews in the focus groups, where the use of power was often evident. The analysis also considered how actors adapted to the views and interests of others. Understanding these interactions and power dynamics is critical to data analysis.

3.6.11 Application of theory of change steps

During the data collection and interview process, the line of questioning followed the theory of change steps outlined by Cukurova and Luckin (2018, p. 7) in their diagram (Figure.3.9). These steps were utilized to identify the necessary actions and assumptions for achieving desired educational outcomes and measuring the overall influence of new technology.

The motive for using the theory of change steps was to explore the impact of digital technology on the clothing industry and curriculum structuring. The study aimed to investigate the intermediate outcomes of emerging technologies and understand the plans for implementing these technologies.

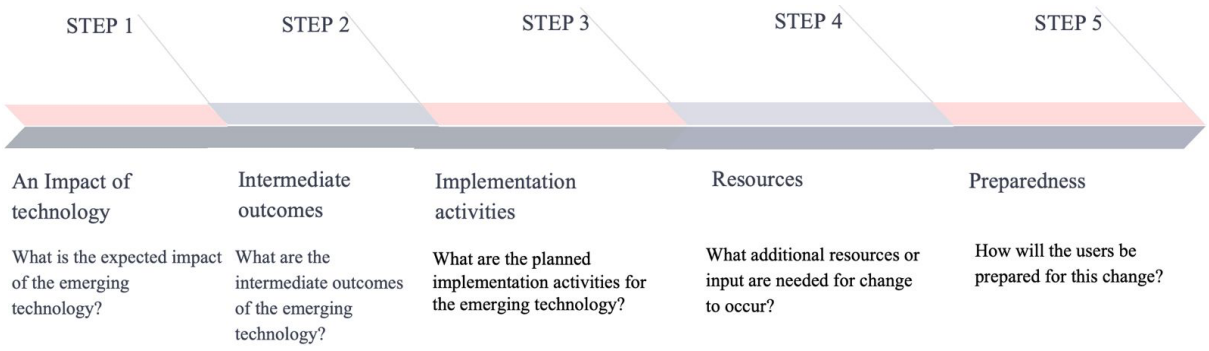


Figure 3.9: A theory of change diagram steps for emerging educational technologies (Adapted from Cukurova & Luckin, 2018)

3.7 Secondary Data: Literature Surveys

Literature surveys were conducted throughout the research process to keep up to date with the current literature that supports the study. In this study, secondary data were collected and reviewed from the following data sources: Books, journals, internet, and colleagues.

The Internet was used to find information on topics not covered in books or magazines. Informal discussions were held with colleagues and collaborators to obtain their opinions on the topic under study and its application. The use of secondary data was essential to this research study. It allowed me to gain an understanding of the current state of the art in fashion product development and education. The secondary data also provided the researchers with a foundation upon which to build their own research.

The literature review was conducted on a regular basis to stay up to date of the current literature supporting the study and to gain an understanding of the current methods and tools used in the apparel

industry and in fashion product development education. Particularly, books, journals, and the internet were reviewed to gain a deeper understanding of current trends in fashion product development and education. In addition, informal discussions were held with colleagues and other academics to obtain their opinions on the topic under study and its application.

3.8 Data Preparation and Analysis Procedure

Data from the interviews were analysed using thematic analysis. Thematic analysis is a method of qualitative data analysis in which patterns in the data are identified, coded, and analysed. The first step in thematic analysis is to read through the interview transcripts and identify the main themes that emerge. The second step is to code the data according to the themes. The third step is to analyse the coded data and identify thematic patterns. The fourth step is to write down the results of the analysis.

Online interviews were conducted using Microsoft Teams (MS Teams), with additional backup recordings stored in the iPhone via the Voice Memo app. In-person interviews, on the other hand, were recorded using only the iPhone. Transcriptions were conducted using MS Teams and MS Word Online and later uploaded to ATLAS.ti, and the process of data analysis is discussed below.

3.9 Recording of Data

Keyword notes were taken during the interviews, and the researcher has audio recordings of all interviews, including the face-to-face interviews. Participants were informed that the data collected would be archived and stored in Cape Peninsula University of Technology (CPUT) approved secure archives for long-term retention. This was done to alleviate their fears and assure them that the information they provided would be kept anonymous and secure.

Due to the nature of the study, and the preservation of the participants' identity, no photographs were taken during data collection. The online recorded interviews were conducted without cameras, and no video technology was used to capture the data. The next section deals with the procedure used to present the findings obtained during data collection.

3.9.1 Presentation of evidence: data coding and creation of themes

To ensure the private presentation of empirical results, whether they reveal new facts or confirm previously assumed phenomena, the data are coded to facilitate analysis. The results obtained from the analysis are described and summarized using tables and figures. The major trends and patterns found in the data are discussed in relation to the research questions (Mouton, 2009, pp. 113 & 125). A summative data analysis method is used where responses are entered into a Microsoft Excel spreadsheet along with

data from the literature, findings, conclusions will be drawn from this combined data set. The spreadsheet was used a data analysis tool that encompasses all the information.

3.9.2 Microsoft Excel spreadsheets as data analysis and thesis writing tools

In this study, Microsoft Excel Spreadsheet is used as a data analysis tool, and later it was used as a dissertation writing tool that provides a detailed overview of the entire dissertation. All participants were colour-coded per Figure 3.10 to distinguish their roles.

A link is provided below to the spreadsheet (Appendix F).

> https://docs.google.com/spreadsheets/d/1cj8VfUSKTDfFAPY8aDL4WqZt5O829NCS/edit?usp=sharing&ouid=110191107532144115020&rtpof=true&sd=true

There are approximately three sheets, with Sheet 1 containing all relevant questions. related to Research Question One (RQ1). The themes and codes are taken from the transcribed research protocols and coded via ATLAS.ti to identify patterns.

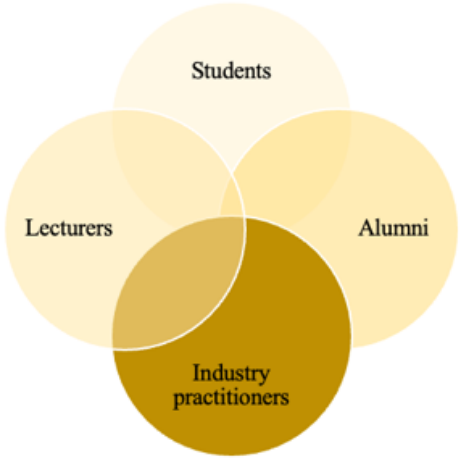


Figure 3.10: An outline of the colours used to identify the participants

For both RQ1 and RQ2, responses are outlined to draw conclusions and make recommendations. "Yes" responses are labelled with the letter “Y”, “No" responses are labelled with the letter “X”, and both methods are labelled with the letter “BM”. In cases where the question asked is irrelevant to the participant, the letter “O” is used as an indication. The third sheet of the worksheet contains all keywords, themes, and short codes that were taken from the interview transcripts and coded into ATLAS.ti. If a participant is unsure about the question asked, the letter “U” was used as a symbol for “unsure". The answers were evaluated, and conclusions were drawn. Sheet 2 of the worksheet contains all questions and answers for RQ2. Table. 3.4 provides a visual image of the data analysis spreadsheet.

Table 3:4: Visual image of the layout of the data analysis spreadsheet

Identification of symbols/codes			UoT (Branch 1 & 2)			UoT 2		Alumnis/Industry practitioners											Data Analysis			
X = No	Y = Yes	O = Not my line of work	Students	Lecturers		Students	Lecturers	Independent Fashion Designers		Alumni	Medium Co: Fashion Designer	Pattern Designers				Garment Technologist	Fabric Technologist	Project Manager	Data Analysis			
Both Methods = BM	Total number of participants = 25		Focus group (x3 third years)	Lecturer 1 : Akha	Lecturer 2 : Stella	Focus group (x5 Adv diploma)	Focus group (x3)	Independent Designer 1/Alumnus 2 (Sihle)	Independent designer 2/Alumna 3 (Ruth)	Buyer's Assistant/Alumna 1 (Nesi)	Lizelle	Confirmitery Interviews - Faeeze & Janet (x2 : Cape Town Pattern Designers - Med Company)	Alumnus 3 (Lukho) : Durban Pattern Designer - Medium	Pattern Designer 1 : Yushaa	Pattern Designer 2 : John	Alumna 2 (Asi)- Garment Technologist - Big Company	Alumnus 1 (Oko)- Fabric Technologist - Big Company	Project Manager- Big Company : Anneline				
Modern digital systems : the utilisation of 3D software (Pattern Making)																						
Q1 : What is the relationship between current design technology and fashion product development?	**THEMES**	**Total**	3	1	1	5	3	1	1	1	1	2	1	1	1	1	1	1	25	UoT, Alumni's & clothing industry practioners		
		CLARIFICATION OF THEMES																				
	1. AD -Anthropometric Data																					
SQ1(a) What digital technologies do you use? (UoT & Clothing Industry). SQ2(b) How have these technologies changed over the past five year's?	1(a) Body Measurements Techniques - Data Collection	**Total**	3	1	1	5	3	1	1	1	1	2	1	1	1	1	1	1	Data Analysis			
		(a) Conventional Methods : Traditional Tape Measure	Y	Y	Y	Y	Y	Y	Y	BM	Y	Y	Y	Y	Y	BM	BM	Y	Y=22	X=O	BM=3	O=0
		(b) Digital Technology : 3D Body Scanning Systems	X	X	X	X	X	X	X		X	X	X	X	X			X	Y=0	X=22	BM=3	O=0
2. DT1: Digital technology integration																						
Step 2 - Pattern Making, Grading and Marker Making Systems		**Total**	3	1	1	5	3	1	1	1	1	2	1	1	1	1	1	1	Data Analysis			
Import and export patterns	2 (a) PDS: Product development systems	1) Gerber systems	X	X	X	X	X	Y	BM	Y	O	BM	BM	X	X	Y	Y	BM	Y=3	X=15	BM=4	O=1
		2) Lectra systems	Y	Y	Y	Y	X	X		X				Y	Y	X	X		Y=14	X=5	BM=5	O=1
		3) V-Stitcher	X	X	X	X	X	X	Y	X	Y	Y	Y	X	X	X	X	Y	Y=6	X=19	BM=0	O=0
		4) CLO 3D	X	X	X	X	X	X	X	X	O	X	X	X	X	X	X	X	Y=0	X=24	BM=0	O=1
		5) Tuca Tech	X	X	X	X	X	X	X	X				X	X	X	X	X	Y=0	X=24	BM=0	O=1
Pattern Grading		6) Grafis	X	X	X	X	X	X	Y	X	Y	Y	X	X	X	X	X	X	Y=4	X=21	BM=0	O=0

3.10 Ethical considerations

During data collection honesty, transparency, and integrity were emphasized in the conduct of this study. Participants were fully informed of the purpose, methods, and potential outcomes of the study to ensure that their rights, protections, and welfare was paramount. Ethical standards were strictly followed throughout the study. A virtues-based ethics approach was used, emphasizing the development of virtuous character traits to guide moral behaviour and decision making, which aligns well with the goals of the study. This approach was inspired by Poultin's research, which highlights its usefulness, especially in insider research situations (Poulton, 2021). The relevance of a virtue-based methodology was particularly evident in the case of former students of the researcher's current employer who volunteered to participate. Given the involvement of three important parties-participant, researcher, and sponsor-a thorough evaluation of ethical implications was required. Participants' clear understanding of the study's objectives, procedures, and benefits, as well as their rights to voluntary participation, withdrawal, and confidentiality, was essential for adherence to ethical standards (Resnik, 2020).

3.10.1 A trusting researcher-participant relationship

A trusting and respectful relationship with participants was maintained throughout the research process, with strict attention to maintaining professional boundaries to prevent exploitation or coercion, especially among undergraduate and graduate students. Vigilance was exercised regarding power dynamics and potential bias that could influence the research process. To overcome language barriers, interviews were conducted in English with opportunities for clarification to ensure participants' active engagement and understanding. When necessary, language was switched to allow for effective communication and to put participants at ease.

3.10.2 Confidentiality and anonymity

In accordance with the South African Protection of Personal Information Act (POPIA), strict measures were taken to protect participant data. Personal information volunteered by participants remained confidential and was coded during data analysis and reporting to protect privacy. Pseudonyms were used to maintain participant anonymity, and no personal identifying information was used. Data were securely archived in authorized CPUT repositories for long-term storage. No images of the participants were taken during the interviews.

3.10.3 Ethical conduct of the researcher

Numerous precautions to ensure unbiased data collection and analysis were considered. Ethical research practices were carefully followed, and recorded interviews serve as evidence of unbiased reporting. Data collection methods were chosen to avoid bias and to ensure that research findings were transparent and

unbiased.

3.10.4 Role of the sponsoring organization

Although CPUT provided the main funding, the study was initiated at the discretion of the researcher for academic purposes. There is no possibility of manipulation by the sponsoring organization, as the study was not conducted on its behalf or in its name. Any unforeseen ethical concerns will be addressed in consultation with the academic supervisors.

3.11 Summary of Chapter Three

This research chapter provided a comprehensive overview of the structure and methodology of the study and demonstrated a systematic approach to exploring the integration of technology into fashion product development education. Emphasis was placed on methods of data collection, analysis, and ethical considerations. Data collection methods were explained in detail, emphasizing the use of semi-structured interviews, focus groups, and literature reviews. The use of these methods provided data that was intended for this study. The development of interview guides, protocols, and data collection tools were discussed here to ensure they align with the research objectives outlined earlier.

The methodology described above enabled the exploration of the integration of digital technologies into fashion product development education and the identification of current approaches used by both the apparel industry and fashion UoTs. The conclusions were drawn on the basis of research findings from the literature and the data collected. The above sources of information helped in collecting the primary and secondary data needed for the research. A sampling strategy for identifying study participants was outlined and the rationale for sample selection was presented to ensure diversity and representativeness. Emphasis was placed on ethical considerations, highlighting the need for informed consent, confidentiality and respect for participants' rights and privacy, and commitment to ethical behaviour and compliance with relevant ethical guidelines and regulations.

The chapter acknowledged limitations of the research design and challenges encountered in accessing participants. Strategies to mitigate the limitations were also discussed to ensure the validity and reliability of the study. While Chapter Three presented the data collection methodology for this study, Chapter Four presents the discussion of the research findings. Finally, Chapter Five provides conclusions, discussion, summary and recommendations for educational practice, policy, and future studies to advance digital technology initiatives while identifying gaps in the current understanding of this transformative potential.

CHAPTER FOUR: PRESENTATION AND DISCUSSION OF FINDINGS

This chapter presents the results of the integration of digital technologies in the development of fashion products. The main objective of this study was to gain insights and perspectives regarding the integration of digital technologies into fashion product development education. To this end, data was collected through individual and focus group interviews with fashion design students, lecturers from two universities of technology, fashion design alumni, and apparel practitioners directly involved in apparel manufacturing processes.

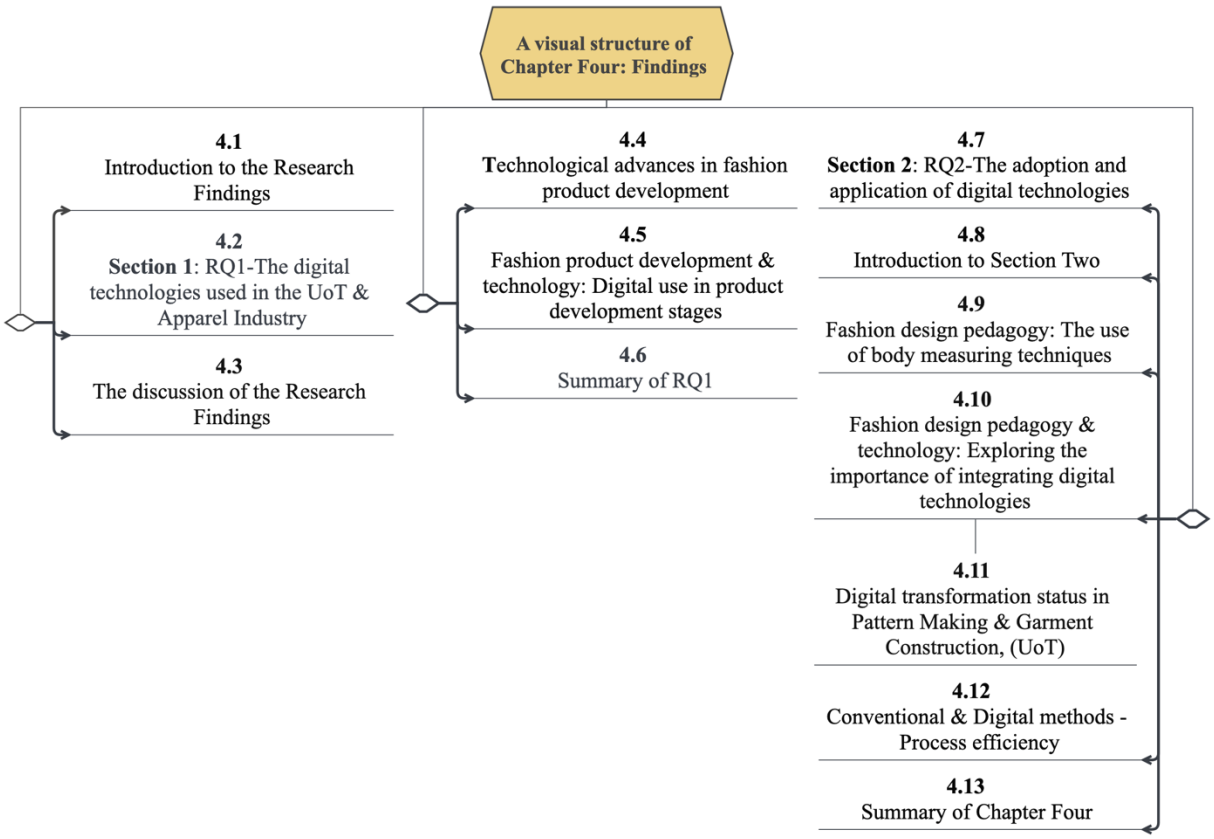


Figure 4.1: Visual structure of Chapter Four

By incorporating their viewpoints, this study aims to provide an understanding of the challenges, opportunities, and potential benefits associated with integrating digital technologies in this field. The views of the participants are presented in the headings and sub-headings in Figure 4.1, with the research findings presented in the first discussion section.

4.1 Introduction to the Research Findings

In the presentation of the findings section, after presenting the data collected, the focus will be on analysing and interpreting the results to answer the research questions as outlined in Figure 3.8 of Chapter Four and provide important insights and contributions to the existing knowledge base in the field of fashion product development and its integration with digital technology.

Through analysis and interpretation of data, key themes, patterns, and trends were identified, leading to an understanding of the topic. The findings provide insights and recommendations for future policies, practice and research in this area that will benefit both academia and industry. The information gathered will inform the conclusion, summary, and recommendations (Chapter.5).

Gaps uncovered by this research will be highlighted and discussed further in the next Chapter. The first and second sections presents the data from these interviews, which provide insights into the perceptions and opinions of those directly involved in fashion education and the clothing industry in an aid to answer research questions one and two.

Two basic objectives guided the collection of data and the subsequent data analysis. One was to test the validity of the assumption that traditional teaching is no longer appropriate due to advances in technology, and to examine how changes in technology are affecting teaching and learning in fashion product development education. Data were collected and then processed in response to the problems posed in Figure. 4.2.

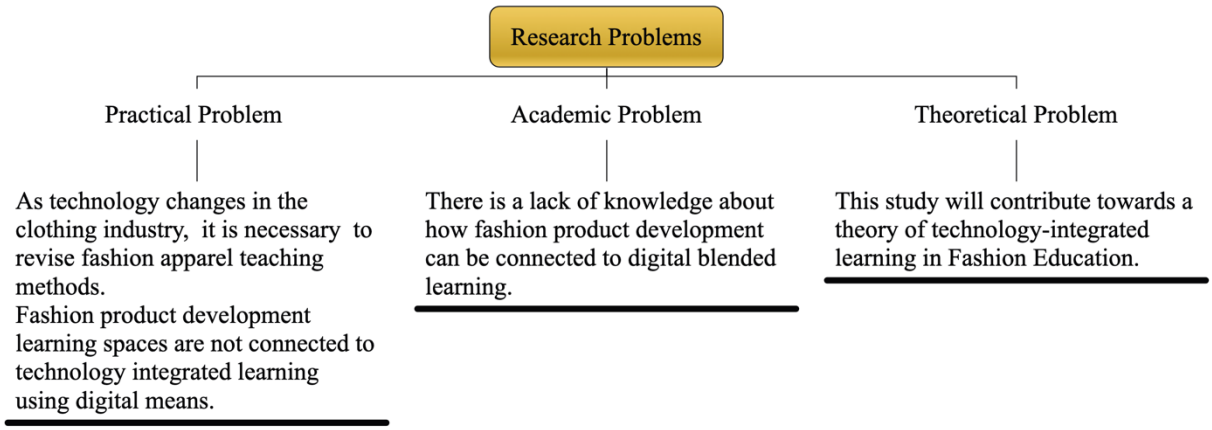


Figure 4.2 Research problems

In the report of participants' responses, pseudonyms are used instead of real names to keep their identities confidential. For convenience, a key to the codes associated with participants and associated responses is repeated here from Chapter 3, as follows:

- Lecturers – L1 and L2;
- Alumni – A1 to A6;
- Fashion designer – FD;
- Pattern designers – PD; and
- Project manager – PM.

4.2 Section 1: The Digital Technologies Used in the UoT and Apparel Industry (RQ1)

Two probing questions influenced the set of questions used to answer Research Question One, and these questions were asked of both UoT participants and apparel industry practitioners. The probing questions were:

1) What digital technologies do you use? The objective for asking the question was "to determine a mix of traditional and current technology"; and
2) How have these technologies changed over the past five years? The objective was to understand the trajectory of innovation with technology. The main research areas are highlighted in Figure.4.3 below.

4.3 Discussion of the Research Findings

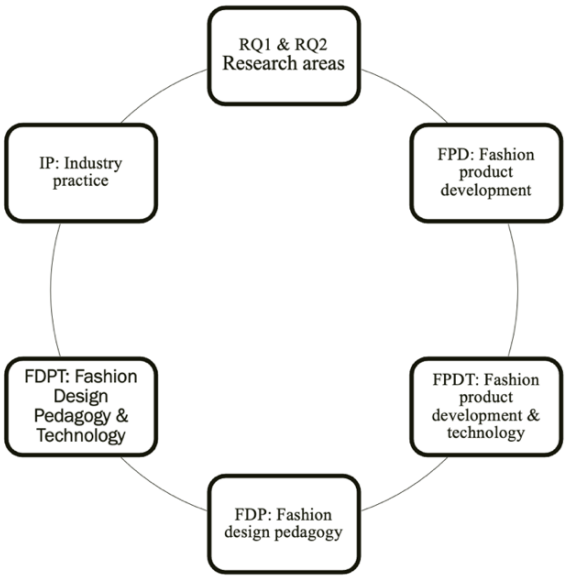


Figure 4.3: Outline of the main research areas, (RQ1 and RQ2)

This section presents an overview of the key findings related to the following main areas of investigation, FPD: Fashion product development; FPDT: Fashion product development and technology; FDP: Fashion design pedagogy; FDPT: Fashion design pedagogy & technology; and IP:

Industry practice, and the emerging themes were: 1) body measurement techniques; 2) the use of digital product development systems (including pattern making, grading, and marker making); 3) digital technologies used in garment construction. construction. Figure.4.3 provides a visual outline of the main research areas.

The questions posed focused on methods of body measurement that fall between the traditional tape measure and 3D body scanning. It was important to know the digital technologies used in product development in order to understand the product development systems used to construct garments for import and export of garment patterns. It was also important to know the systems used to confirm garment fit, sample garments, and produce prototypes. Figure 4.4 shows the probing questions, themes, and questions of the study.

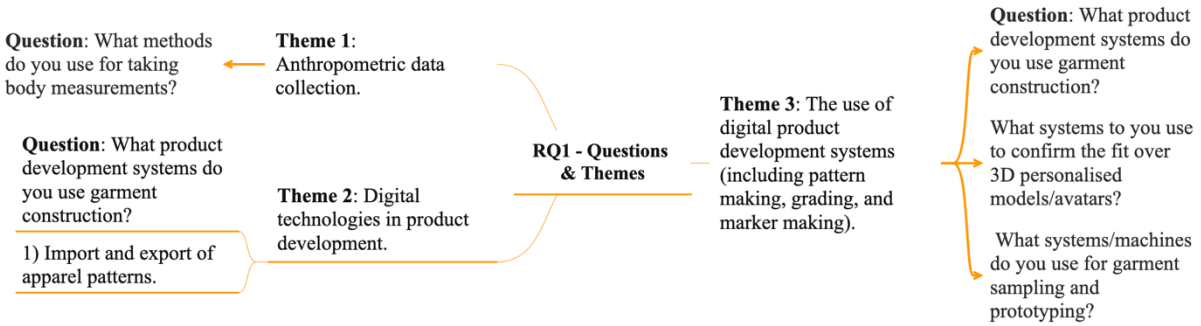


Figure 4.4: Research Question One – probing questions, themes, and interview questions

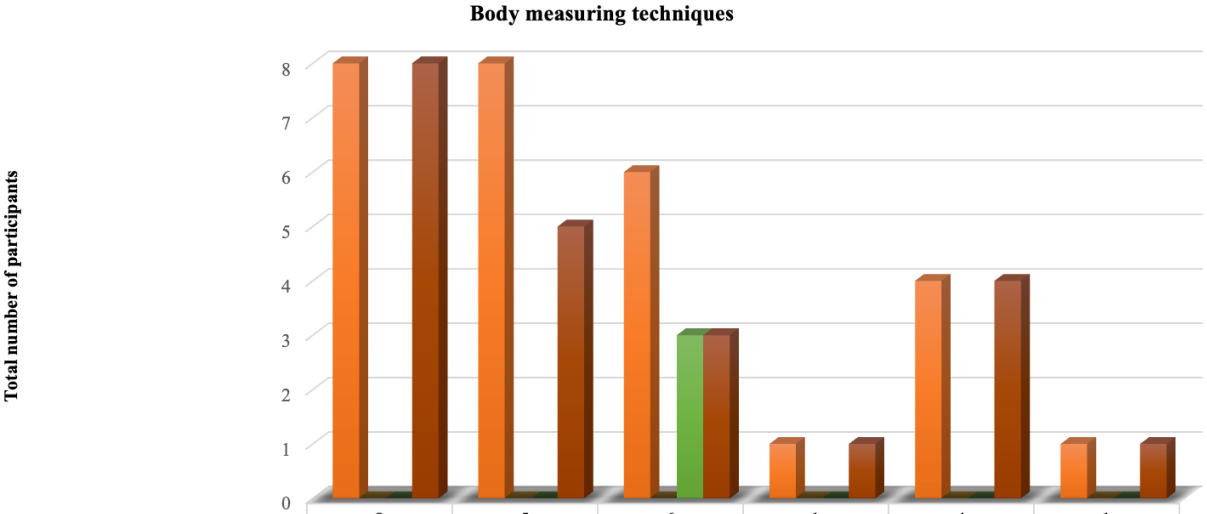
During data analysis, I carefully evaluated the responses provided and drew conclusions and recommendations from the data collected. This data helped to illuminate differences within the apparel industry and participating universities of technology (UoTs), particularly with regard to digital technology use and familiarity. As a result, gaps were uncovered, which are discussed in more detail in the following chapter of this thesis. The subsequent sections present the guiding themes of the study and the associated codes to convey the insights gained from the data collected.

4.4 Technological Advances in Fashion Product Development

Under the research area of "Fashion Product Development and Technology", the following discussion topics emerged: 1) Anthropometric data-body measurement techniques; 2) Use of digital technologies in the stages of product development; and finally, 3) Sewing machines and use of digital technologies in garment construction. It should be noted that this study does not draw statistical conclusions. However, charts and numerical data are used to visually represent the participants' responses, which facilitates the drawing of conclusions.

The first question addressed participants' preferred methods of body measurement, distinguishing between conventional methods using tape measures and modern digital methods using 3D body scanning technologies. The specific question asked, "What methods do you use to take your body measurements, choosing between a traditional tape measure and a 3D body scanner?" Participant responses were systematically categorized, with "yes" and "no" responses assigned to the traditional tape measure and the same categorization assigned to 3D body scanning technologies. The responses were then logged to draw conclusions.

Figure 4.6 provides a summary of responses from all participants, including students from UoT1 and UoT2. It also illustrates the differences between universities and apparel industry professionals in terms of body measurement techniques. In the bar chart, the colour "green" is used to indicate participants with experience using a 3D body scanner.



	8 Students	5 Lecturers	6 Alumni	1 Fashion designers	4 Pattern designers	1 Project managers
Traditional tape measure (Yes)	8	8	6	1	4	1
Traditional tape measure (No)	0	0	0	0	0	0
3D Body scanning technology (Yes)	0	0	3	0	0	0
3D Body scanning technology (No)	8	5	3	1	4	1

Figure 4.5: Theme One: Fashion product development-body measurement techniques

In this study, it was found that the majority of participants primarily relied on traditional body measurement methods, and most of the participants have not made use of the 3D body scanning technology. Notably, 12% of alumni surveyed had experience with both tape measure and 3D body scanning methods during their studies. In the bar chart, the colour "green" is used to indicate participants with experience using a 3D body scanner.

It is worth noting that, the results show that some alumni study participants had the opportunity to perform 3D body scans during their studies, while apparel industry participants did not have this

experience, highlighting the costs associated with the technology [A3]. This highlights a potential gap in access to and familiarity with 3D body scanning systems between educational institutions and industry professionals.

In discussions with alumni who had been exposed to 3D body scanning systems, their responses revealed a wide range of experiences and perspectives. For example, Nesi [A1], who currently works as a buyer's assistant in a retail company, found the 3D body scanning system fascinating. She emphasized the speed and convenience of the system and expressed satisfaction with its accuracy. In contrast, Oko who now works as a fabric technologist, expressed reservations about the accuracy of 3D body scanners. He based his scepticism on his previous experience as a student. However, he expressed confidence that newer models could be better. These differences in participants' views suggest that they had different experiences with 3D body scanners despite attending the same university and being exposed to the same technology.

The different perspectives and experiences of the participants show that there is no single approach to body measurement methods and that the traditional tape measure is still the most commonly used tool. Regarding the availability and use of 3D body scanning systems, factors such as cost, accuracy concerns, and accessibility play an important role in users' perceptions of 3D body scanning technology.

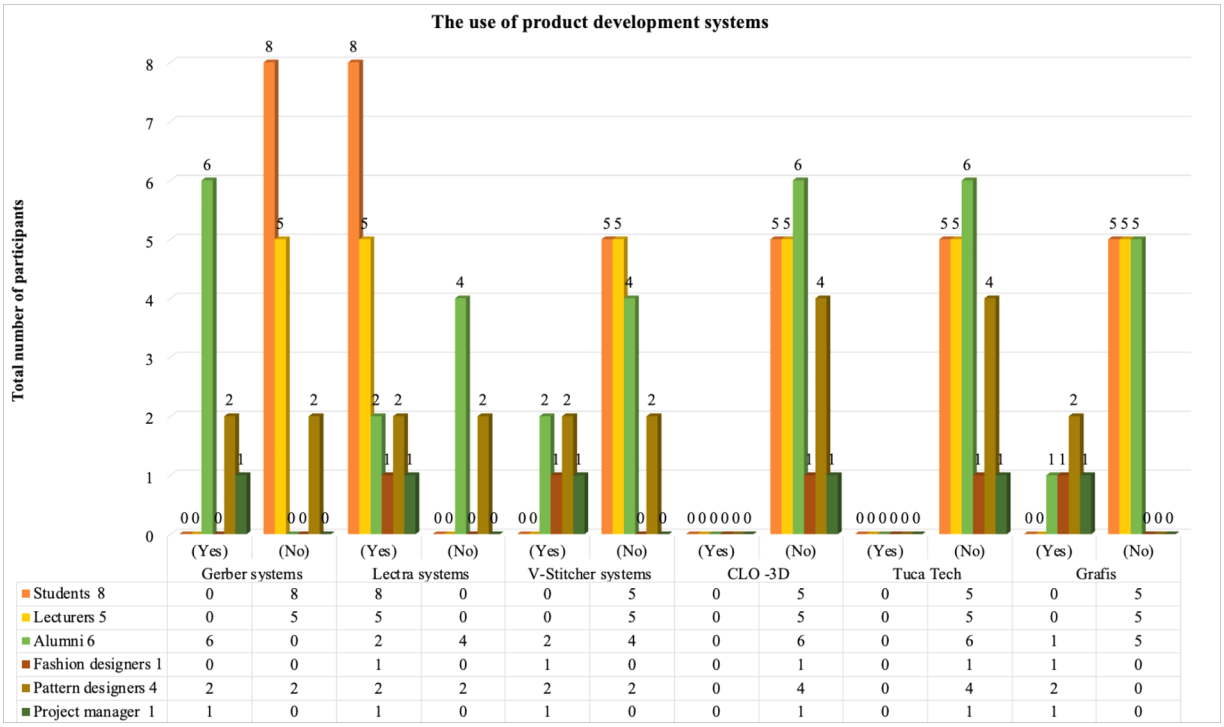
Despite highlighted advantages such as speed and convenience, issues related to cost and availability, as well as concerns about accuracy, emerge as problem areas that could stand in the way of widespread adoption of the 3D body scanning technology. This study notes that some UoT have access to 3D body scanning technology and not the participating apparel manufacturing companies. The study identifies gaps between the apparel industry and participating universities, as the apparel industry appears to be having trouble adopting the technology.

As result of this identified gap, this study highlights the need for further research into the adoption and effectiveness of 3D scanning technology in the fashion industry. It also highlights that future studies should aim to clarify these issues and provide insights into how 3D body scanning can be used effectively in both fashion education and the apparel industry.

4.5 Fashion Product Development and Technology: Digital Technology Use in Product Development Stages

In the investigation of digital product development systems, particularly pattern making, grading, and marker-making systems, the study revealed a landscape of advances and limitations. Participants were asked, "What digital technologies do you use for product development?" This question aimed to identify the machines and digital technologies used to import and export apparel patterns and their digital

visualization. As shown in Figure 4.6, the data collected shows how differently these digital systems are used by the two participating sectors and individuals.



	Gerber systems		Lectra systems		V-Stitcher systems		CLO -3D		Tuca Tech		Grafis	
	(Yes)	(No)	(Yes)	(No)	(Yes)	(No)	(Yes)	(No)	(Yes)	(No)	(Yes)	(No)
Students 8	0	8	8	0	0	5	0	5	0	5	0	5
Lecturers 5	0	5	5	0	0	5	0	5	0	5	0	5
Alumni 6	6	0	2	4	2	4	0	6	0	6	1	5
Fashion designers 1	0	0	1	0	1	0	0	1	0	1	1	0
Pattern designers 4	2	2	2	2	2	2	0	4	0	4	2	0
Project manager 1	1	0	1	0	1	0	0	1	0	1	1	0

Figure 4.6: Use of product development digital technologies

Among the six available digital systems for garment production, including Gerber; Lectra; V-Stitcher; CLO 3D; Tuca Tech; and Grafis, which are mainly used for pattern grading, the results show that despite the availability of the other systems, the Lectra systems used for pattern grading are the preferred systems, especially by the participating UoTs. This could be due to the fact that I understand that the Gerber systems are being phased out by the service provider, so those who attended training in 2022 were trained on the Lectra systems.

In a focus group discussion with UoT1 students, it became clear that UoT1 has limitations in practice. Students highlighted that, digital pattern systems such as Lectra are taught theoretically but not used practically due to hardware issues, training costs, and expired licenses. This limitation hinders students' practical experience with these systems. Lecturers highlighted this issue, attributing it to the lack of resources and the non-renewal of system licenses in 2022. This has resulted in current students not receiving digital skills training, unlike previous students, Akha [L1] and Stella [L2].

In contrast, five lecturers from another participating University of Technology (UoT2) who participated in a focus group interview mentioned that students at their institution are introduced to Lectra systems as part of their curriculum to align their education with industry practices. However, it was highlighted

that the focus is primarily on pattern making systems, with less emphasis on garment manufacturing systems suitable for sampling, visualisation, and prototyping. This highlights a gap in garment construction digital learning.

4.5.1 Garment construction

The collected data from the interviews highlights the importance of using digital systems to confirm fit through personalized 3D avatars, as it speeds up the production process and eliminates phases such as prototyping. Anneline [PM], a digital project manager, confirmed the presence and use of systems such as Grafis for pattern making and V-Stitcher for 3D visualization, which help in viewing garments digitally and reduce the need for prototyping and fitting [PM]. This view was confirmed by two pattern designers who participated in the confirmation interviews, as well as a fashion designer, who is now working in the industry as a garment technologist.

The data collected indicate that these systems are not accessible across the participating educational institutions. Ruth [A6], an independent fashion designer and quality manager, shared her experience as a fashion design student and emphasized that "*she was involved with 3D systems primarily in pattern making but not in sewing or production"*(2022). For example, Grafis systems, which are commonly used for pattern grading, are not used in the two participating fashion schools.

Among alumni, 2 out of 6 confirmed the use of these systems, while among the participating pattern designers, 2 out of 4 and the project manager responded positively. The V-Stitcher system, used for pattern making and visualization, also received similar responses to the Grafis systems. The study shows that availability varies among industry and UoT participants, with most participants citing cost as a barrier to adopting digital product development technologies. While universities lag behind in the adoption of 3D systems, practitioners like Ruth [A6] *value digital tools but affirm that the integration of digital pattern making and related skills should complement, not replace, traditional methods.*

This approach ensures well-trained professionals who are proficient in both the manual and digital aspects of garment design and production [A6]. She further stated that it provides students with a comprehensive understanding of garment construction, which is critical to understanding how garments are assembled. Nonetheless, she acknowledged the environmental benefits of 3D systems that reduce material waste because garments can be viewed and modified on the computer.

These findings underscore the importance of considering the interaction between human actors (students, faculty, and industry professionals) and non-human actors (digital systems and resources) when implementing technologies. The data underscore the need for educational institutions to bridge the gap between theory and practical experience with digital systems and to align with industry practices.

In summary, this study underscores the continued value of using both traditional and digital methods, with digital technology offering efficiencies. Based on the collected data from the apparel industry participants, it is evident that the adoption of digital systems in the apparel industry is dependent on the preferences of individual companies, with a focus on pattern making rather than garment construction. The data suggest a complex network of human and non-human factors influencing technology adoption, considering cost, accessibility, and hands-on educational experience. The third theme focuses on the type of sewing machines used to provide insight into the machines used and their stage of development.

4.5.2 Fashion product development and technology – sewing machines and digital technology use in garment construction

The study explored the product development systems used in the sectors involved and highlighted the prevailing technologies and the reasons for their use. One of the machines of interest in this study was the lockstitch machine. It is a key component in the garment manufacturing process and sews two pieces of fabric together to create a seam. In the past, sewing machines were operated by hand, a labour-intensive and time-consuming process to which there was no alternative.

Figure 4.7 shows an old model of a Singer sewing machine that was commonly used in earlier times. Over the years, these machines have evolved with advances in the apparel industry. As the apparel industry grew, there was a need for computerised sewing machines to speed up the process. According to Smith (2009), a sewing machine quickly speed up the any job, whether it be a quick repair or a huge sewing project, and it quickly speed up the any job, whether it be a quick repair or a huge sewing project.

Figure 4.7: A sample of a vintage sewing machine (Pinterest.com)

Most sewing machines today are aided by computer technology, which enhances stitch quality and ease of use (Smith, 2009). Figure 4.8 provides an image of a modern computerised lockstitch machine.

Figure 4.8: A sample of a modern computerised/digital lockstitch sewing machine (Pinterest.com)

In this section, I needed to examine the kind of sewing machine used in both the apparel industry and UoTs, exploring the types of sewing machines used. The question asked was the same as the above, "What digital technologies do you use for product development?" and the responses are outlined in Figure 4.9. The figure illustrates the use of computerized lockstitch sewing machines in both UoTs and the apparel industry. The orange line indicates the "No" responses with blue line indicating the "Yes" responses to the use of computerised lockstitch machines.

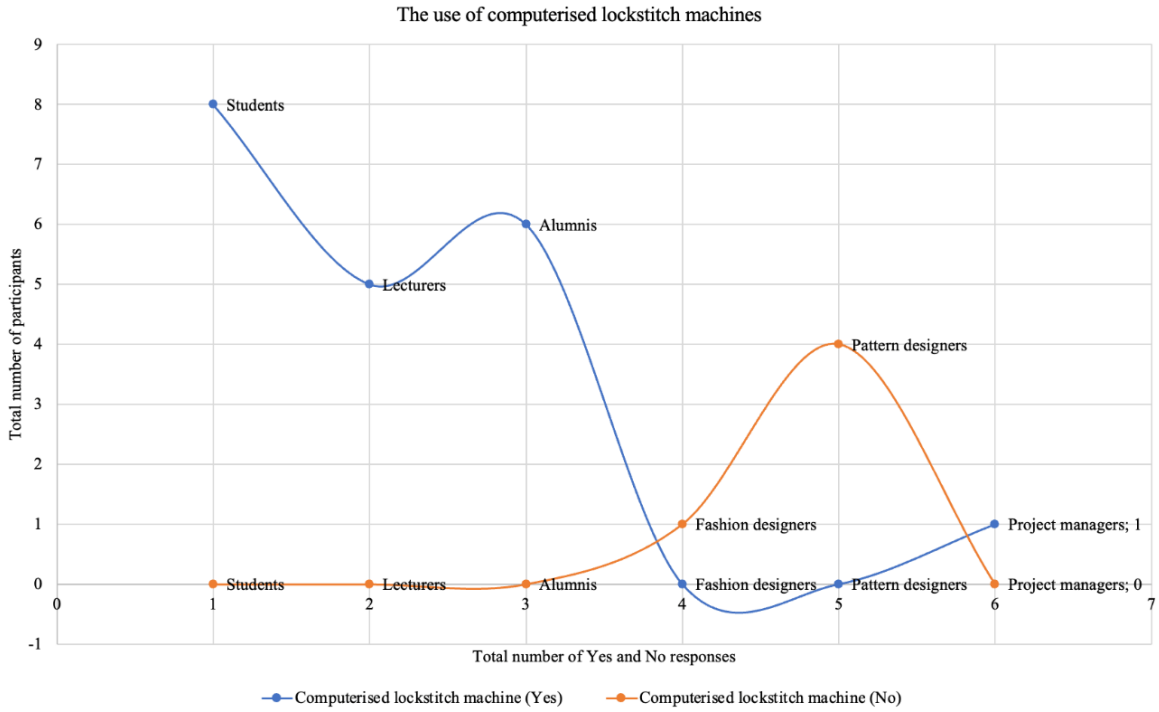
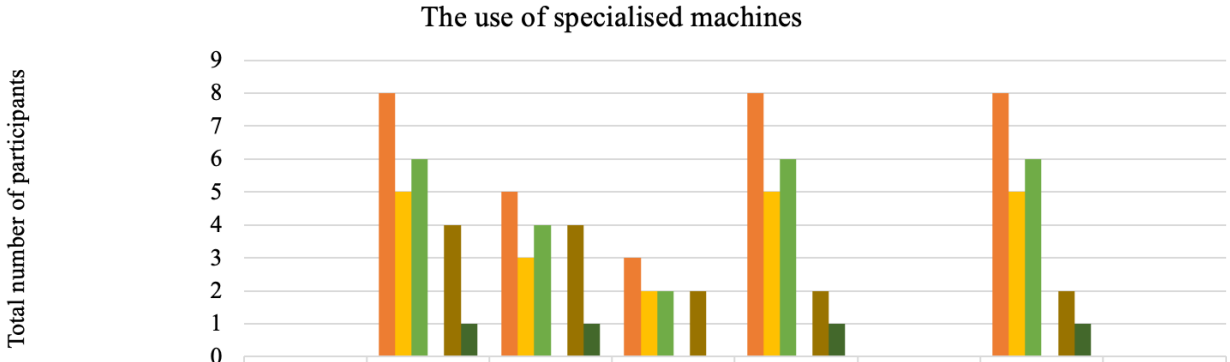


Figure 4.9: The use of computerised lockstitch machines

The results show that most participants have experience with computerized lockstitch machines, including those in the apparel industry. However, there are exceptions among those who aren't directly involved in garment production, such as the fashion designer and the two pattern designers, who have no experience using sewing machines. Although the participating project manager and the other two pattern designers and alumni aren't primarily garment sample machinists in their current roles, they could provide insight into this area based on their previous experiences. Despite their different roles in the industry, all participants are involved in the production process, so they can provide their first-hand insights. This suggests that both the industry and fashion universities use computerised machines to a similar extent.

4.5.3 Specialised sewing machines

Generally, in product development, there are various machines that perform specific sewing functions, such as sewing jet pockets, buttons, and buttonholes. Specialized machines, like ultrasonic machines, are used for specific types of garments and fabrics. This study examined the use of such specialized machines. Figure 4.10 illustrates that while specialized machinery exists and is used in both sectors, advanced equipment such as ultrasonic machines is not yet widely used in apparel manufacturing and UoTs.



	An ultrasonic welding machine		An automatic jet pocket machine		An automatic button sewing machine		An automatic buttonhole sewing machine	
	(Yes)	(No)	(Yes)	(No)	(Yes)	(No)	(Yes)	(No)
Students 8	0	8	5	3	8	0	8	0
Lecturers 5	0	5	3	2	5	0	5	0
Alumni 6	0	6	4	2	6	0	6	0
Fashion designers 1	0	0	0	0	0	0	0	0
Pattern designers 4	0	4	4	2	2	0	2	0
Project managers 1	0	1	1	0	1	0	1	0

Figure 4.10: Responses towards the use of specialised sewing machines

The study highlights that the evolving technological landscape offers the opportunity to speed up processes that were once done manually, however, these technologies are not widely used. Pattern designers Faeeze [PD1] and Janet [PD2] who participated in a confirmatory interview, emphasised the need for students to stay current with methods and systems relevant to the industry. Based on the data collected, it is imperative that students are familiar with current practices in the apparel industry.

Only specialised machinery is available, and students do not have access to digital garment construction systems; everything is done in the traditional way. Students have not had any experience of the digital systems that are available for use in garment sampling, prototyping, and visualisation systems. Students from UoT1 recognised the need to keep up with technology to avoid being at a disadvantage (UoT1 students). This opinion was also expressed by fashion designer Lizelle [FD], who pointed out the limitations of her education and emphasized that she was familiar with different design technologies but not with pattern and garment technologies. Due to the lack of digitalization during her education, she was limited to traditional methods, which she described as outdated. The UoT2 students who participated in a focus group interview pointed out that independent designers often face challenges due to the high licensing costs of digital systems.

4.6 Summary of Research Question One

This section of the study presents the findings that relates to the Research Question One, *what is the relationship between current design technology and fashion product development?* Additionally, this

research provides insights into the relationship between current technologies and fashion product development. It shows that access to 3D body scanning systems is not widespread among participating UoTs educational institutions and industry professionals due to cost constraints, highlighting the need for further research to address this disparity.

One notable finding is the experience of graduates who were exposed to 3D body scanning systems during their studies. While some embraced the technology for its speed and accuracy, others had reservations, highlighting the complexity of its application and the impact of factors such as cost and availability on their opinions. This underscores the presence of 3D body scanning technology at selected universities.

In addition, discrepancies in the use of digital product development systems between educational institutions and industry became evident. Industry professionals emphasized the efficiency and cost-effectiveness of digital pattern making, while lecturers reported limitations in hands-on student training, often opting for theoretical resources due to issues such as damaged hardware and expired licenses. This underscores the importance of aligning fashion education with industry practices and ensuring that students receive hands-on training in digital skills.

The study also highlights the role of digital technology in the future of the apparel industry, as it offers efficiency gains and sustainability benefits. However, the significant cost barrier must be carefully considered. It was also noted that 3D garment visualization and fitting systems are not widely used in educational institutions, while industry professionals are familiar with them and would like to use them. Participants like Ruth [A6] stressed the importance of integrating digital tools into fashion education while maintaining manual pattern making to give students a comprehensive understanding of garment construction.

In summary, this research contributes to our understanding of the evolving landscape of design technology in fashion product development. It underscores the need for ongoing research to bridge the gap between education and industry, promote digital literacy, and prepare future professionals for the dynamic fashion industry.

4.7 Section 2: Adoption and Application of Digital Technologies (RQ2)

This section presents the research findings related to Research Question Two (Appendix F), which addresses the adoption and application of digital technologies by both the UoTs and the apparel industry. The probing questions that guided the research revolve around the questions, “How would you teach differently if you were a lecturer compared to the way you were taught?” and “What impact have technological advances had on teaching and learning?”

4.7.1 Introduction to Section 2

In this section I provide an overview of the findings related to the following main research areas and the questions posed: FPD: fashion product development; FPDT: fashion product development and technology; FDP: fashion design pedagogy; and IP: Industry Practice.

4.7.2 Background of anthropometric data collection – body measurements

Anthropometry deals with the measurement of the human body. Artists, scientists, anthropometrics, and tailors have accurately measured the human body using traditional tools such as tape measures, gaining centuries of experience. However, since the 1980s, research in 3D scanning technologies has rapidly evolved and gained increasing acceptance, from research projects to commercial 3D measurement of custom apparel and prosthetic and ergonomic devices for the body Fashion design software such as 3D body scanners, computer-aided design applications (CAD), and 3D software are available worldwide, (Taylor & Unver, 2005). Participants' views on the use and benefits of the 3D scanner were explored and are presented in Figure 4.12 diagram below.

4.8 Fashion Design Pedagogy: The Use of Body Measuring Techniques

In this section of the study, the initial question focused on the preferred methods of body measurement, specifically asking, *what are the critical body measurement techniques that should be included in the curriculum to better equip students for the industry?* This question aimed to gather participants' insights on the methods they believe should be part of the curriculum.

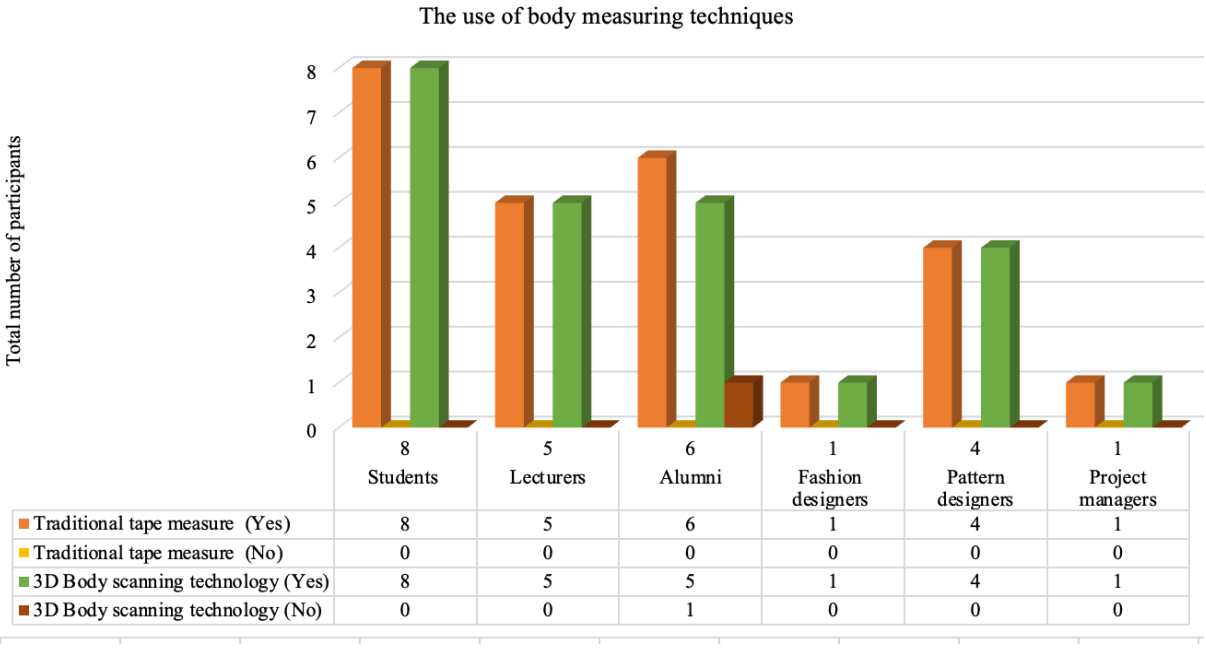


Figure 4.11: Use of body measuring techniques: fashion design pedagogy

As shown in Figure 4.11, the results indicate that most participants recognize the importance of including both "traditional and digital" body measurement methods in the curriculum. They view this as a critical step in establishing the field. However, one alumna highlighted in "*brown*" in Figure. 4.12 bar chart, expressed hesitation about the inclusion of 3D body scanning methods in the curriculum, citing concerns about accuracy based on personal experiences as a student. During the interview, this participant also noted that while there may have been improvements since his student days, he was strongly in favour of staying with traditional methods.

Other participants, however, emphasized that 3D body scanning is an important first step in garment production. It enables the precise collection of anthropometric data, which can then be used to personalize 3D body models in software libraries. Consequently, they support the integration of 3D body scanning into the fashion product development curriculum and emphasize the need to improve access to this technology for students and practitioners.

These findings underscore the importance of providing students with access to 3D body scanning technology to prepare them for careers in the apparel industry and its evolving landscape, a viewpoint strongly supported by industry representatives. They emphasize the value of introducing students to 3D body scanning, as it enhances their readiness for the industry and its future developments.

4.9 Fashion Design Pedagogy and Technology – The Importance of Integrating Digital Technologies

In answering the second research question, which relates to the impact of technological change on teaching and learning in fashion product development, it is clear that the integration of digital technologies into the fashion education curriculum is of paramount importance. When asked about the importance of integrating digital technologies into fashion product development, all participants were unanimously in favour of this integration, as shown in Figure 4.12.

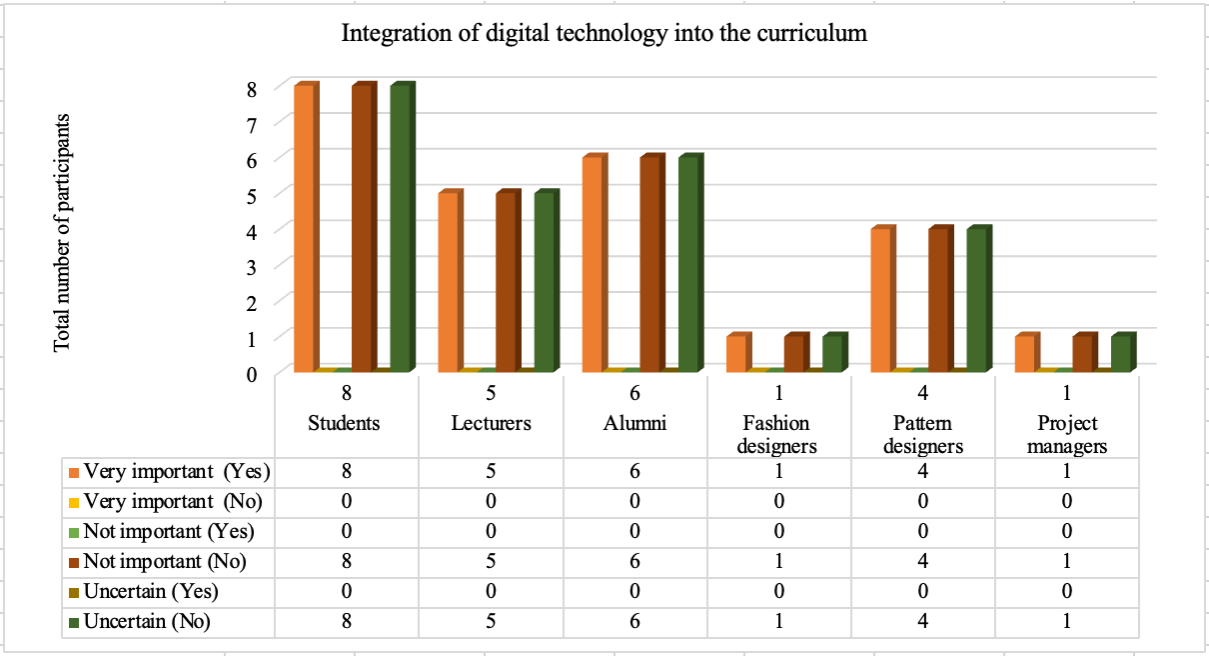


Figure 4.12: Integrating digital technologies into the curriculum

From the interviews conducted, both fashion design students and the lecturers agree on the essential role of digital technologies in fashion product development, and participants from the apparel industry also agree on the indispensability of digital technologies in fashion product development. They emphasize how digital technologies accelerate and improve product development and contribute to greater creativity and innovation.

However, it is important to point out a significant challenge that was uncovered in the interviews: Many students emphasized that they lack a solid foundation in digital technologies, which can prevent them from effectively using the software and hardware required for digital product development. Further complicating matters is the limited resources available at UoT1 to provide a comprehensive education in digital technology. The study recommends the need for students to be exposed to digital technologies. Despite these obstacles, the insights gained in the interviews underscore the undeniable need to incorporate digital technologies into fashion product development education and emphasize their central role in shaping the future landscape of the fashion industry.

4.9.1 Conventional product development: role of conventional skills and background knowledge (UoTs)

In this study, it was important to evaluate the importance of conventional pattern making knowledge before the introduction of digital pattern making. This research theme focuses on the importance of conventional skills training as a foundation for effective use of digital tools and technologies in product development. As a result, participants were asked to share their experiences and views on the importance

of conventional pattern making knowledge in the context of digital software in the apparel industry. By asking this question, the interest was on gathering the views of the participants on whether the UoTs must stop teaching the conventional methods or not.

The feedback is summarized in Figure.4.14 below. In response to the question, Ruth [A6], a fashion designer at a mid-sized company, expressed the following: "*Suppliers today use both manual and digital methods of pattern making, therefore, both methods are valuable and offer unique opportunities. The reason is that manual patterns offer insights that are not directly applicable to electronic patterns. Both have their advantages and disadvantages, and both are important, especially in terms of design development."* [A6, 2022].

In contrast, Anneline [PM] noted that familiarity with conventional methods can hinder older workers' adaptation to new practices such as 3D software as it requires a shift in thinking. This resistance can be a barrier to successful implementation. She went on to say that, on the other hand, young pattern designers without experience in conventional pattern making adapt more easily to digital pattern making [PM]. This illustrates different points of view about the subject in question.

Despite differing opinions, participants agree that conventional pattern knowledge is important as a foundation for exploring digital pattern making. Yushaa [PD3] and John [PD4] work as digital pattern makers, but had no formal training in pattern making, but learned from peers and later received formal training in conventional pattern making. John said of his background, *"I have no training as a pattern maker. I ran the cutting department and got experience there"* [PD4, 2023]. Patterns designers at mid-sized companies believe that pattern making requires a traditional pattern making background and is necessary for digital pattern making ([PD1], [PD2]). They emphasize the importance of proper conventional pattern training.

The results highlight the multi-layered relationship between conventional and digital pattern making, highlighting the need for a solid foundation in traditional methods to survive in the rapidly evolving world of digital pattern making within the apparel industry.

4.9.2 Fashion design pedagogy and technology – skills development (UoT)

In this study, gathering the level of study in which the participants were first introduced to the digital technologies was of importance. Research results show that students' experiences with integrating digital technologies into fashion education vary. Some graduate students learned about digital systems for pattern making in their first year together with the traditional methods of pattern making and garment construction, while others did not begin until their second year, and others in third year (Figure.4.13).

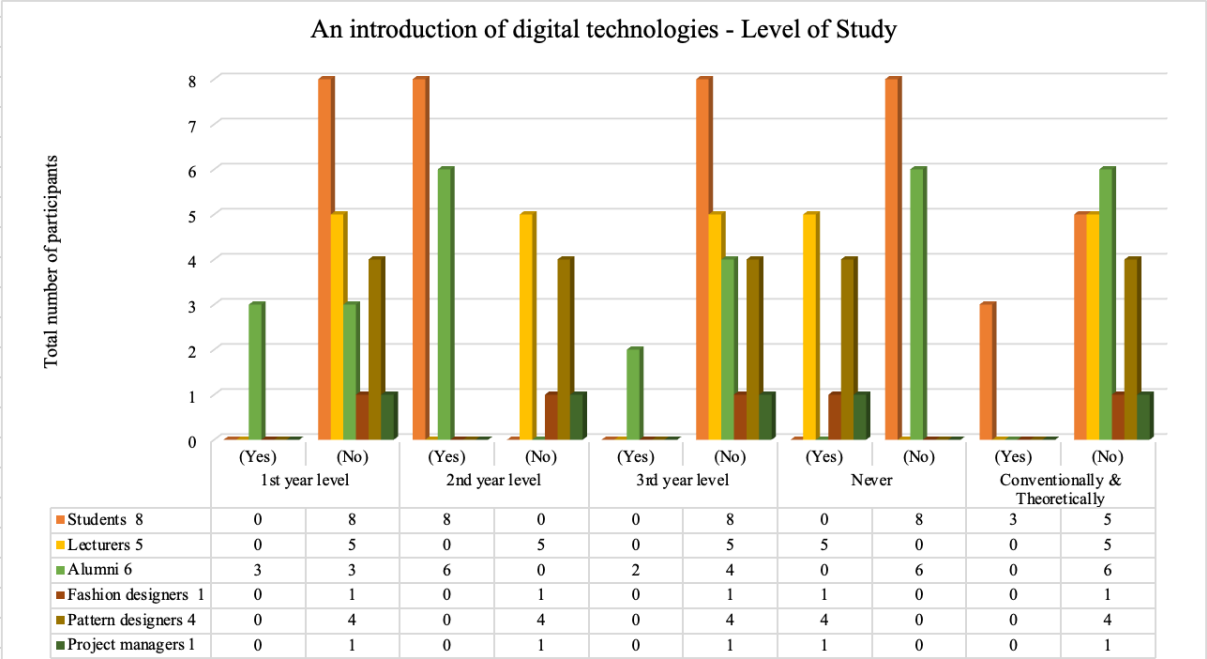


Figure 4.13: Introduction to digital technologies at the UoT

Those who began in the first year emphasized the importance of understanding the principles of garment making before engaging with digital systems, as this provided a solid foundation for later learning. The UoT1 students noted that they only gained the traditional theoretical knowledge of digital pattern making, which highlights the challenge of teaching practical topics exclusively in theory and hence the indication of "Yes" in the diagram, which is a disadvantage to them.

Lecturers also experienced the use of digital technologies in their training while in the job. Unlike the students, they did not receive digital training during their studies, but became familiar with digital tools only in their professional careers. UoT 2 lecturers, for example, had to teach the system themselves after only five days of training and faced the problem of processing an overwhelming amount of information. Similarly, Lizelle [FD] was proficient in digital technology for fashion design, such as Photoshop, and Illustrator, but had no knowledge of digital pattern and garment construction.

UoT 2 lecturers mentioned that learning digital technologies used to be part of the curriculum, but budget constraints prevented them from attending training. The curriculum has been adjusted to allow knowledge of digital technologies to be taught without extensive training, as less time was allocated for this in the timetable. However, due to the increasing importance of digital technologies in the industry, they were formally included in the curriculum.

The six participating alumni indicated that they have had training in digital technologies and those who did not learn digital technologies during their studies confirmed their importance to their professional

lives. Although not all graduates actively use these systems, the basic knowledge acquired during their studies is beneficial, especially for roles such as apparel technologists and independent designers.

In conversation with the industry practitioners, participants were asked the following leading question: "How has the use of technology changed the way fashion products are developed?" Follow up discussion led to responses to a question exploring the level of study in which the participants first experienced digital technologies. Figure 4.14 shows some participants responded "never" indicating they had not been introduced to digital technologies during their studies. They highlighted that, before embarking on the pattern design journey, they did not have any sort of formal training in digital technologies, some received training when digital technologies were introduced in their professional environment. This includes, pattern designers, fashion designer, as well as the project manager. This could be because digital technologies were not part of the curriculum when they were students. Those who had worked with traditional pattern making found it challenging at first, while those who had little experience pattern making found digital pattern making less challenging.

The study shows that the integration of digital technologies into fashion education presents challenges and opportunities. The evolving technology landscape requires an adaptable curriculum to provide students with modern industry skills. The experiences of students, lecturers, and industry experts like Lizelle [FD] underscore the importance of adapting education to technological advancements.

4.9.3 Skills development: apparel industry and conventional skills as background

In order to effectively collect data, gaining insight into the traditional skills of apparel industry professionals before embarking on integrated product development processes involving digital technology was critical. This research was motivated by the need to determine participants' views on the importance of conventional skills when venturing into the realm of digital technologies as part of this study. Their views were to help make recommendations about whether or not conventional skills should be retained in the fashion curriculum.

The question asked revolved around, *as an industry practitioner or a fashion designer lecturer, have you received any formal training or education in conventional pattern making*? This question involved lecturers, and industry practitioners, only. Students were not involved as they were still in the course, hence their responses appear as nil. The participants responses are presented in Figure 4.14.

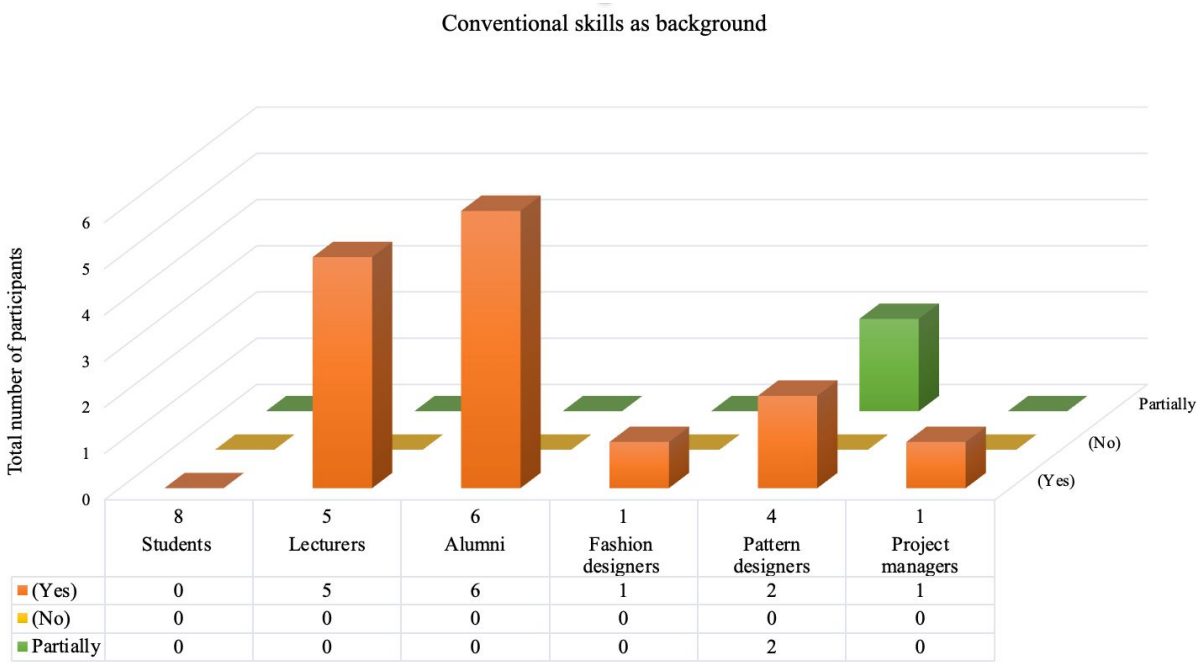


Figure 4.14: Conventional skills as background (lecturers and industry practitioners)

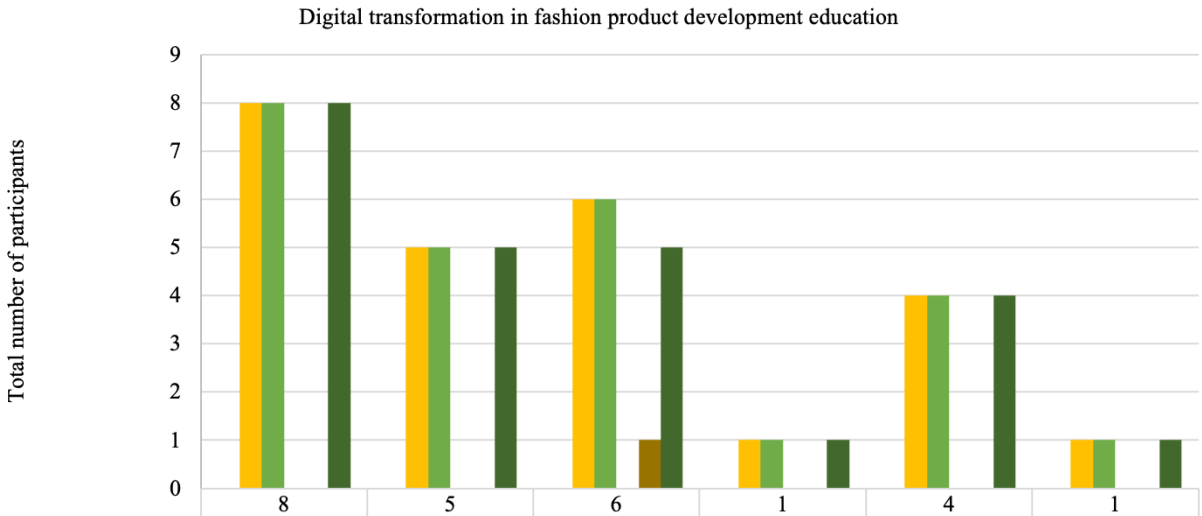
Most participants confirmed that they had received training in conventional skills before venturing into the realm of digital expertise. In contrast, pattern designers like John [PD4] and Yushaa [PD3] shared that they had no prior experience with traditional methods. They began their pattern making journey informally by learning from their peers, which presented challenges such as a limited understanding of pattern terminology and techniques as they relied on their peers for guidance. Both pattern designers indicated that while they didn't have major problems with digital systems, some basic knowledge of conventional methods would have been beneficial.

In the telephone interviews with John [PD4] and Yushaa [PD3], they mentioned that they eventually sought formal training in traditional pattern making after gaining work experience. When asked about their initial difficulties without formal training, John explained, "*I can't say I didn't face any challenges. The first two months were quite tough, but luckily, we had an experienced pattern in the company, so I was able to get advice from him. When I started working with him, it happened to be his last two months with our company before he moved on to another"* [PD4, 2023]. This shows that a background in conventional techniques is important because it serves as a foundation for developing digital skills.

4.9.4 Digital transformation in fashion product development: paradigm shifts for UoTs

Knowledge and technical skills are two very important components in the fashion industry. Producing beautiful and high-quality designs requires precise pattern making skills and intricate sewing, the lack of which has led to ideas being stolen and imitated by other designers (Maryamet al., 2019). Given these

considerations, the extent to which digital technology should be incorporated into fashion education was critical. Therefore, participants' viewpoints in this regard were collected and presented in Figure 4.15.



	8 Students	5 Lecturers	6 Alumni	1 Fashion designers	4 Pattern designers	1 Project managers
50% (Yes)	0	0	0	0	0	0
50% (No)	8	5	6	1	4	1
50% / 50% (Yes)	8	5	6	1	4	1
50% / 50% (No)	0	0	0	0	0	0
100% (Yes)	0	0	1	0	0	0
100% (No)	8	5	5	1	4	1

Figure 4.15: Participants' views regarding the extent to which digital technologies need to be integrated into product development education

In this section of the study, "Digital Transformation in fashion product development education," the extent to which digital technology should be integrated into fashion education was explored. In the interviews with all participants, the following question was asked: "To what extent should digital technology be integrated into fashion product development education?" This question served as the basis for the investigation into how UoTs in fashion can best equip students with the knowledge and skills they need to succeed in the digital age. Through insightful dialogue and sharing of experiences, I aim to uncover innovative approaches that will empower the next generation of fashion professionals to lead the industry into a digitally enhanced future.

The majority of participants recommended a balanced approach and favoured a curriculum consisting of 50% conventional methods and 50% digital technologies. However, there were also diverse opinions, with an alumnus and students from UoT1 suggesting a gradual introduction of digital technology alongside traditional methods in the first year of education stressing the importance of establishing a solid foundation in conventional product development techniques.

One student who participated in the focus group interview alluded that, *"I would prefer the first year because currently we are only introduced to technology at a secondary level. Since we have only received a theoretical introduction so far, a more in-depth look at the practical aspects in the first year would improve our understanding. That way we would not be so unsure because we would have practical experience"* in UoT 1 [S1, Student Focus Group, 2022].

This view was also expressed by an independent designer and graduate student who is also a garment technologist. She said that there needs to be a shift to digital technology and that more work needs to be done with digital pattern making or pattern design and that students need to be introduced to plotting, etc. so that they can use that in their designs. She then continued, "But I do not think CPUT (Cape Peninsula University of Technology) should give up manual pattern making" [A6]. This confirms that despite the need to familiarise students with digital technology, conventional skills remain a fundamental skill.

In essence, the collected data from interviews underscore the coexistence of digital and conventional teaching methods in fashion education. While digital technology is crucial, traditional skills remain fundamental. This holistic approach is essential to equipping the next generation of fashion professionals for a digital future in the industry.

4.9.5 Digital transformation in fashion product development: paradigm shift for apparel industry

The theme, "Digital transformation in fashion product development: paradigm shift for the apparel industry," explored the impact of digital technology on the apparel industry and the extent to which it has been adopted. Participants were asked for their views on the digitization of the industry, highlighting various facets of this transformation, including its impact, challenges, and opportunities for fashion product development.

To answer this question, Oko [A3], an alumni and textile technologist, stated that, "*not all industry players readily adopt new technologies and practices; adaptation is often. the adoption of digital systems in the South African fashion industry was delayed due to retailers' reluctance, but the COVID-19 outbreak in 2020 forced a change in this regard",* [A3, 2022). He further alluded that, "*the pandemic forced the industry to integrate digital systems, especially as retailers who had initially been hesitant had to adapt to the "new normal"*, [A3, 2022]. However, Ruth [A6, 2022] who is an independent designer and a garment technologist pointed out that, "*despite technological advances in garment manufacturing, traditional methods using human-operated sewing machines still dominate mass production"*.

Similarly, a study conducted by Kutnjak *et al.*, (2019) confirmed that digital transformation is not equally applicable to all industries. This was echoed by [A3, 2022] who stated that, *"the pandemic forced the industry to integrate digital systems, especially as retailers who had initially hesitated had to adapt to the "new normal"*. However, Ruth [A6] pointed out that despite technological advances in garment manufacturing, traditional methods using human-operated sewing machines still dominate mass production.

In terms of digital integration, participants were divided in their opinions. Some were in favour of incorporating digital technologies, while others expressed concerns. Oko [A3] expressed concern about the potential redundancy of skilled workers as machines could take over tasks previously performed by humans. He stressed the importance of finding a balance between digital and manual work based on previous manufacturing experience. Sihle [A4], an independent designer, echoed this sentiment, emphasizing the irreplaceable role of humans in operating machines and expressing concern about job loss in a fully digital apparel industry, Anneline [PM] argued that training pattern makers without digital skills could limit job prospects.

In summary, the collected data highlights that, digital technology (DT) is having a significant impact on the apparel industry, but participants' opinions about its integration vary. While some are in favour of digital technologies, others worry about job loss, human expertise, and the value of human relationships in the industry. It is evident that there is still resistance to change, but the pandemic has accelerated the adoption of digital systems. Therefore, it is critical for the apparel industry to find a balance between adopting digital technologies and preserving the human element that is so important to its identity. Since the focus of the study is pattern making and garment construction, it was crucial for me to investigate the extent of digital transformation in these two key stages of product development.

4.10 Digital Transformation Status in Pattern Making and Garment Construction (UoTs)

An innovative approach to learning encourages curiosity and the application of critical and experimental thinking. This approach can be aligned with industrial trends by using 3D tools such as 3D pens, simulations, and pattern making software (Maryam et al., 2019). These simulations enhance the learning of engineering design in a virtual environment. New design processes and methodologies are constantly emerging in response to evolving tools, situations, and technologies (Meyer & Norman, 2020). Views on incorporating digital technologies into product development at UoTs vary among participants due to the changing role of the professionals in the industry for which students are being prepared. Some argue that a purely digital approach is efficient because it reduces reliance on manual labour.

In conversation with Oko [A3] who now works as fabric technologist, he stressed the importance of preserving human craftsmanship citing concerns that students will learn predominantly digital skills and fears that it will limit their overall knowledge, “if you put more emphasis on digital technologies, I think we are taking a lot away from them. We are only going to give them 10% of what they should be learning." [A3].

During data collection, it was important to understand the overall innovation status of digital technologies in both pattern making and garment construction, as these are the key areas of this research, and the results show that the transformative effect of technology is evident as it revolutionizes conventional processes.

4.10.1 Pattern making

To gain insight into the integration of digital transformation pattern making within the apparel industry and at universities of technology (UoTs), the research question was, "What approaches and techniques are used in the product development process, particularly as they relate to digital transformation and pattern?"

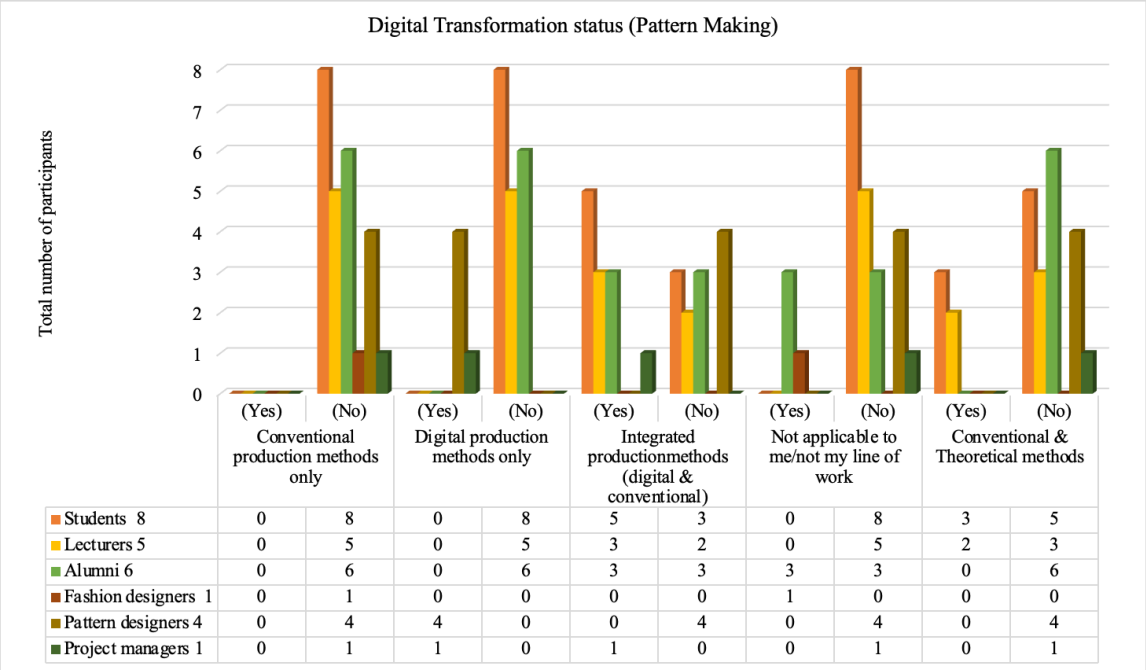


Figure 4.16: Exploration of the digital transformation in pattern making

As shown in Figure 4.16, participants were offered various response options, such as conventional production methods only, digital production methods only, integrated production methods (combining digital and conventional approaches), not applicable to their work, and including conventional and theoretical methods.

The goal was to understand the strategies and techniques used by industry practitioners to integrate digital transformation into their product development processes. It also explored the dynamics within UoT in relation to digital transformation.

The responses indicate that the apparel industry and one of the UoTs (UoT2) are using integrated product development methods in pattern making. In the conversations with industry practitioners, what came up strongly was that conventional methods are very useful when patterns are printed out and there is a need for alteration; hence, they all agreed to the importance of conventional skills as a foundation.

As for the universities, it is evident that the UoTs are in the process of introducing digital technologies into pattern making courses. However, one UoT opts for theoretical pattern making because, as highlighted earlier, lecturers are unable to train students in new systems and software due to limited staff development. Inadequate funding leads to outdated software and a lack of training. Digital technology vendors require annual training for faculty to keep their software current, but software license renewal issues further limit access. Hardware maintenance issues also affect support for lecturers and students.

In interviews with UoT1 students, they pointed to challenges with repeated manual fitting of garment patterns, which limits their practical skills and readiness for industry. Akha [L1], highlighted the rarity of factory visits due to the lack of garment factories and the impact of the COVID-19 pandemic, which has led to factory closures. Student access to factories in more advanced urban provinces has been limited since 2021 due to the ongoing tense situation.

In contrast, UoT2 appears to have better access to advanced resources, software tools, and infrastructure, face fewer constraints, and is better equipped for digital product development. This advantage may be attributed to its location, which provides access to apparel manufacturers and retailers, allowing students to interact with them. It is suggested that further research be conducted to investigate the impact of geographic location on the availability of digital technologies at UoTs.

However, as the UoT 2 lecturer pointed out, they are not immune to constraints in the adoption of digital technologies, including challenges related to curriculum allocation, which is primarily controlled by the Department of Education. "As long as we are controlled by the Department of Higher Education in terms of curriculum, we will continue to be pressed for time", UoT 2 lecturers said in a focus group interview in 2023, [UoT 2, Lecturers Focus Group].

Students and lecturers at UoT 2 said they began digital integration in 2022 after receiving training on Lectra pattern making systems. However, due to budget constraints that prevented timely training, they were not able to take full advantage of these technologies. One of the lecturers pointed out that they lacked the time and money for training that began last year at a basic level.

UoT 2 faced additional challenges related to the inclusion of computer-aided design studies to the schedule. While these were previously allowed, they were not part of the curriculum, making their inclusion difficult. The previous curriculum did not consider the digital aspect, and it was incorporated into the curriculum rather discreetly. Now it has become an official part of the curriculum, necessitating the allocation of resources for training.

Large class sizes of more than fifty students in average and the time allocated to teach digital skills were also cited as problems that hindered the smooth adoption of digital technologies. Instructors often had to teach the same material several times a day [UoT 2, Lecturers Focus Group]. To overcome these challenges, UoT 2 faculty creatively invited digital technology vendors to provide training and practice opportunities for students. They recognized the value of ongoing engagement and hands-on experience, which benefited both faculty and students significantly.

In addition, lecturers emphasized the need to train digital systems lab assistants so that students could work independently outside of their assigned class time. While not all students need to become digital experts, they should meet basic standards. Industry typically employs digital systems specialists, and it's important that students meet these basic requirements by the end of the course.

Industry participants acknowledged the efficiency of digital patterns and generally praised their benefits. The participants who indicated “not applicable to me/not my line of work” designer and alumni/buyer’s assistant did not really participate in this question because of their line of work which does not include pattern making systems.

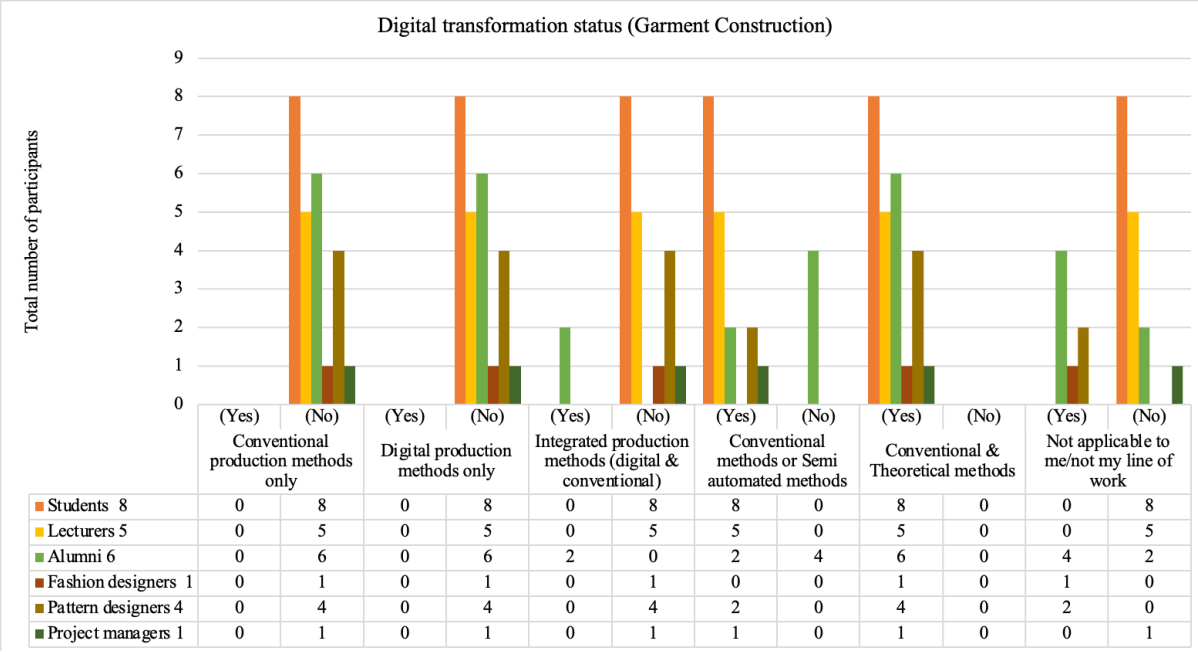
As highlighted by all participants, common barrier to the adoption of digital technologies was the initial start-up costs, which led to resource constraints, as reported by pattern makers who had difficulty with computer availability and booking, but this is something of the past. UoT 2 students expressed their willingness to enter the industry but preferred conventional garment manufacturing when starting their businesses. Limited resources, such as the cost and space required to store equipment like digital plotters and digitizers, influenced this decision. Anneline [PM], an industry practitioner, emphasized the importance of educating students in digital technology and pointed out potential infrastructure and budget issues.

In summary, this study provides valuable insights into the adoption of digital transformation in pattern making within the apparel industry and UoT. It sheds light on the challenges that higher education institutions face in providing practical experience while also highlighting the benefits and barriers associated with the adoption of digital technologies. The findings highlight the importance of balancing theory and practical application for students, particularly in the context of digital advancement.

4.10.2 Garment construction

This section of the study addresses the current state of digital transformation in the stage of garment construction, an important component of the broader apparel manufacturing industry. In order to comprehensively cover this topic, it was essential to examine the various approaches and techniques used by both the apparel industry and the collaborating UoT. The research was guided by a fundamental question, *what approaches or techniques are used by both the apparel industry and the participating UoT in the context of garment construction*?

To explore this question, participants were presented with several options to illuminate their practices in this area. These included conventional production methods, digital methods, both digital and conventional methods, semi-automated methods, and theoretical digital methods. This study seeks to shed light on the evolving landscape of garment construction and provide insight into the influence of digital technologies in the context of fashion product development education.



	Conventional production methods only		Digital production methods only		Integrated production methods (digital & conventional)		Conventional methods or Semi automated methods		Conventional & Theoretical methods		Not applicable to me/not my line of work	
	(Yes)	(No)	(Yes)	(No)	(Yes)	(No)	(Yes)	(No)	(Yes)	(No)	(Yes)	(No)
Students 8	0	8	0	8	0	8	8	0	8	0	0	8
Lecturers 5	0	5	0	5	0	5	5	0	5	0	0	5
Alumni 6	0	6	0	6	2	0	2	4	6	0	4	2
Fashion designers 1	0	1	0	1	0	1	0	0	1	0	1	0
Pattern designers 4	0	4	0	4	0	4	2	0	4	0	2	0
Project managers 1	0	1	0	1	0	1	1	0	1	0	0	1

Figure 4.17:Exploration of the digital transformation in garment construction

Feedback indicates that technology has not yet been fully integrated into aspects of apparel industry operations, such as garment construction (Figure 4.17). The data show that, in accordance with the disruptive potential attributed to technological solutions such as 3D and virtual sampling, the apparel industry has been hesitant to adopt these innovations. Originally focused on physical artefacts, the demands of the industry have evolved in the face of new materials, manufacturing techniques, powerful tools, electronic media, and virtual representations. Despite technological advances in other fields,

design, development, and production in the fashion industry rely predominantly on conventional procedures (Gill et al., 2020).

Research findings confirm this observation. Although technology has advanced in pattern making, lead times in garment production remain a major concern for professionals such as Ruth [A6], who emphasizes the importance of pattern designers when time is of the essence. The actual sewing of garments still relies heavily on human labour. Ruth noted, "The factory is still very traditional; there is nothing three-dimensional on this platform, no. 70% or 80% digital and 20% manual or the more traditional way; the only thing we still do traditionally is, I would say, production"[A6].

Independent fashion designer Sihle [A4] shares this view and emphasizes the importance of the human touch to product quality. He commented, "With my brand, I feel very comfortable (sewing garments by hand) because I do not know if the quality can sometimes be affected when the human hand is removed from a product". Both UoT1 students and UoT 2 lecturers and alumni indicated that access to digital technology in garment manufacturing is limited and primarily limited to specialized machines.

Anneline [PM] noted that 3D technology has entered the apparel industry, streamlined the prototyping phase, and allowed garments to be visualized on screen. Faeeze [PD1] emphasized the immediate satisfaction of seeing patterns on the body through systems like V-Stitcher and the ability to make quick adjustments. In addition, lower costs for companies were highlighted as a fundamental benefit of using digital technology in garment manufacturing.

Finally, regarding the integration of digital technologies into product development at UoT, participants' opinions vary due to the changing role of the professionals for whom students are being prepared. The current state of digital technology adoption at the UoT is mixed, with UoT 2 having better access to advanced resources and infrastructure, while UoT 2 faces adoption challenges. For both participating UoT, adoption challenges include limited technology infrastructure, remote location, lack of apparel manufacturers and retailers, curriculum constraints, and budget constraints.

Regardless of the issues facing UoT, industry practitioners emphasize the need to train students in digital technology, even if they do not need to be experts. Interestingly, UoT 2 students express a willingness to enter the industry but, due to limited resources, prefer conventional garment manufacturing when they later start their own businesses.

4.11 Conventional and Digital Methods – Process Efficiency

In the previous sections of this thesis, participants' views on the use of conventional and digital product development methods in the setting of UoT and the apparel industry were explored. Now, I will shift focus and explore participants' views on the effectiveness of these two product development approaches.

To gain insight into the effectiveness of conventional and digital product development methods, the following question was asked: "How do conventional and digital product development approaches perform in practice?" This question was intended to solicit participants' responses based on their practical experiences, and their perspectives are presented in Figures 4.17 and 4.18.

The data collected underscores that the decision between digital and conventional methods depends on how familiar and proficient the operator is with each method, as well as the specific needs of the business. Most participants acknowledged the efficiency of conventional manufacturing methods but also pointed out the drawbacks, including the extensive steps and prototyping that result in significant loss of materials and time.

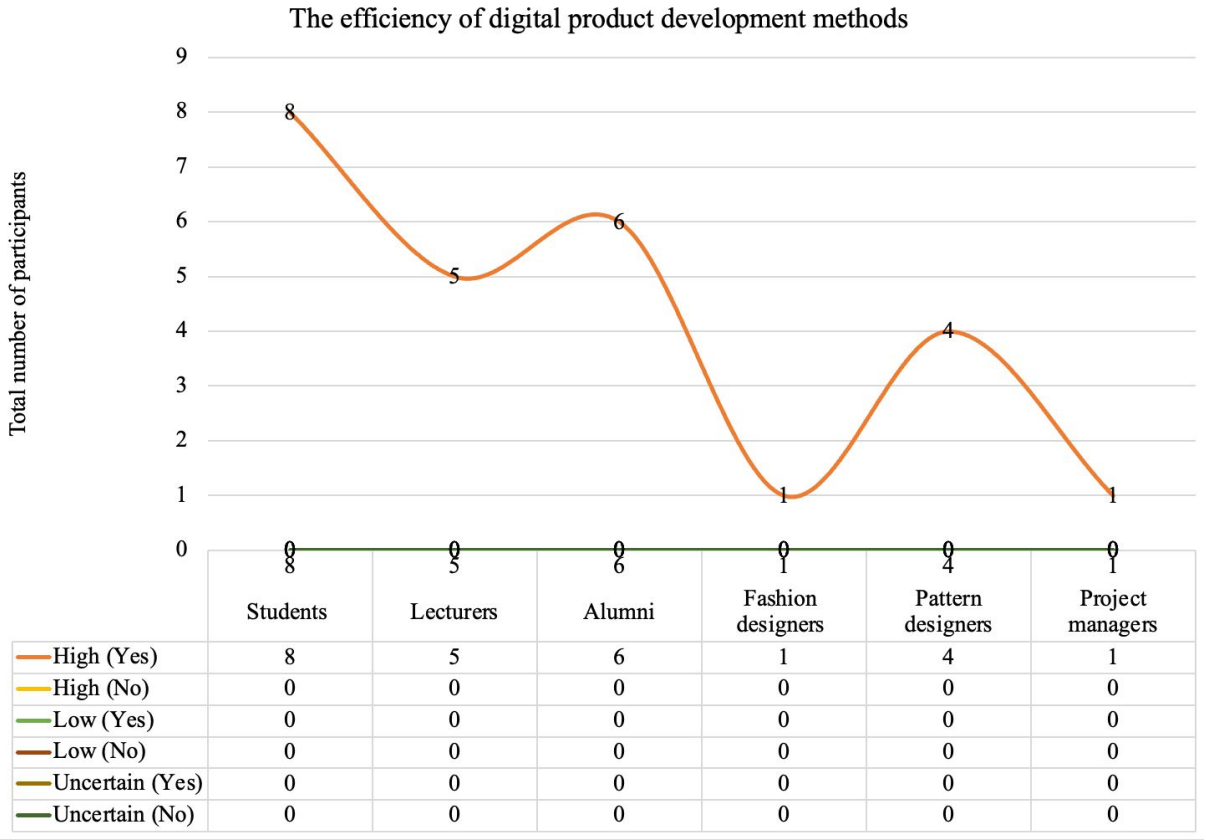
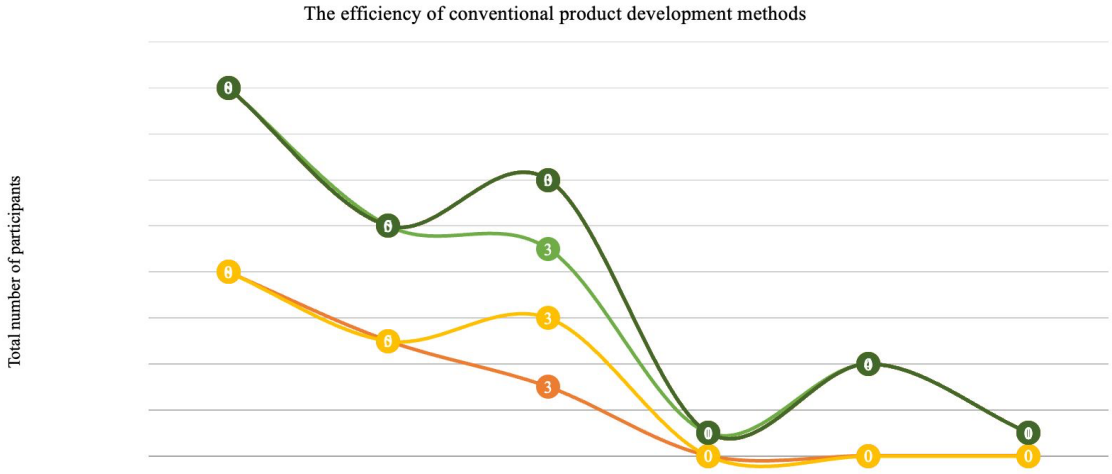


Figure 4.18: Participants' views on the efficiency of digital product development methods

Some of the participating alumni had different views. In an interview with Oko [A3], he alluded that, both manual and digital systems have their strengths and weaknesses. He further mentioned that, despite the increasing use of digital methods, conventional methods are still preferred because of their historical importance, convenience, and efficiency. They are seen as basic skills that should be taught to students before they engage with digital technologies, [A3]. This viewpoint was also expressed by pattern designer Lukho [A5], who emphasized the value of traditional pattern making patterns, especially when alterations are required.

Of particular concern was the environmental impact of these conventional methods of pattern making, including paper and fabric waste. UoT 2 students noted that despite their preference for conventional methods, there is still a significant amount of material waste, and they acknowledged that the adoption of digital methods could help reduce this waste [UoT 2, Lecturers Focus Group]. As a result, industry practitioners increasingly prefer digital over conventional production methods, especially in pattern making.

In response to the efficiency of digital systems, most participants favoured digital methods over conventional methods, citing advantages such as speed and efficiency (Figure 4.19). Ruth [A6] highlighted the advantages of digital pattern making, noting that it provides the same quality without the added cost of manual cutting. She also pointed out that manual garment production can be time-consuming, especially if adjustments are needed after the initial pattern is cut, causing delays in the mock-up/prototype testing phase.



	8 Students	5 Lecturers	6 Alumni	1 Fashion designers	4 Pattern designers	1 Project managers
Low (No)	0	0	0	0	0	0
Low (Yes)	0	0	0	0	0	0
Average (No)	0	0	3	0	0	0
Average (Yes)	8	5	3	1	4	1
High (No)	0	0	3	0	0	0
High (Yes)	8	5	3	0	0	0

Figure 4.19: Participants' views on the efficiency of conventional product development methods

Regarding concerns about the environmental impact of conventional production methods and material waste, Oko [A3] suggested educating students about recycling and reusing garments to mitigate these problems. In addition, he suggested collaboration between industry and UoT to find solutions, such as recycling fabrics and reducing paper waste.

Anneline [PM] strongly argued that digital technology is the future and emphasized that those who are not exposed to it risk falling behind in terms of speed and economic competitiveness. She also pointed

to the noticeable shortage of pattern designers trained in digital technology and stressed the importance of Fashion design UoT equipping their students with digital tools to close the gap between supply and demand in the industry.

In addition, digital technology can to improve the accessibility of fashion design and promote inclusion for people with disabilities by removing the physical limitations associated with traditional pattern tables. This opens up opportunities for people with height limitations. Sustainable and environmentally friendly processes and interdisciplinary collaboration were cited as key benefits of using digital systems in product development.

In summary, the adoption of digital methods offers numerous benefits, including efficiency, cost savings, sustainability, and improved accessibility, while solving the material waste issues associated with conventional methods. As a result, the fashion industry's usage of digital technology is a rising trend among industry practitioners and experts.

Conventional methods continue to be preferred because of their historical significance, convenience, and efficiency. These skills are considered fundamental for students before they engage with digital technologies. However, to address the environmental issues associated with conventional methods, the study recommends teaching students about garment recycling and encouraging industry/UoT collaborations for sustainable solutions such as recycling and reusing fabrics through sustainable design methods and reducing patternmaking paper waste.

4.12 Summary of Research Question Two

To answer the second research question, *how does change in technology affect teaching and learning in fashion product development?* the study provides several findings. First, the study discovered that fashion design students lack a solid foundation in digital technology, which affects their ability to effectively use the software and hardware required for digital product development. Limited resources at the fashion design schools further hinder education in digital technology.

Despite these challenges, the study highlights the importance of integrating digital technologies into fashion product development education and highlights its central role in determining the apparel industry’s future. The evolving technology landscape that requires adaptable curricula to equip students with modern industry skills. Insights from students, lecturers, and industry experts underscore the need to align education with technological advancements.

The changing setting of the apparel industry, which emphasizes the integration of technology, is evident in the feedback. In addition, the research findings underscore the complicated relationship between

conventional and digital pattern making. A solid foundation in traditional methods is seen as essential for survival in the rapidly evolving world of digital pattern making in the apparel industry.

The study reveals different perspectives on digital integration in the apparel industry. While some stakeholders support digital technologies, others express concern about potential job losses, human expertise, and the continued importance of human relationships in the industry owed to the use of digital technology replacing that human hand. This highlights resistance to change remains, although the study highlights that the pandemic has accelerated the adoption of digital systems. Finding a balance between the introduction of digital technologies and preserving the human element remains a challenge for the industry.

The study also notes that the start-up costs associated with digital technology adoption are a barrier and lead to a lack of resources. In addition, the adoption of digital technologies varies from educational institution to educational institution, with different approaches to integrating digital systems into curricula.

Lastly, the research findings highlight the transformative effect of digital technologies on the apparel industry and underscore the need to adapt education to technological advances. Although there are challenges, the integration of digital technologies is recognized as essential to the growth and integration of the industry. Ultimately, it is necessary to strike a balance between digital innovation and preserving its unique human touch.

CHAPTER FIVE: CONCLUSION

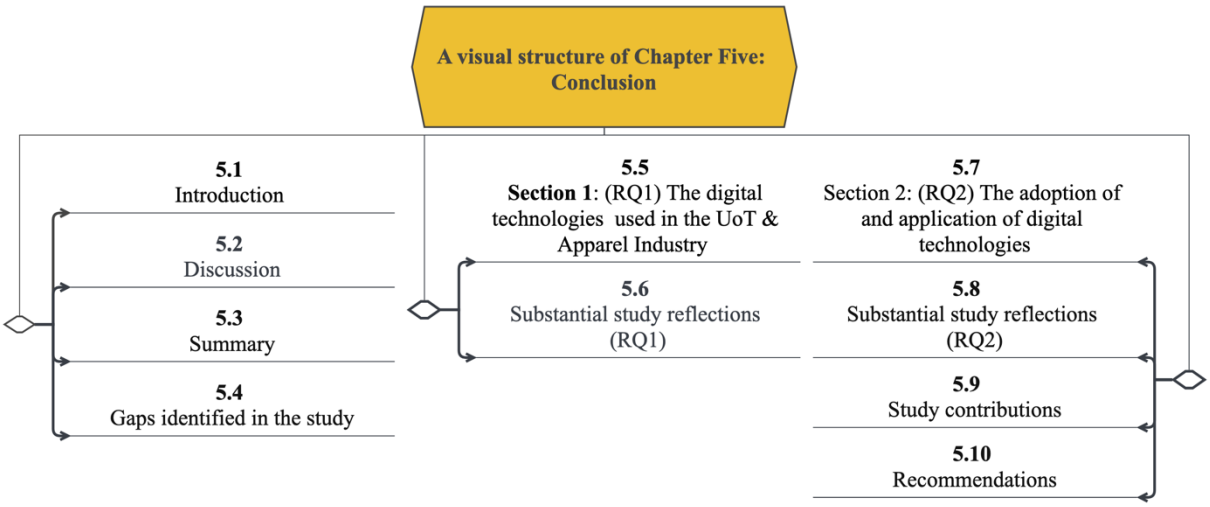


Figure 5.1 Visual structure of Chapter Five

5.1 Introduction

The study explored the integration of digital technologies into fashion product development education, and Chapter Five concludes by reflecting on the findings in response to both Research Question One and Research Question Two. Through this study, I hope to lay the foundation for a future in which fashion education not only adapts to the digital age, but thrives within it, preparing the next generation of fashion professionals to navigate this dynamic terrain with competence and creativity.

This section further discusses the implications, limitations, and recommendations for practice, policy and further studies highlighting. It also addresses the gaps that were uncovered. Figure. 5.1 presents the visual structure of Chapter Five in detail.

5.2 Discussion

This study adopted a qualitative methodology to obtain a deep meaning that may resonate with other people and to explore the lived technical know-hows of the participants from both the apparel industry and those from UoTs. The use of interviews provided a rapid way of gathering data from a geographically dispersed audience through in-person and online conversations.

A mixed data collection method was not considered because the use of statistics will not reveal the underlying story and meaning that I want to reveal, furthermore, the scope of the study will be too big, and the recommended sample is not too large. The use of interviews provided me with a rapid way of gathering data from a geographically dispersed audience through in-person and online conversations. A systematic sampling approach was used to select participants with relevant experience and expertise in

the research field, applying a non-probability-based sampling method to choose participants with relevant expertise in the field (Taherdoost, 2016).

Individual and focus group interviews were conducted in person, when possible, supplemented by online sessions via Microsoft Teams and telephone chats. Because this study employed a qualitative research methodology to examine the impact of technology on fashion product development, semi-structured interviews were conducted. Through semi-structured interviews participants could express their views in a comfortable and preferred environment as the interviews were conducted in their preferred and convenient methods. For those participants who were available for face-face interviews, I visited them in their comfortable work and schooling environment.

The interview schedule or questions were designed (see Appendix E) to explore the impact of technology on the apparel industry and higher education institutions, as well as its impact on curriculum design as well as to answer the research questions. In this study, there was no need to scale the questions because they were all open-ended. Through the use of open-ended questions, the respondent made his or her suggestions or comments without being restricted by a predetermined set of questions. However, in certain cases, closed-ended questions were taken into consideration; these questions could only have one of a restricted number of possible solutions, like "Yes" or “No”.

Because the interviews were open-ended, probing questions relied on the answers given and the questions were formulated with the research questions of this study in mind as well intended outcomes and contributions of this study to the body of knowledge of fashion design education context. Before embarking on the field work data collection process, the interview process questions, and consent form were first discussed with the study supervisors and then shared with the CPUT ethics committee for the approval of the ethics considerations research questions to issue the ethics certificate.

In this study, the narrative inquiry approach is used for data analysis because it focuses on collecting data that comes from participants' personal experiences. This approach is appropriate for this study because it allows for the analysis of information shared by participants during data collection, thus contributing to the findings of the study. Additionally, using a thematic analysis approach, the collected data from the interviews and focus groups were systematically analysed and the responses of all participants were categorized in order to gain meaningful insights from the material.

With regards to the strengths and weaknesses presented by online focus groups and individual interviews, I could gather qualitative data from multiple respondents at their convenient time and spaces, and data could be administered easily after the process by automatically transcribing the interviews and getting data ready for coding and safe storage. The other advantage is that participants were assured of anonymity as no images nor mentioning of the real names was necessary which enabled free

participation. However, the success of these methods solely relies on the skills of the researcher and require careful planning and professional interaction with the participants and ensuring that there is no sampling bias. I experienced that data analysis process can be complex.

Additionally, the online data collection method proved to be convenient, cost effective and with no geographical issues. Reflections to disadvantages revolve around issues that concerns sampling may be bias. During the face-face focus group interviews, there was a great experience of social interaction with human beings' face-face and the group dynamics were an advantage as I could learn from participants' lived experience and perspectives. Issues were encountered when transcribing the collected data as I needed to identify each participant's viewpoints.

5.3 Summary

The research problem driving this study revolves around understanding the relationship between current design technology and fashion product development. In an effort to understand the evolving landscape of fashion education and its intersection with technological advances, this study has ventured into uncharted territory to answer Research Question One and Research Question Two that relates to knowing:

- What is the relationship between current design technology and fashion product development?
- How does change in technology affect teaching and learning in fashion product development?

This study looked into the experiences, perspectives, and insights of participants from UoTs and apparel industry and conducted a literature review until data saturation was reached at a point where no new data was received from both primary and secondary data collection. In the process of data collection, the study realised a gap between the fashion industry's progressive steps in adopting digital technologies and the inherent limitations of the participating universities for technologies. The gaps uncovered though the literature is discussed.

5.4 Gaps Identified in the Literature

In the course of the literature research, uncovered gaps included:

- Integration of new technologies into fashion design education;
- Empirical studies on the impact of 3D technology in fashion design;
- Sustainable fashion and zero-waste design;
- The role of new technologies in transforming apparel manufacturing; and
- Comparing educational approaches to industry practices.

Integrating new technologies into fashion design education

While the literature highlights the need for a shift toward technology-integrated learning in fashion design education, there is not enough investigation of techniques and best practices for incorporating these new technologies into curricula.

Empirical studies on the effect of 3D technology in fashion design

The use of 3D technology is addressed in the literature, but there is a lack of substantial empirical research on the practical impact on fashion design and designers' ability to explore new creative scenarios.

Sustainable fashion and zero-waste design

While the literature mentions the concept of zero-waste fashion design, it does not elaborate on the challenges and opportunities associated with implementing these strategies in the fashion industry, particularly with respect to teaching and learning.

The role of new technologies in transforming apparel manufacturing

While the potential of new technologies to revolutionize the manufacturing process is highlighted, how these technologies impact design education practices is not fully explored. In order to boost our confidence in the ability of the educational technologies to achieve the desired outcomes, determining the impact on educational outcomes is indisputably necessary. That being said, “the results of impact evaluations may be better utilized to support "informed change" rather than serving as a basis for implementation guidelines and standard operating procedures, especially with regard to developing technology” (Cukurova & Luckin, 2018).

Comparing educational approaches to industry practices

Given the rapid pace of technological change, there is a need to examine more closely whether the methods used in fashion design education are consistent with those used in industry. This literature review has paved the way for a thorough exploration of the impact of technology on fashion product development education. The benefits, challenges, and opportunities related with the integration of digital technologies is highlighted.

Additionally, this section of the study reports on research questions one and two, each of which is addressed in separate subsections, namely sections 1 and 2. The goal is to provide a concise summary of the various approaches to answering the two questions and to reflect on the processes applied. As shown in Table 5.1 below, Section 1 of this chapter is dedicated to exploring the first research question

and includes its objectives and the underlying problem it seeks to solve. It also highlights the themes that emerged and ultimately contribute to a comprehensive understanding of the answer to the first research question.

The study recognizes that technology has an important role to play in shaping the future of fashion education and industry practices. The findings have outlined a way forward, one that requires a harmonious blending of tradition and technology to ensure that future generations of fashion professionals leave their educational institutions ready to engage with the dynamic, technology-driven landscape that awaits them.

5.5 Section 1: Digital Technologies Used in the UoTs and Apparel Industry (RQ1)

The focus of this study was on fashion product development, with a specific focus on manufacturing methods such as pattern making and garment construction. Therefore, this section of study reports on the reflections that relates to pattern making and garment construction as well as the discussion of the emerging themes associated with RQ1 (Table 5.1).

Table 5:1: Research Question One, objective, rationale, and themes

RQ1 – Research question one		
What is the relationship between current design technology and fashion product development? Objective: to identify the aspects to be considered in the redevelopment of a curriculum for pattern making and garment construction. Research problem: Due to the changing ways in which garments are developed in professional practice, fashion schools should explore new methods of teaching product development that relate to garment construction and pattern making.		
Rationale	• To discover how the physical learning spaces of apparel product development can be digitally enhanced. • Look for ways to improve traditional fashion education and manufacturing methodologies, as well as promote the incorporation of digital technology into fashion design education.	
Theme 1	Theme 2	Theme 3
Limited exposure to digital systems.	Lack of hands-on experience with technology.	Digital technology and inclusivity.

The collected data indicates that, while the fashion industry has made significant progress in advancing its design processes and systems, this technological advancement is not uniformly reflected in fashion product development education at universities of technology and apparel industry. The collected data highlights the differences in technology use and access to modern tools among students.

A limited exposure to digital systems owing to the issues that relates to costs resulting in limitations comprises:

- Limited exposure to digital systems;
- A lack of hands-on exposure to technology; and
- Digital technology and inclusivity.

Limited exposure to digital systems

The first theme that emerged from the research was the "limited exposure to digital systems: From the participants' point of view, it appeared that fashion education is insufficient in terms of teaching of advanced technologies, especially in the field of 3D systems and garment construction. Among other 3D systems, the use of 3D body scanning systems appears to be an issue. The limited introduction to this technology in the fashion program left some students with the impression that it lags behind traditional measurement methods, suggesting a possible inadequate preparation of students for the evolving industry landscape.

The study also showed that although 3D technologies have advantages, there are still barriers to their full integration into fashion education in some fashion UoTs. This contrasts with the fashion industry's familiarity and utilization of these systems. The first step in closing this gap is to match curriculum with industry demands. Research from the participating UoTs and industry experts highlights the necessity for a well-rounded approach that integrates digital technology while maintaining the basic manual skills required for pattern making and garment construction.

Student’s highlighted concerns with this lack of exposure and practical experience citing a desire to access digital machines and their recognition of the potential benefits, such as streamlining garment manufacturing processes and acquiring new skills, highlighting the importance of integrating digital technologies into fashion education. Further to their concerns was lack of skills when they hit the industry.

Furthermore, it is evident that, while specialized machinery is used in both contexts, advanced digital technologies such as 3D printing and visualization software are not widely used for garment construction. Since technology advancements have made it possible to do tasks faster and more effectively, evidence shows that in order for students to be more prepared for their future employment, they should become familiar with current industry practices.

Lack of hands-on exposure to technology

Another theme that emerged is the lack of hands-on experience with technology. The findings highlighted the lack of practical awareness and knowledge students have with digital methods and machines in garment manufacturing. It is a reality that many institutions do not have the necessary digital tools on their premises, so students must rely on external visits to gain insight into these transformative technologies. The lack of awareness and practical experience of other students regarding digital methods and machines in garment manufacturing is a major problem. The students' responses reflect the stark reality: it is evident that, the UoTs who participated in the study do not have enough digital tools on their premises. As a result, students from UoT1 have to depend on external visits in order to learn about these technologies and get a feel of how the apparel industry operates.

Student's highlighted concerns with this lack of exposure and practical experience citing a desire to access digital tools and their recognition of the potential benefits, such as streamlining garment manufacturing processes and acquiring new skills, highlighting the importance of integrating digital technologies into fashion education. Further to their concerns was lack of skills when they hit the industry. The study emphasizes the necessity of investigating the possibilities and constraints of emerging technologies, dismantling conventional barriers within disciplines, and implementing more pragmatic and integrative methods (Gómez Chova et al., 2019a).

Digital technology and inclusivity

Another theme that emerged is the "lack of hands-on experience with technology". In a world where technological inclusivity is a growing concern, the theme "digital technology and inclusivity" highlights the potential of technology to promote more inclusive approaches in the apparel industry. While these findings are enlightening, they are also a call to action. It is becoming increasingly clear that UoT offering fashion product development education must undertake the task of bridging the technology gap that separates academia from industry.

The study suggests that incorporating digital technology into fashion product development education has the potential to make the course accessible to disabled people who are currently excluded due to their impairments. This includes the consideration of previously marginalised and still marginalised sectors of society. In addition, the study highlights that existing machinery and equipment are not ergonomically designed to accommodate the needs of these individuals. In light of these research findings, it is important for the UoTs that provide fashion product development education to use technology as a means to create an inclusive environment for all and to bridge the inclusivity gap that appear to be a concern.

5.6 Substantial Reflection (RQ1)

This section summarizes the findings and highlights the need for balance and adaptability in fashion education. Research Question One findings and reflections are addressed, and the different themes that emerged as well as the summary of Research Question Two.

5.6.1 Pattern making systems: benefits

The study highlights that digital pattern making is widely acknowledged to have several advantages, including speed, ease, and efficiency. A more efficient nature of digital pattern is evident, emphasising the prospect for instant gratification and less costs involved as an advantage. However, most participants cited cost as the initial obstacle to the adoption of product development technologies.

The financial burden associated with these technologies remains a significant barrier, suggesting that strategies are needed to reduce these costs while promoting broader access to digital advances in fashion product development. One of the important findings of the study is that the combination of tradition and technology in product development signifies both an opportunity and a challenge. It is understood that gaining a foundational understanding of manual pattern making is necessary before advancing to digital skills. Among the most important tools for advancing the construction of clothing are digital systems like Lectra, Grafis, Gerber, etc.

5.6.2 The impact of digital technologies in garment construction

The integration of CAD and computer technologies into the apparel industry has been a progressive journey. However, the study highlights that the garment construction phase of garment manufacturing still relies heavily on traditional production techniques that require human involvement.

Interviews with garment industry professionals underscore the importance of digital technology. It is noted that apparel production companies mainly use digital systems for pattern making and garment construction, however, it is noticeable that more attention is paid to pattern making systems and less to garment construction systems.

5.6.3 Making the choice of digital systems

According to the research, a company's preferences and needs determine which digital system to use, which emphasizes how important it is to expose students to a variety of digital systems in order to foster skill development and adaptability in the workplace. Pattern designers who alternated between various digital systems further support this, highlighting the importance of being familiar with a variety of manufacturing methods.

In conclusion, to answer Research Question One, *what is the relationship between current design technology and fashion product development?* this study found a disconnect between the fashion industry's technology advancements and their incorporation into UoT's fashion product development curriculum. It shows how important it is for fashion education to close the gap between conventional practices and technology, emphasizing how students must be familiar in both manual and digital practices in order to be ready for the fast-paced world of the garment industry. Overall, this study aims to serve as an invitation and advocates for the integration of digital technologies into fashion education to ensure that students are equipped to meet the needs of the industry.

5.7 Section 2: Adoption and Application of Digital Technologies (RQ2)

This section of the chapter is dedicated to the second research question. It highlights the themes that emerged and ultimately contribute to a comprehensive understanding of the answer to the second research question, RQ2 (Figure 5.2).

To answer the second research question, *how does technological change affect product development teaching and learning in the fashion industry?* The aim was to identify needed curriculum changes; the function of technology in product development was also investigated. The study findings produced many insights that highlight the evolving landscape of fashion education in the digital age. The findings unfolded insights that underscore the evolving landscape of fashion education in the digital age. As shown in Table 5.2 below, this section of the chapter focuses on the second research question and includes its objectives and the underlying problem it seeks to solve as well as the themes that emerged in the research.

Table 5:2: Research Question Two, objective, rationale, and themes

RQ 2 – Research Question Two		
How does change in technology affect teaching & learning in Fashion Product Development? Objective: Objective: Objective: to identify the changes needed in curriculum redevelopment and the role of technology in product development is also addressed. Research problem: Due to the changing ways in which garments are developed in professional practice, fashion schools should explore new methods of teaching product development that relate to garment construction and pattern making.		
Rationale	• To discover how the physical learning spaces of apparel product development can be digitally enhanced. • Look for ways to improve traditional fashion education and manufacturing methodologies, as well as promote the incorporation of digital technology into fashion design education.	
Theme 1	Theme 2	Theme 3
The discrepancy between theoretical instruction and practical experience.	Geographical differences among participating universities.	The co-existence of traditional and digital methods in the fashion industry.
Theme 4		Theme 5
The challenges that fashion educational institutions face in integrating digital technologies into their curricula.		The slow adoption of technologies in both the apparel industry and academia.

It also highlights the themes that emerged and contribute to a comprehensive understanding of the answer to the second research question. The underlying research problem of this study is highlighted.

This section importantly examines key, emergent themes emanating from the research and reviews how they relate to the research questions. Themes include:

- The discrepancy between theoretical instruction and practical experience;
- Geographical differences among participating universities;
- The co-existence of traditional and digital methods in the fashion industry;
- Challenges that fashion educational institutions face in integrating digital technologies into their curricula; and
- Slow adoption of technologies in both the apparel industry and academia.

The discrepancy between theoretical instruction and practical experience

The first theme that emerged was the discrepancy between theoretical instruction and practical experience, highlighting the need for tailored teaching methods to bridge this gap. This brought to light the lack of competent pattern designers in the industry and underscored the importance of equipping fashion design students with digital technology skills.

Geographical differences among participating universities

Geographical differences among participating universities made the findings of the study more complex. Access to modern resources and infrastructure revealed a gap between urban and remote institutions, with the former having better access while the latter struggled to keep up. This underscores the need to address disparities in resources to provide equal access to all fashion students regardless of location, a theme that runs throughout the research.

The co-existence of traditional and digital methods in the fashion industry

Another theme that emerged from the data collection is the co-existence of traditional and digital methods in the fashion industry. Conventional methods such as flat pattern making and draping have long been the foundation of pattern making education, but the adoption of digital tools and techniques has been uneven. While digital technologies offer efficiency and accuracy, they cannot erase the value of conventional pattern skills. This highlights the importance of balanced education that provides students with skills in both traditional and digital methods.

Challenges that fashion educational institutions face in integrating digital technologies into their curricula

Challenges that fashion educational institutions face in integrating digital technologies into their curriculum. These challenges include limited resources, limited budgets, and differences in access between urban and remote institutions. Bridging these gaps in resources and setup is critical to providing equal access to digital tools for all fashion students, regardless of geographic location.

Slow adoption of technologies in both the apparel industry and academia

The research highlights the slow adoption of technologies in both the apparel industry and the UoT. While digital technologies such as 3D and virtual prototyping have the potential to transform the industry by reducing waste and time to market, their full integration is hindered by factors such as limited budgets and access to technology. Overcoming these obstacles requires strategic investment, ongoing education, and a commitment to keeping pace with industry demands.

In summary, fashion education is in a position where tradition and innovation must coexist harmoniously. The integration of digital tools should complement, not replace, the basic knowledge and skills acquired through conventional methods of pattern making. As the industry continues to evolve, educators and experts must strive to balance tradition and innovation to prepare the next generation of pattern designers for success in the digital age.

Ultimately, the research findings call for a all-inclusive method to fashion product development education—one that combines conventional and digital methods, promotes sustainability, and equips students with the diverse skills they require to succeed in the dynamic and ever-changing setting of the apparel industry. By addressing these issues and challenges, educational institutions and the industry can work together toward a more environmentally conscious, competitive, and innovative future.

5.8 Substantial Reflection (RQ2)

This section of the chapter is dedicated to the second research question. It highlights the themes that emerged and ultimately contribute to an understanding of the answers and reflections to the second research question. This section of the study discusses the reflections of the findings that relates to the Research Question Two (RQ2).

5.8.1 The adoption of digital technologies: anthropometric data

This study explored the preferred methods of body measurement from the perspective of both universities of technology (UoTs) and the apparel industry, specifically comparing traditional tape

measure methods with modern 3D body scanning systems. Anthropometry, a centuries-old method of measuring the human body, traditionally used equipment such as tape measures. However, the 20th century saw significant changes in garment production, driven by technological advances and knowledge in pattern making.

Today, both manual and computerized methods are used to measure the human body, with 3D scanning emerging as a transformative technology capable of creating highly detailed digital representations of physical surfaces. Recommendations for the respectful use of 3D body data for learning purposes are provided to encourage open use for experimental learning and teaching.

All UoT and industry practitioners acknowledged the importance of including 3D digital body measurement techniques in curricula to prepare students for industry. Although they continue to use traditional tape measures, they confirmed that 3D body measurements that are generated through the 3D body scanning systems can result to improved garment fit, less waste, and increased customer satisfaction. However, the study also found that students and the apparel industry have little experience with 3D body measurement technologies, suggesting that availability needs to be improved.

The high cost of 3D body scanners and the limited experience of students and practitioners are cited as barriers to adoption of the technology. As the technology becomes more common, costs should decrease, and accuracy should increase. In summary, the study highlights the potential of 3D body scanning technology to revolutionize manufacturing processes in the apparel industry and highlights the challenges that must be overcome for more adoption.

5.8.2 Digital technological change (UoTs)

In relation to the numerous research findings and literature presented; it is evident that the field of fashion education is at a critical stage. The research highlights the key points that should guide the future direction of fashion education.

5.8.3 Digital transformation: UoTs skills development and innovation

The collected data shows that apparel industry is advancing, and the use of digital technologies is becoming important. This study examined the use of digital technologies in fashion product development education at two South African UoTs. It is evident that that there is a gap between the use of digital technologies in the apparel industry and UoTs. Whereas the industry is embracing digital technologies, the participating UoTs are lagging behind.

The literature highlights the significance of digital transformation (DT) in the fashion industry. Kutnjak *et al.* (2019) emphasize how DT can open new business opportunities, foster innovation, and improve

knowledge acquisition. The adoption of digital manufacturing is highlighted as an important aspect of Industry 4.0, combining conventional manufacturing technologies with digital techniques. However, integrating digital technologies into fashion education presents challenges.

The findings emphasize the importance of understanding that there is no single path for students when it comes to digital integration. From the different early days of digital learning to the varying resources and experiences of the lecturers, a clear picture emerges, one size does not fit all.

One of the key takeaway from this study is that, as presented and discussed in chapter four, an understanding of the traditional methods of apparel manufacturing is the cornerstone for the effective use of digital tools, digital and conventional methods must co-exist. The study underscores that digital technologies have great potential for product development but cannot replace the essential knowledge and fundamentals of apparel manufacturing.

5.8.4 Bridging the Gap Between Tradition and Technology in Fashion Education

The fashion industry has experienced significant growth in recent years, which has sparked interest among young people seeking careers in this dynamic field (Maryam et al., 2019). As a result, fashion education has undergone significant changes to accommodate the evolving industry landscape and technological advances. The collected data highlighted that fashion education has adapted to the changing landscape by aligning its practices with those of the industry itself.

Collaborative learning, hands-on experiences, specialised skills development, and communication skills enhancement have been integrated into curricula to promote student-centred learning while enhancing technical skills and supporting innovation (Maryam et al., 2019).

Based on the collected data, these changes reflect a commitment to preparing students for a dynamic and ever-evolving industry and encompass:

- Balance between tradition and technology: pedagogical adaptations;
- Digital technology integration: balanced learning techniques;
- Barriers to adoption;
- Foundation skills; and
- Collaboration skills.

Balance between tradition and technology: pedagogical adaptations

The broader context of design education in fashion is undergoing a change in response to global changes,

including socioeconomic shifts and technological advances. These changes are impacting four different areas, design practice; teaching methods; student expectations; and pedagogy. According to Pontis and Waarde (2020) traditional approaches to problem solving that rely on artefacts are giving way to user-centred research and the adoption of new digital technologies in the field. They further said that, while the incorporation of technology-based teaching models is central to modernizing fashion education and teaching basic skills to students, traditional production methods are still important as a basic skill.

It is important to recognize that the industry still relies heavily on manual methods in certain aspects of design, development, and production (Papahristou & Bilalis, 2017b). This underscores the need for continuous updating to ensure graduates are well prepared to meet the diverse demands of the industry (Yezhova et al., 2018).

Digital technology integration: balanced learning techniques

The results of this study confirm the views expressed in the literature. The collective voices of study participants unanimously agree that the integration of digital technologies into fashion product development education is paramount. The passionate testimony of Yushaa [PD3] a pattern designer whose expertise differs from conventional pattern making, vividly illustrates the potential benefits of integrating digital pattern techniques into fashion school curricula. His insights underscore the tangible relevance of such training, as companies increasingly seek skilled workers equipped with digital pattern making knowledge.

Despite the challenges that emerge blocking the way for the integration of digital technologies into fashion product development, the study concludes that the introduction of digital technologies into fashion product development education is essential. This move will equip students with the necessary skills and promote a smoother transition from education to industry.

The use of digital technologies is transforming the apparel industry, it is recommended that this should also be a practice at UoT as well. The study highlights that by integrating digital technologies into fashion product development education, students can improve the efficiency of production processes, productivity, and sustainability of their garments. Universities also need to embrace digital technologies to prepare students for the future of the apparel industry.

The findings of this study confirm the impact of educational technology as a tool for integrating digital technologies into fashion product development training. As the fashion industry continues to evolve, educational institutions must alter their practices to ensure that they are providing students with the skills and knowledge they need to succeed in the workplace.

Barriers to adoption

The integration of learning technologies into apparel industry training is often met with scepticism and resistance. Educators cited non-educational factors such as commercial interests, organizational politics, cost considerations, and the need to increase enrolment as barriers to change (Palaskas, 2002). Digital pattern design systems offer improved accuracy and efficiency, but their implementation requires significant investment in software and training (Datta & Seal, 2018).

Financial constraints are proving to be a major barrier to integrating digital technologies into education, forcing institutions to consider innovative approaches, partnerships, and resource optimization. Against this dynamic background, the ability to adapt, evolve, and empower both students and lecturers will be critical to preparing the next generation of fashion professionals for a technology-driven industry.

Ultimately, the path to seamlessly integrate digital technologies into fashion education faces hurdles, but it holds promise for shaping digitally savvy fashion designers and industry-competent professionals. Consequently, this study uncovers a complex web of challenges and perspectives associated with integrating digital technologies into fashion education. It calls for adaptive curriculum redesign to accommodate technological advances and argues for the integration of technology-enhanced teaching methods.

Foundation skills

The study places great emphasis on the formative stage of introducing students to digital systems, recognizing that a well-designed introduction can lay a solid foundation for their learning journey, thereby enhancing their success in integrating digital technologies into their studies. It also emphasizes the key role of aligning education with industry practices. Therefore, the study recommends that, to achieve a successful integration of digital technology into the fashion design curriculum, fashion design schools need to work closely with industry partners to ensure that their curriculum align with the dynamic demands of the professional world.

Collaboration Skills

During data collection, participants expressed a desire for more hands-on experience with digital pattern software. This suggests that Fashion design UoT should expand their curriculum to provide students with hands-on training in the use of these tools. Hands-on experience is important to build skills and confidence in digital pattern design.

Apparel industry participants made suggestions that digital technology has created opportunities for collaboration among all those involved in digital product development processes. Therefore, this study

concludes that, fashion designers need to learn how to use digital pattern software to collaborate effectively with other members of the product development team. This highlights the importance of developing fashion students' communication and teamwork skills to meet the demands of modern industry.

5.9 Digital Innovation Status (Garment Construction)

The research shows that specialized machines are used by both the apparel industry and some UoTs. It is evident that the apparel industry is moving toward digitization, which allows designers to view apparel designs on avatars, reducing the need for manual prototyping or pattern making, but not all apparel manufacturers have this technology and participating universities have not yet adopted it. The research findings and literature review provide valuable insights into the evolving landscape of fashion design and production, particularly with regard to the integration of technology, traditional practices, and the skills gap in the industry.

Findings of the study address:

- Overuse of digital technologies;
- The digital integration dilemma;
- Scepticism and resistance;
- Limited exposure and inequalities between urban and remote areas: geographic location;
- Skills gaps in the industry; and
- Shortage of pattern designers as a gap.

Overuse of digital technologies

The use of digital technologies is widely spread in the manufacturing sectors. The future of our design practices is to "produce ideas and design solutions that demand a high level of education, skills, and creativity (Faerm, 2012). However, some students and industry professionals express concern that the overuse of digital technologies could lead to a loss of craftsmanship and the human touch in fashion production. However, they do not oppose the integration of digital technologies into the curriculum but continue to learn the conventional methods of product development to meet the aforementioned challenges that may arise in the future.

The digital integration dilemma

The question of when and how to introduce digital technologies into fashion education remains controversial. The reason for this may lie in the belief that practice-based subjects primarily focus on physical and bodily actions and that they therefore usually depend on the students' opportunities to

collaborate physically in workshops and/or in groups on campus (Nortvig et al., 2020). Differing viewpoints among fourth year students from UoT 2 (2023) and graduates (2022) reflect the challenge of transitioning from traditional methods to new digital techniques.

The prevailing trend of introducing digital technologies in the second year, with some beginning in the first year, attempts to strike a balance by aligning with the traditional progression of skill development, Alumnus2 & Independent designer [A4]. However, Akha [L1] who is a lecturer from UoT1 raised concerns that relates to inconsistent integration of digital skills across institutions and resource constraints have hindered practical application, leaving students with theoretical knowledge but limited practical experience.

Scepticism and resistance

Data shows that, scepticism, and resistance to integrating learning technologies into apparel education often stems from concerns related to commercial interests, organisational politics, anticipated cost savings, and the increased enrolment of students in the fashion courses which affects the ability of the lecturers to offer one-on-one attention to students during training. Therefore, suggestions of training lab assistants were offered to enable to assist students beyond their class allocated times.

To meet the changing expectations of the fashion industry, a more seamless alignment between fashion education and industry needs is required. According to (Meyer & Norman, 2020), different schools might choose different paths (some deciding not to alter what they do). Some will choose to focus on components of new skills. In their study, they recommended that all schools of design cover a set of core principles, but then offer advanced courses that might be unique to the special talents of the school or that might lead to one of a number of specialties within design. Ruth [A6], an alumna who is an independent designer and a garment technologist echoed this by highlighting that, *"graduates need to be equipped with the skills and knowledge required for real-world careers in the fashion industry"* [A6, 2022]. However, it is imperative to lead the way in effectively integrating digital technologies into fashion curricula while maintaining a solid foundation in traditional methods.

Limited exposure and inequalities between urban and remote areas: geographic location

The study notes a divide among participating universities based on geographic location. Differences in access to modern resources and infrastructure between urban and remote areas affect fashion students' readiness to use digital technologies. Urban institutions have better access to these resources, while remote institutions struggle to keep up. Addressing inequities in access to resources and infrastructure is critical to creating equal access for all fashion students, regardless of geographic location. The study recommends further research in this regard.

The research shows that it is imperative to address the above challenges. Therefore, it is recommended that more time be allocated in the curriculum to teach digital skills and that on-site lab assistants be trained to help students in the absence of instructors. In addition, it is recommended that industry professionals be brought in to provide hands-on training for students.

In this way, students could receive hands-on training from someone who is directly involved in the profession and can share information from their own experience. However, the data collected makes it clear that not all students can become digital experts in the future, but basic digital skills are important to prepare them for the industry, to cater for those who will enter the area of digital technologies.

Skills gaps in the industry

Despite the emphasis on these competencies, it is evident that there is a persistent gap in the industry and in fashion schools, particularly with regard to students' understanding of digital production methods such as 3D systems. The research indicates that this gap is due to the way in which garment production techniques are taught and learned, which points to the need for more effective teaching methods as this may influence students' understanding of the processes used by the apparel industry in the future.

Shortage of pattern designers as a gap

In addition to the challenges posed by wait times, there is a notable shortage of pattern designers trained in digital technology. This gap underscores the importance of Fashion design UoTs focusing on training students in these digital tools to close the gap between supply and demand in the industry.

In addition, digital technology can play a critical role in fashion design for people with disabilities by enabling accessibility and inclusion by removing the physical limitations of traditional pattern tables and creating opportunities for people with disabilities who are height restricted when working with traditional pattern tables.

5.10 Industry Practice: Digital Technological Change

Regarding digital technological change in the apparel industry, several key factors were derived from the collected data and literature review and are discussed in the below sections. Key factors include:

- Technology skills: career transition;
- Human involvement in garment manufacturing fears of job loss;
- The importance of human capabilities; and
- User technophobia: diversity in the adoption of digital transformation.

Technology skills: career transition

The apparel industry places emphasis on technical skills, including pattern making, design, and sewing. These skills are considered essential by fashion designers to establish their unique niche and branding in the market (Maryam et al., 2019). Therefore, it is important that these skills are taught in the classroom so that students are able to withstand the pressures of the apparel industry in the future and keep up with the challenges that arise in the apparel industry.

Human involvement in garment manufacturing: fears of job loss

Despite technological advances, garment manufacturing is still labour-intensive, and there is no substitute for human hands in sewing various fabrics. The data collected shows that this human touch is considered essential for maintaining quality. There is concern that the loss of human involvement in garment manufacturing could lead to job losses and quality issues, leading to industry opposition to the elimination of the human hand in garment manufacturing.

The fashion industry is at a crossroads where traditional practices are meeting product development new technologies. This is because, manufacturing companies in the apparel industry face several challenges, involving the need for advance, fast pace to market, a diversified product line, and higher garment quality (Wijewardhana et al., 2021). Although there are still some challenges and difficulties to overcome, the introduction of 3D technology in garment construction and prototyping promises to increase efficiency, reduce waste, and improve the creative and innovative aspects of fashion design and production. Clearly, the balance between these technological advances and the skill and human hands remain as an important aspect for the future of the industry.

The importance of human capabilities

Despite the digital transformation, the data collected makes it clear that human skills are still essential in the apparel industry. Machines used to make garments often need to be operated by humans. This shows the importance of acquiring both digital and conventional skills [A4].

Based on these findings, it can be concluded that the fashion industry is undergoing a significant transformation driven by digital technologies and the need for innovation and shorter time-to-market.

While technical skills such as pattern making, designing, and sewing are still critical, the industry is gradually shifting to digital pattern making and design processes.

The human element remains important, however, and a combination of digital and conventional skills is seen as valuable. COVID -19 acted as a promoter for the adoption of digital methods in response to

changing market demands. The fashion industry is on the path to digital transformation, with different players in the industry making varying degrees of progress.

User technophobia: diversity in the adoption of digital transformation

Digital transformation (DT) plays a crucial role in the evolution of the fashion industry. It involves the use of digital technology to transform key business models (Kutnjak *et al.*, 2019). Obviously, the adoption of DT varies from industry to industry, and the fashion industry is gradually embracing it.

The research indicates that not all companies in the fashion industry have embraced digital transformation equally. Some have adapted more quickly, while others are still in the early stages of adoption (Kutnjak et al., 2019). Research shows that some companies in product manufacturing have been slow to adopt available digital technologies. However, the COVID -19 outbreak accelerated the adoption of digital methods in apparel production as companies were forced to adapt to new ways of working [A3].

5.10.1 Conventional methods – process efficiency

One of the highlights of the research is that the conventional product development process in the fashion industry has long been depicted by a costly and time-consuming iterative cycle. This process, which involves multiple rounds of sample creation, fitting, and design changes, has traditionally relied on the expertise of designers and product development teams.

However, data indicates that this approach presents a significant challenge, particularly in terms of waste reduction and time spent following all conventional product development processes in the fashion industry and at fashion schools, which are characterized by a costly and time-consuming iterative approach. As discussed in the findings section of this research, data shows that conventional manufacturing processes are labour intensive and can account for up to 70% of the typical lifecycle of a garment, while manufacturing accounts for only 30%.

Despite the shift toward digital methods, the study indicates that, conventional methods are still preferred, especially by those with a background in the industry. Both manual and digital methods have their advantages and disadvantages, and the choice often depends on the skill and comfort level of the operator. Regardless of the concerns, the research shows that it is increasingly seen as valuable to be proficient in both digital and traditional methods, as they can complement each other in product development.

Conventional methods: sustainability and ecologically friendly production

An important issue highlighted in the literature is the impact of conventional methods on the environment, particularly in terms of material waste during pattern making and garment production. The research show the growing need to promote recycling and reuse of fabrics and reduce the industry's environmental footprint. Collaboration between traditional and digital approaches and a focus on sustainability can help address these challenges.

The study concludes that the fashion industry, known for its conventional practices, is in a process of transformation. While conventional product design and development have their advantages, the study show that one of the benefits of digital technologies is that they have the potential to reduce waste, increase efficiency and help companies adapt to changing market demands. This transition, guided by a commitment to sustainability, can help the industry not only preserve its heritage, but also evolve and thrive in a more environmentally conscious and competitive landscape. The sections below reflect on the findings about the use of digital technology and the ongoing trends in the apparel industry and UoTs.

5.10.2 Digital technology use & trends: process efficiency

First and foremost, as McQuillan (2020) points out, the use of 3D software in apparel design not only improves visualization and marketing, but also proven to be invaluable in zero-free fashion design. As indicated by a synthesis of various research results, the integration of digital product development technology in the field of fashion design, especially in the context of zero-waste fashion design, offers numerous benefits that include cost savings, efficient use of production materials, and time optimization.

Although initial start-up costs are perceived as a barrier, the lasting benefits of digital technology in terms of cost savings and efficiency are evident. Many study participants emphasize that the use of digital technology has significantly reduced costs, as patterns can be created in a fraction of the time it took using traditional methods. Cost savings include:

- Production cost savings;
- Time efficiency;
- Sustainable fashion;
- Virtualization;
- Digital methods: Cross-Disciplinary Collaboration; and
- Training and resources.

Production cost savings

The data collected indicates that digital product development technology significantly reduces the costs

associated with traditional prototyping methods. Traditional apparel manufacturing often requires multiple physical prototypes and iterations, resulting in significant material and labour costs. However, the use of 2D and 3D digital tools enables designers and manufacturers to create virtual prototypes, eliminating the need for physical samples in the beginning stages of product development. This leads to significant cost reductions in sample making, as indicated by Faeeze [PD1] and Janet [PD2].

Time efficiency

The findings of the study indicates that digital technology streamlines the product development process and saves valuable time. Designers, garment engineers and garment manufacturers can iterate product designs virtually, adjusting various features, materials and dimensions without the delays associated with creating physical prototypes. Using 3D software for visualization and modelling also speeds decision-making and design changes. The perspective of Lukho [A5] the pattern designer underscores the value of digital patterns for rapid customization. One of the many benefits is being able to see results and changes immediately, which increases productivity.

Sustainable fashion

Technology has played a vital role in sustainability efforts in the fashion industry, leading to advances in production efficiency, reduced material waste, and improved product quality. Sustainable fashion as a whole requires a comprehensive focus on various aspects of the supply chain, including the product development process (Fung et al., 2021). These efforts are slowly gaining traction and underscore the industry's growing awareness of its responsibility to contribute to a sustainable future. This is as a result of the role played by new technologies.

Technologies such as 3D printing have demonstrated their potential to transform the development of fashion products. As Sun and Zhao (2017) point out, 3D printing not only allow for the customization and personalization of products, but also offers sustainable manufacturing solutions from an environmental, social, and economic perspective. Moreover, as Arribas and Alfaro (2018) mention, the use of 3D technology facilitates the tracking of design changes and the creation of digital archives for future use, which contributes to a reduction in physical garment production and production waste.

Virtualization

A key benefit of incorporating digital technologies into fashion product development is the virtualization of the production process. By eliminating physical prototypes and minimizing waste, this approach contributes significantly to sustainability (Spahiu et al., 2021). However, it is important to recognize that the shift to digital methods comes with initial costs, including investments in hardware, software, and training.

Testimony from industry experts such as Anneline [PM] confirm that the role of digital technology is inevitable for the future of the industry. The speed and efficiency of digital production processes, combined with the elimination of labour-intensive steps, lead to long-term cost savings. Still, upfront costs can be a challenge, leading some fashion designers to outsource their product development.

The cost inequality between digital and traditional production methods is an issue raised by several interview participants. The experience of Ruth [A6] shows that different pattern designers can charge different fees, with pattern designers often charging higher prices due to their efficiency. Nevertheless, the rush to meet high demand can sometimes negate their speed and lead to longer lead times [A6].

Digital methods: Cross-Disciplinary Collaboration

In today's rapidly evolving society, interdisciplinary approaches and hybrid methods between disciplines have become increasingly important and have also impacted the field of fashion design. The integration of digital manufacturing tools and processes highlights the importance of interdisciplinary collaboration (Gómez Chova et al., 2019a) in the fashion industry and impacts all aspects of the industry, from design to concept stage.

Fashion designers face the challenge of adapting to the digital age, which requires a comprehensive understanding of programming and physical computing, as technology continues to transform the fashion industry (Han et al., 2020). This shift toward technology is revolutionizing communication, improving product innovation, cost efficiency, and speed to market, and promoting sustainability by fostering adaptability to change (Sun & Zhao, 2018).

Digital design tools that seamlessly integrate 3D sketches, 2D patterns, and 3D samples promote a holistic approach to apparel manufacturing and reduce waste (McQuillan, 2020). These tools also facilitate communication between designers and suppliers and minimize production errors (Pasricha & Greeninger, 2018).

This study highlights the challenges in promoting interdisciplinary collaboration between students and lecturers due to different approaches to technology (UoT 1 and UoT 2). To address this gap, joint lectures with industry professionals are recommended [L1]. In this evolving setting, educational institutions play an important role in preparing professionals for the workplace (Gómez Chova et al., 2019b).

Digital technologies have done away with isolated roles in the apparel industry and encouraged effective communication and better understanding between designers, pattern makers, and product technologists [FD]. Collaboration between fashion companies and 3D software providers is critical to promote mutual learning and technologies that are suitable for the needs of the fashion industry (Arribas & Alfaro, 2018).

These changes are further facilitated by digital systems that promote collaboration between teams and increase customer satisfaction and efficiency.

The integration of digital technologies, interdisciplinary collaboration, and hybrid methods is transforming the fashion and apparel industry. Designers and professionals must adapt to these changes and improve their skills to increase efficiency, sustainability, and innovation. Educational institutions, in collaboration with industry experts, play a vital role in closing the gap between theory and practice. The digital age is promoting collaboration and integration that will ensure the continued development and success of the industry.

Training and resources

Although digital technology offers benefits, study participants highlighted that, there are also challenges associated with its adoption, including start-up costs and the need for training. Furthermore, adequate resources and training are essential to appreciating the full potential of digital systems. Overcoming these barriers is critical to maximizing the benefits of digital technology in fashion design.

In summary, the use of digital product development technologies, including 2D and 3D software tools, has the potential to revolutionize the fashion industry by reducing costs, minimizing waste, and improving efficiency. By embracing these technologies and addressing the challenges they present, fashion designers and manufacturers can contribute to sustainable and cost-effective practices while maintaining their creative freedom and competitiveness in the market.

5.11 Contributions of the study

As mentioned in Chapter One, a practical problem was identified. As technology changes in the fashion industry, it is necessary to revise fashion apparel teaching methods. An academic problem relates to fashion product development where learning spaces are not connected to teaching technology-integrated learning using digital means. Lastly, a theoretical problem is associated with the potential contribution towards a theory of technology-integrated learning in fashion education. In response, this study contributes to the existing body of knowledge in three ways – theoretically, methodologically; and practically.

This exploratory research study is significant in its evaluation of the need for change within fashion design product development courses. Consequently, Figure 5.2 presents a digital product development process design framework for change that serves as a contribution of this study to an existing body of work. Its primary contribution lies in the realm of fashion design education, specifically in the integration of technology into product development teaching methods. This process design framework refer on the theory of change steps (Cukurova & Luckin, 2018) and incorporates insights from Pontis and Waarde (2020) concerning changes in design education and research areas that emerged during data collection.

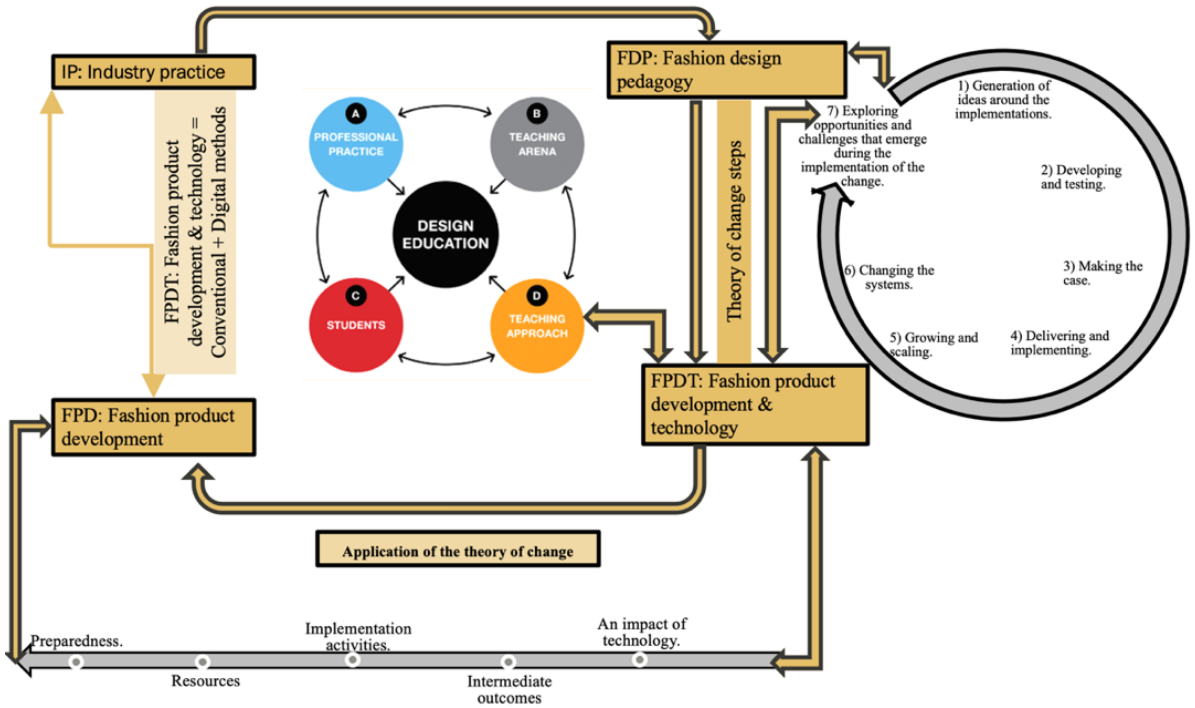


Figure 5.2: A synthesised process framework for a theory of change – the theoretical contribution of the study (Extended from Cukurova & Luckin, 2018; Pontis & van der Waarde, 2020)

It is important to note that in the conceptual diagram, the elements highlighted in mustard represent my own contributions, while the remaining components are derived from existing literature. The proposed concept of the theory of change begins with FDP (fashion design pedagogy), which serves as the driving force behind this study. Then, change in design education is included to highlight the first phase of change implementation in FPDT (fashion product development and technology), the core area of this research. This is followed by the theory of change steps to be followed in FPD (fashion product development) education, finally leading back to FPDT (fashion product development and technology). This section of the concept highlights the research findings that point to the need for conventional and digital methods to coexist, as conventional methods are the foundation for digital production techniques.

Of importance is the guidance it provides for enhancing the teaching and learning experience in this field. By integrating technology and identifying avenues for improvement, the study offers recommendations aimed at elevating educational standards. Additionally, the study extends its impact to different facets of fashion education. It explores the changing educational space, shedding light on the challenges that arise when traditional methodologies co-exist with modern technology and theoretical concepts meet practical application. Notably, it underscores the need for greater alignment between fashion design UoT and the developing apparel industry, addressing the existing gap between these two realms.

The policy recommendations emanating from this study serve as a pragmatic roadmap for policymakers and educators, offering guidance in bridging the gap. These recommendations span across educational policies, teaching practices, and areas for further exploration. Additionally, the research enhances our comprehension of the dynamics involved in integrating digital technologies into fashion education. It offers insights into the complexities and challenges associated with this integration process, drawing from the perspectives of students, graduates, and industry professionals. It also underscores the importance of early adoption and the balance required between traditional craftsmanship and modern innovation.

In summary, this study makes contributions to the field of fashion education addressing the gap between academic and industrial practices, while providing practical guidance for policymakers and educators. It also clarifies the complex process of integrating digital technologies into education. Above all, the study underscores the significance of adaptability and equilibrium in fashion education, laying the foundation for a generation of fashion leaders equipped to navigate the continually evolving fashion landscape. The contribution of this study lies in its vision for the future of fashion education, where tradition and technology coexist harmoniously to prepare fashion leaders for the challenges of the future.

5.11.1 Theoretical contributions

The study proposed a digital product development process design framework for change that serves as a contribution to the existing body of knowledge. It focused on the need for conventional and digital methods to coexist in fashion design education. Furthermore, it stressed the importance of early adoption of digital technologies and the balance between traditional production methods and modern innovation.

5.11.2 Methodological contributions

Based on existing theoretical insights and qualitative data analysis of empirical data, an exploratory research approach synthesized a process design framework for a digital product development process (Figure 5.2) providing guidelines for change whilst informing change theory and fashion design education.

5.11.3 Practical contributions

The study proposed policy recommendations for policy makers and educators to bridge the gap between fashion education and the apparel industry. Furthermore, it evaluated the need for change within fashion design product development education, especially in pattern making and garment construction.

5.12 Recommendations

The field of fashion education stands at a critical intersection between tradition & technology, theory practice. Throughout this research journey, it became clear that a noticeable gap exists between the rapidly evolving demands of the apparel industry and the paradigms of fashion education. This gap is particularly evident in the integration of digital technologies - an aspect that is important in shaping the future of fashion design and apparel production.

Given the research and insights gained in this study, it is crucial to address this gap. To achieve this goal, I present a set of policy recommendations that revolves around the areas of educational policy and practice and suggest possibilities for further investigation. These recommendations are based on the need to address the fundamental challenges that destructs the integration of digital technologies into fashion design education.

The following sections provide a roadmap of recommendations aimed at promoting alignment, adaptability, and innovation in fashion education. They outline key policy recommendations, practical strategies, and areas for further research that have the potential to restructure the fashion design education setting. They serve as a blueprint for academic and industry sectors to provide our students with the important skills and knowledge they need to succeed in a changing apparel industry space.

These recommendations are intended to provide a promising vision for the future of fashion education, where tradition and technology co-exist harmoniously to pave the way for tomorrow's fashion leaders. Furthermore, through the implementation of these recommendations, the study aims to propose an adaptable, industry-responsive, and sustainable fashion education ecosystem.

5.12.1 Recommendations for educational policy

Recommendations for educational policy include:

- Standardization of digital inclusion; and
- Collaboration with industry.

Standardization of digital inclusion

Research has shown that it is important for fashion design UoTs to develop industry-wide standards or policies for integrating digital technologies into fashion education to ensure curriculum consistency and relevance.

Collaboration with industry

Resource allocation appears to be a barrier at the participating UoTs. This study recommends that partnerships between fashion education institutions and industry stakeholders be fostered to align curricula with industry needs. Collaboration between the UoTs and the apparel industry is critical. Partnerships can give students practical insights, access to modern tools, and a better understanding of industry needs.

5.12.2 Recommendations for educational practice

The universities of technology (UoT) should consider integrating technologies that promote inclusivity in the fashion industry and ensure that students are well prepared to work in a diverse and evolving environment. Higher education institutions must prioritize the integration of digital technologies into their curricula and ensure that students are skilful in both traditional and digital methods.

This can be achieved by updating the curriculum and investing in the necessary equipment as follows:

- Raise awareness of 3D body scanning;
- Introduce cost reduction strategies to promote inclusivity;
- Explore curriculum improvement and early exposure;
- Facilitate collaboration with industry;
- Introduce digital technologies in a flexible way;

- Promote hybrid skills; and
- Provide professional development for lecturers.

Raise awareness of 3D body scanning

Educational institutions and industry associations should work together to conduct awareness campaigns about the benefits of 3D body scanning. This can include workshops, seminars, and online resources to educate students, practitioners, and the public about the potential of the process.

Introduce cost reduction strategies to promote inclusivity

The UoTs should look for approaches to reduce the financial burden on students related to digital technology and make it more accessible and inclusive for people with disabilities. This will allow UoTs to attract disabled students and create a future for inclusive clothing designs and jobs for disabled people.

Explore curriculum improvement and early exposure

The study recommends that a continuous updating of the curricula is necessary. This is to ensure a balanced mix of traditional and digital methods so that students gain practical experience as well as theoretical knowledge. The study further recommends that the fashion design UoTs should incorporate digital technologies earlier in the curriculum so that students can gradually get used to these technologies and build confidence in using them. Early adoption is key to success.

Facilitate collaboration with industry

The fashion design offering UoTs should encourage a closer collaboration with industry professionals to ensure that training programs remain relevant and provide students with practical industry insights. To bridge the gap between theory and practice, the UoTs must integrate digital technologies into their curricula. This integration should include both basic knowledge and practical applications to ensure that students are well prepared for the demands of the industry. Finding the right balance is critical to preparing students for a diverse industry that values both traditional craftsmanship and modern innovation.

Introduce digital technologies in a flexible way

Fashion education UoT must consider flexible approaches to introducing digital technologies, considering students' varying needs and preferences. Gradual integration can be effective while maintaining a solid foundation of traditional methods. This study recommends that the integration should include both foundational knowledge and practical application.

Promote hybrid skills

This study highlights the need to encourage students to nurture a blend of traditional clothing product development and digital skills. Courses that bridge the gap between conventional and digital techniques can enable fashion design students to create innovative and useful fashion products.

Provide professional development for lecturers

The research indicates that lecturers should receive training and professional development opportunities to stay current with emerging technologies. This will ensure that lecturers can effectively teach and guide students in learning software design, physical computing, and digital design.

5.12.3 Suggestions for further studies

In this section of the study, the recommendations for further studies that emerged from this study are presented. Suggested recommendations include:

- Long-term effects of 3D body scanners and effectiveness;
- Inclusivity in digital adoption;
- Geographic location;
- Analysis of industry needs;
- Resource accessibility; and
- Impact of the COVID -19 pandemic.

Long-term effects of 3D Body Scanners and effectiveness

The study highlights the need for further exploration and research into the adoption and efficiency of 3D body scanning in the fashion industry. The views and experiences of participants indicate that there is no one-size-fits-all approach, and factors such as cost, accuracy, and accessibility play an important role in the perception of this technology. Future studies should aim to clarify these matters and provide insights into how 3D body scanning can be used effectively in both fashion education and the apparel industry.

Inclusivity in digital adoption

Explore the aspect of inclusion of disabled people in the adoption of digital technologies in fashion education. Analyse how different demographic groups and geographic regions are engaging with and adapting to digital tools.

Geographic location

The study notes a divide among participating universities based on geographic location. Differences in access to modern resources and infrastructure between urban and remote areas affect fashion students' readiness to use digital technologies. Addressing inequities in access to resources and infrastructure is critical to creating equal access for all fashion students, regardless of geographic location. The study recommends further research in this regard.

Analysis of industry needs

Schools offering fashion design should continually analyse industry trends and needs to adjust curricula accordingly and ensure graduates meet current and future industry demands.

Resource accessibility

It is important that further studies explore strategies to improve accessibility of resources, especially for institutions with limited budgets, to enhance the practical application of digital skills and necessary support.

Impact of the COVID -19 pandemic

Evaluate the lasting impact of the COVID -19 pandemic on the adoption of digital technologies in the apparel industry and fashion education. Assess whether these changes are permanent or temporary.

5.13 Overall Conclusion

This study has shown the important role that digital technology can play in improving education in fashion product development. By integrating digital tools and technologies into the curriculum, fashion educators can better prepare students for the needs of the fast-paced apparel industry. The findings of this study provide a roadmap for fashion educators who considers the incorporation of digital technologies into their teaching practices and eventually contribute to the development of more skilled and flexible fashion industry employees.

As the fashion industry continues to embrace digital technologies it is important that fashion education does not lag behind. By embracing the transformative power of technology, fashion educators can empower their students to become the creative and innovative professionals the industry demands. This study highlights that integrating digital technology into fashion product development education is not just a matter of moving with the times but about building the future of fashion education.

This study constitutes an advancement in the understanding of the role that digital technology can serve in the world of fashion education. The findings provide insights for the fashion educators, curriculum developers, and industry professionals who want to integrate digital technology into their respective fields. By continuing to explore the potential of digital technology, we can ensure that fashion education remains relevant, dynamic, and capable of empowering future generations of fashion professionals.

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APPENDICES

APPENDIX A: Research Ethics Certificate from CPUT (Cape Peninsula University of Technology)

Cape Peninsula University of Technology
creating futures

PO Box 1906, Bellville,7535 Symphony Way, Bellville, Cape Town, South Africa
+ 27 (0)21 959 6767 www.facebook.com/cput.ac.za info@cput.ac.za www.cput.ac.za

Office of the Research Ethics Committee
Faculty of Informatics and Design
Room 2.09
80 Roeland Street
Cape Town
Tel: 021-469 1012
Email: ndedem@cput.ac.za
Secretary: Mziyanda Ndede

24 November 2021

Ms Bongiwe Kolisi
c/o Department of Design
CPUT

Reference no: 201100924/2021/39

Project title: The integration of technology into fashion product development education

Approval period: 24 November 2021 – 31 December 2022

This is to certify that the Faculty of Informatics and Design Research Ethics Committee of the Cape Peninsula University of Technology conditionally approves the methodology and ethics of Bongiwe Kolisi (201100924) for Doctor in Applied Art and Design contingent on obtaining site permission from the participating institutions.

Any amendments, extension or other modifications to the protocol must be submitted to the Research Ethics Committee for approval.

The Committee must be informed of any serious adverse event and/or termination of the study.

Dr Blessing Makwambeni
Acting Chair: Research Ethics Committee
Faculty of Informatics and Design
Cape Peninsula University of Technology

APPENDIX B: Walter Sisulu University of Technology (UoT1): Gatekeeper Permission Letter to Conduct Research

WSU
Walter Sisulu University
In pursuit of excellence

DIVISION OF ACADEMIC AFFAIRS AND RESEARCH DIRECTORATE OF RESEARCH AND INNOVATION

Nelson Mandela Drive
Mthatha Campus
Private Bag X1
MTHATHA 5117
Tel: + 27 47 502 2137/2044
502 2185 *wakpan@wsu.ac.za*

Buffalo City
Potsdam Campus
EAST LONDON
Tel: + 43 708 5444
Fax: + 43 708 5458 Fax: +27 47

01 December 2021

Ms Bongiwe Kolisi
Cape Peninsula University of Technology
Department of Clothing & Textile Technology
CAPE TOWN
5100

Dear Ms Kolisi

Gatekeepers Permission Letter to conduct research at Walter Sisulu University

Ethical Clearance Number: 201100924/2021/39

Institution: Walter Sisulu University

A Gatekeeper Letter is hereby granted for the study "**The integration of technology into fashion product development education**" provided that copies of your completed study will be submitted to the Campus Rector of the campus in which the study will be conducted and the Directorate of the Research & Innovation.

All data pertaining to Walter Sisulu University will be treated confidentially and you are required to abide by ethical principles at all times. It is your responsibility to seek consent from participants.

Kind regards

Directorate: Research Development
WALTER SISULU UNIVERSITY
PRIVATE BAG X1 MTHATHA 5117
REPUBLIC OF SOUTH AFRICA
TEL +47 502 2947 FAX: +47 502 2185

Prof W Akpan
Senior Director: Research & Innovation

APPENDIX C: Tshwane University of Technology (UoT2): Gatekeeper Permission Letter to Conduct Research

Tshwane University of Technology
We empower people

Research Ethics Committee

The TUT Research Ethics Committee is a registered Institutional Review Board (IRB 00005968) with the US Office for Human Research Protections (IORG# 0004997) (Expires 14 Jan 2023). Also, it has Federal Wide Assurance for the Protection of Human Subjects for International Institutions (FWA 00011501). In South Africa it is registered with the National Health Research Ethics Council (REC-160509-21).

August 22, 2022

REC Ref #: REC/2022/02/017
Name: Kolisi B
Student #: CPUT

Mr B Kolisi
C/o Prof JC Cronje
Faculty of Informatics & Design
Cape Peninsula University of Technology

Dear Mr Kolisi,

Decision: Gatekeeper Permission – Final Approval

Name: Kolisi B
Project title: *The integration of technology into fashion product development education.*
Qualification: Doctor in Applied Art & Design
Supervisor: Prof JC Cronje
Co-supervisor: Prof D Smal

Thank you for submitting the revised project documents for review by the Research Ethics Committee (REC), Tshwane University of Technology (TUT). In reviewing the documents, the comments and notes below are tabled for your consideration, attention and/or notification:

- **Proposal**
  - The revised proposal is in order.

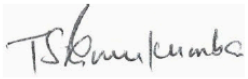
The Chairperson of the Tshwane University of Technology Research Ethics Committee reviewed the revised project documents on July 20, 2022. **Gatekeeper** has been granted to the project.

The proposed research project may now continue with the proviso that:

1) The researcher/s will conduct the study according to the procedures and methods indicated in the **approved proposal**, particularly in terms of any undertakings and/or assurances made regarding the confidentiality of the collected data.
2) The proposal will be submitted to the Committee for prospective ethical clearance if there are any substantial **deviations** and/or changes from the approved proposal.
3) The researcher/s will act within the parameters of any applicable **national legislation, professional codes of conduct**, institutional guidelines and scientific standards relevant to the specific field of study. Strict adherence to the following South African legislation, where applicable, is especially important: Protection of Personal Information Act (Act 4 of 2013), Children's Act (Act 38 of 2005) and the National Health Act (Act 61 of 2003).
4) The researcher will inform the REC as soon as possible of any **adverse events** involving research participants that may have occurred during the course of the study. It includes the actions and/or processes that were implemented to mitigate and/or prevent any further injuries and/or adverse outcomes.
5) The researcher will inform the REC of any **new or unexpected ethical issues** that may have emerged during the course of the study, as well as how these ethical issues were addressed. The researcher must consult with the REC for advice and/or guidance in any such event.
6) The current ethics approval expiry date for this project is **August 21, 2024**. No research activities may continue after the ethics approval expiry date. An application for the extension of ethics approval must be submitted for projects that need to continue beyond the expiry date.

Note:
The reference number [top right corner of this communiqué] should be clearly indicated on all forms of communication [e.g. Webmail, E-mail messages, letters] with the intended research participants.

Yours sincerely,



Prof TS Ramukumba
Chairperson: Research Ethics Committee
[TUTRef#2022=02=017=KolisiB]

APPENDIX D: Participant Consent Letter

Cape Peninsula
University of Technology

FID/REC/ICv0.1

FACULTY OF INFORMATICS AND DESIGN

Individual Consent for Research Participation

Title of the study:	**The intergration of technology into Fashion Product Development.**	
Name of researcher:	Bongiwe Kolisi	
Contact details:	email: kolisib@cput.ac.za	phone: 0834693656
Name of supervisor:	Prof J.C Cronje	
Contact details:	email: cronjej@cput.ac.za	phone:0825585311

Purpose of the Study: The proposed research aims to propose an integrated learning approach to fashion product development, focusing on garment production and pattern making. It seeks to figure out how the physical learning spaces for apparel product development can be enhanced digitally as part of blended learning.

Participation: My participation will consist essentially of data recording, rather than to participate in the data collection process.

Confidentiality: I have received assurance from the researcher that the information I will share will remain strictly confidential unless noted below. I understand that the contents will be used only for a PhD study and that my confidentiality will be protected by coding to secure its identity, and will be stored accredited repositories for long-term preservation and curation. Furthermore, the supply of personal information to the researcher will be voluntary and treated confidentially in accordance with South Africa's Protection of Personal Information Act (POPIA).

Anonymity: The use of subject's images on videos or photos will be voluntary, and faces will blanked out if subjects prefer.

Conservation of data: The data collected such as recorded iinterviews and videos will be kept in a secure manner through storing it in accredited repositories for long-term preservation and curation. Only the researcher, supervisors and examiners of the study will have access to the stired data.

Voluntary Participation: I am under no obligation to participate and if I choose to participate, I can withdraw from the study at any time and/or refuse to answer any questions, without suffering any negative consequences. If I choose to withdraw, all data gathered until the time of withdrawal will be destroyed if permission for use is not granted by me.

Additional consent: I make the following stipulations (please tick as appropriate):

	In thesis	**In research publications**	**Both**	**Neither**
My image may be used:				
My name may be used:				
My exact words may be used:				
Any other (stipulate):				

Acceptance: I, (print name)_____

agree to participate in the above research study conducted by *Bongiwe Kolisi* of the Faculty of Informatics and Design Applied Arts in Design at the Cape Peninsula University of Technology, which research is under the supervision of Prof J.C Cronje.

If I have any questions about the study, I may contact the researcher or the supervisor. If I have any questions regarding the ethical conduct of this study, I may contact the secretary of the Faculty Research Ethics Committee at 021 469 1012, or email naidoove@cput.ac.za.

Participant's signature: _____ Date: _____

Researcher's signature: _____ Date: _____

APPENDIX E: Research Interview Schedule

Cape Peninsula University of Technology

Interview Schedule
Researcher: B. Kolisi
Student number: 201100924
Title: The integration of digital technologies into Fashion Product Development education.

Background to the structure of the interview questions

Research Aim: The overall purpose of this research is to explore the dynamics between design technology, and pattern making and garment construction and its implications for teaching and learning. The research questions are listed in Table1 below.
The line of inquiry revolves around the following aspects:

- knowing the relationship between design technology and fashion product development.
- knowing how a change in technology will affect teaching and learning in Fashion Product Development.

The interview questions will be open-ended, and the line of inquiry will be written as a spoken phrase. Table 1 shows the key line questions, the rationale for asking the questions and participants in which the questions will be asked. The questions in the table below will serve as a framework for the types of inquiries I might ask to elicit further information.

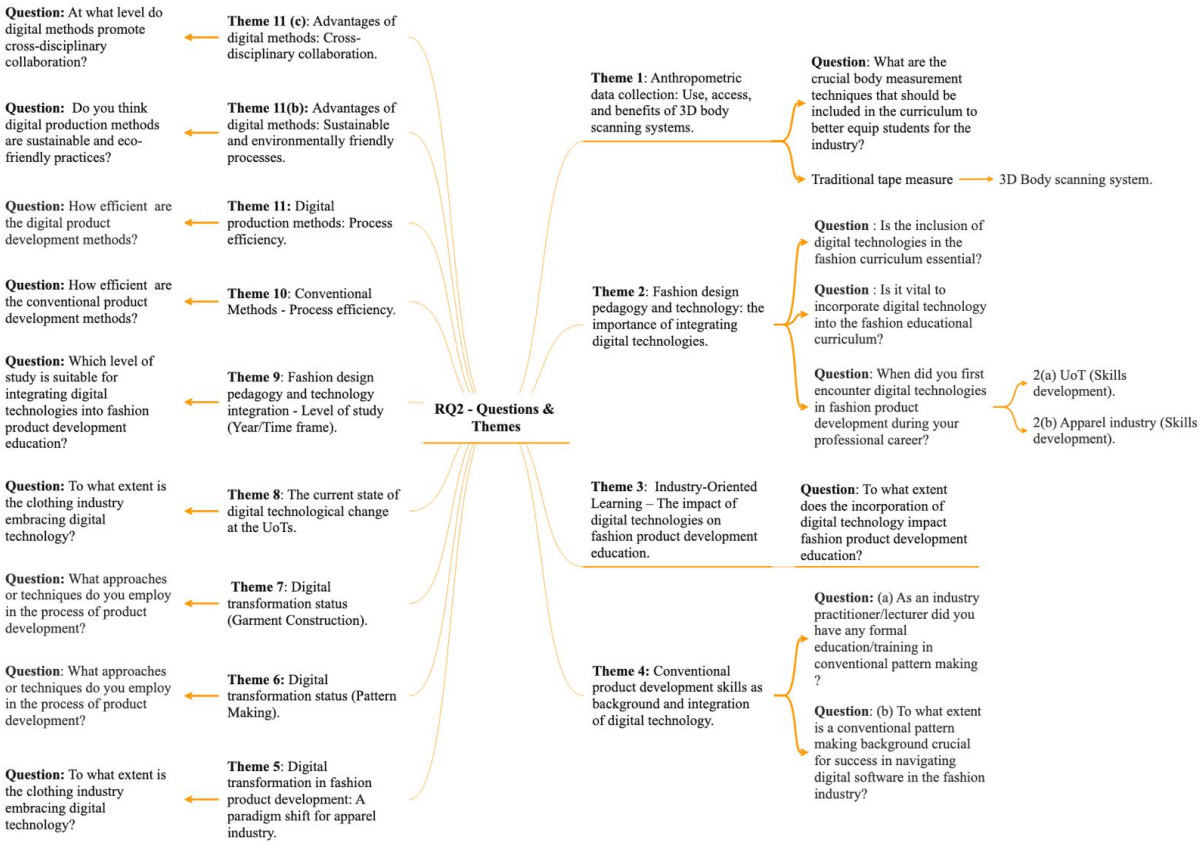
To answer question two, consistent questioning will be utilized to find areas of commonality and determine where responses coincide and where they radically differ.

The use of technology

Table 1: An outline of the Research Interview Questions, (Author's Construct).

Interview Questions	Rationale	Who
Q1 - What is the relationship between current design technology and fashion product development?		
What technologies do you use?	To determine a mix of traditional and current technology	Industry practitioners Lecturers Alumni
How have these technologies changed over the past five years?	To understand the trajectory of innovation with technology	
Q2 - How does a change in technology affect teaching and learning in fashion product development?		
How would you teach differently if you were a lecturer, compared to the way you were taught?	To figure out how to improve the methodologies for teaching fashion product development.	Industry practitioners Alumni Final year students
What effect does technological advancement have on teaching and learning?	To identify the potential for change because of the integration of technology into the fashion product development.	

APPENDIX E: Research Question Two Emerging Themes and Interview Questions



APPENDIX F: Data Analysis Spreadsheet: RQ1, RQ2 and Keywords

https://docs.google.com/spreadsheets/d/1cj8VfUSKTDfFAPY8aDL4WqZt5O829NCS/edit?usp=sharing&ouid=110191107532144115020&rtpof=true&sd=true

APPENDIX G: Editing Certificate

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To Whom It May Concern

This document certifies I have copy-edited the following thesis by Bongiwe Kolisi.:

THE INTEGRATION OF DIGITAL TECHNOLOGIES INTO FASHION PRODUCT DEVELOPMENT EDUCATION

Please note this does not cover any content, conceptual organisation, or textual changes made after the editing process.

Best regards

Dr Patricia Harpur

20 November 2023