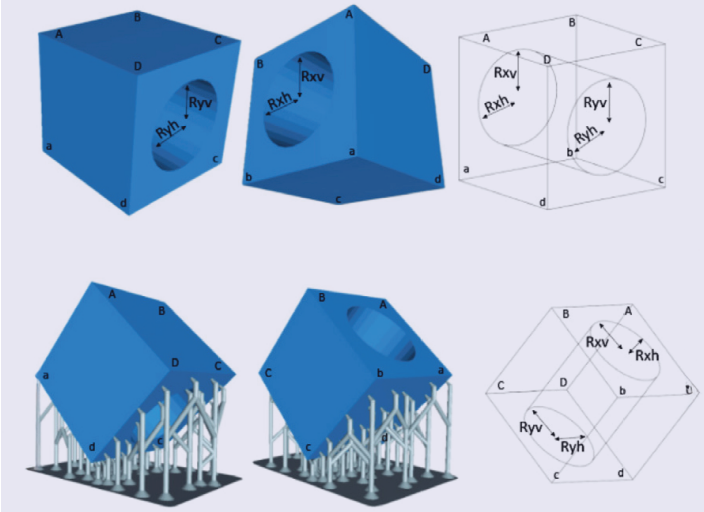
ISSN 2217-379X

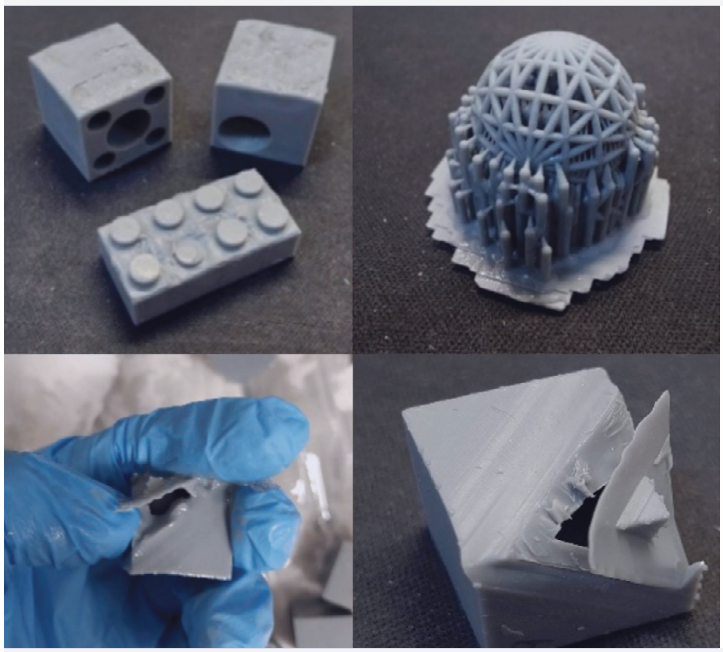
University of Novi Sad
Faculty of Technical Sciences
DEPARTMENT OF GRAPHIC
ENGINEERING AND DESIGN

Volume **16**
Number **3**
September **2025**

JGED

JOURNAL OF GRAPHIC ENGINEERING AND DESIGN





JGED

JOURNAL OF GRAPHIC ENGINEERING AND DESIGN

3/2025

Volume 16, Number 3, September 2025.

Published by

UNIVERSITY OF NOVI SAD, SERBIA
Faculty of Technical Sciences
Department of Graphic Engineering and Design

PUBLISHED BY

University of Novi Sad
Faculty of Technical Sciences
DEPARTMENT OF GRAPHIC ENGINEERING AND DESIGN

Address:
Faculty of Technical Sciences,
Department of Graphic
Engineering and Design,

Trg Dositeja Obradovića 6
21000 Novi Sad, Serbia

Telephone numbers:
+381 21 485 26 20
+381 21 485 26 26
+381 21 485 26 21

Fax number:
+381 21 485 25 45

Email:
jged@uns.ac.rs

Web address:
www.grid.uns.ac.rs/jged

Frequency: 4 issues per year
Printing: Faculty of Technical Sciences, Department of Graphic Engineering and Design

Circulation: 200

Electronic version of journal available on www.grid.uns.ac.rs/jged

E-ISSN 2217-9860

The journal is abstracted/indexed in the Scopus and Directory of Open Access Journals

CIP - Katalogizacija u publikaciji
Biblioteka Matice srpske, Novi Sad
655
JGED : Journal of Graphic Engineering and Design / editor Dragoljub Novaković. - Vol. 1, No. 1 (nov. 2010) - Sciences, Department of Graphic Engineering and Design,
2010-. 30 cm
Četiri puta godišnje
ISSN 2217-379X
COBISS.SR-ID 257662727

Art Director
Uroš Nedeljković

Layout design
Bojan Banjanin
Tamara Ilić

Journal cover design
Nada Miketić

JOURNAL OF GRAPHIC ENGINEERING AND DESIGN

Volume 16, Number 3, September 2025.

Contents

Professional paper
http://doi.org/10.24867/JGED-2025-3-005

The development of community products using design thinking based on cultural heritage: A case study of Kamphaeng Phet Province, Thailand

ABSTRACT

The purposes of this research were 1) to study community products towards the development of product potential for tourism, 2) to develop community products using design thinking methods using the cultural heritage capital, and 3) to assess tourist satisfaction towards community products based on cultural heritage. The research was conducted in three phases: Phase 1 studying community products towards the development of product potential for tourism, Phase 2 developing community products using design thinking methods using the cultural heritage capital, and Phase 3 assessing tourist satisfaction towards community products based on cultural heritage. For Phase 1, two cultural tourism communities in Kamphaeng Phet Province, Thailand, were chosen for this research. The development of community products included consideration of community potential, cultural heritage, and tourism products (CCT), and these resulted in CCT Model. For Phase 2, the use of the five stages of design thinking and design thinking tools were employed with CCT Model of the communities in order to create their community products based on cultural heritage (i.e., three products for each community). For Phase 3, the satisfaction of 100 tourists were assessed in terms of five aspects, including 1) connection with tourism, 2) connection with cultural heritage, 3) value based on identity and cultural heritage, 4) marketing ability, and 5) product quality. The community products were successfully created, and the overall satisfaction assessment result was at a high level. Recommendations for further research are also discussed.

KEY WORDS
community products, design thinking, cultural heritage

Pojtom Narongwit
Nirat Soodsang

Naresuan University, Department of Art and Design, Faculty of Architecture, Art and Design, Phitsanulok, Thailand

Corresponding author:
Pojtom Narongwit
e-mail:
gapomdesign@gmail.com

First received: 3.5.2024.
Revised: 19.12.2024.
Accepted: 9.1.2025.

Introduction

Cultural heritage is something that humans have invented or created since the past, and it has been inherited from generation to generation. This includes, for example, antiques, language, dresses, various cultural traditions, and so on.

Regarding the term "cultural heritage", there are important characteristics based on the word "culture", relating to the period of inheritance or existence. It is accepted as something of value which shows the identity or uniqueness of that community or society.

It is something to be proud of for people in the society. As a result, the design and development of cultural heritage products is one of the most important issues affecting the perception of product users as well as the communication between cultural heritage products and the users (Hofstede, Hofstede & Minkov, 2010). It can be said that, the development of community products is a process that arises from the foundation of the community's culture (Spencer-Oatey, 2012).

Therefore, the relationship between community products and culture influences the demand for the products and the expression of those products.

Tschimmel (2012) stated that design thinking is a mechanism that drives innovation. It does not only drive designers, but it can also contribute to many careers and all types of organisations through process models and design thinking tools based on the combination of "thinking" and "design". This provides interdisciplinary careers with the opportunities to use tools and design to solve problems and develop products and services. These days, design thinking is not only a cognitive process or a conceptual framework, but it is also a powerful toolkit for developing any products and innovation by logically linking creative design approaches with traditional business thinking.

From this concept, the researchers therefore would like to develop community products by using people in the community as the center to meet the needs of consumers, product selection, and services in which the designers must be agents in solving various problems. This notion is consistent with Lawson (2012) who places importance of people in the community as a center in responding to customers' needs. As a result, this present research conducted a case study in two communities, namely Khlong Suan Mak Ban Nakhon Chum Community and Ban Wang Phra That Trai Trung Community in Kamphaeng Phet Province, Thailand. They were chosen since they were cultural tourism communities of Kamphaeng Phet Province, and Kamphaeng Phet Province is a province that has been certified as "World Cultural Heritage City" as certified by UNESCO in 1991 (UNESCO, n.d.).

The study was conducted by using the design thinking with various design thinking tools. From the study of the design thinking method tools of Lewrick, Link & Leifer (2018) in order to solve problems for communities in linking their own community products with tourism based on cultural heritage. People in the community were the center of thinking, creativity, design, and the development of community products. This aimed to create valuable tourism products of world cultural heritage cities. This research therefore explored and organised activities with participation from the communities using the following design thinking tools: 1) creating a persona, 2) asking WH questions (i.e., what, who, why, where, when, and how questions), 3) considering multiple perspectives, 4) creating a flower map, 5) structuring and selecting ideas, 6) making an idea communication sheet, 7) considering prototype creation, 8) using feedback-capture grid, and 9) using a retrospective board.

Research objectives

1. To study community products towards the development of product potential for tourism
2. To develop community products using design thinking methods using the cultural heritage capital
3. To assess tourist satisfaction towards community products based on cultural heritage

Literature Review

The concepts of design thinking

Johansson-Sköldberg, Woodilla & Çetinkaya (2013) analysed that the design thinking from two main source groups: designers and businessmen. These two groups place importance on working in a group. This is an important factor in the design thinking process. When the design thinking processes of both groups are properly integrated, it results in creating good work. Seidel & Fixson (2013) were interested in using design thinking with interdisciplinary groups in order to help students from different professional fields who had little design experience to display their creative designs. From their research, it was found that the design thinking model could help to create the ideas and select ideas. However, when it had been used for a long time and repeatedly, it would not create new ideas. Additionally, although working in a group helped to create effective thinking, brainstorming depended on the composition of people in the group who had little experience in designing. Consequently, this could only succeed if the group received good advice to help them find ways to combine their ideas.

It is important to note that, when conducting this present research, the researchers brought design thinking, transferred it to people in the communities, and acted as "facilitators" to provide advice, build confidence, and create courage to the communities to express themselves.

Jobst et al. (2012) conducted a study comparing creative confidence and self-efficacy. It was found that there were four factors that led to confidence in creativity, including 1) experience from experts, 2) experience from reading, listening, and studying other people's work, 3) creating motivation from suggestions, and 4) emotional state and expression. These factors help to create a positive experience and confidence in creating designs. Also, Goldschmidt & Rodgers (2013) studied the design thinking of three groups of designers, aiming at comparing individual differences in their design thinking process. It was revealed that each individual would solve the problems differently and take different time.

Abraham, Howard & Asinyo (2022) studied the use of design thinking methods in small and medium-sized textile enterprises in Ghana. The results showed that the use of design thinking methods based on human-centered design made the products connected to and influenced by customer needs. These entrepreneurs could also use different strategies to find solutions for customers and continuously interact with customers to solve innovative and creative problems. It was also found that there was a lack of empirical studies on design thinking in small and medium-sized enterprises (SMEs) in textile,

such as organisational design thinking in the context of developing countries. Therefore, there is a call for the study of innovation in SMEs, which is of great importance in economic development (Daksa et al., 2018; Fu, Pietrobelli & Soete, 2011; Pisoni, Michelini & Martignoni, 2018).

Lake et al. (2024) explored and extended current research, aiming to understand the value and limitations of teaching design thinking in higher education. The findings showed that following a structured learning process, participating in active listening, and focusing on others' perspectives are the most valuable design thinking practices across disciplines.

Moreover, design thinking also encourages collaboration and project framing that emphasizes shared critical analysis. From a study by Cai, Lin & Zhang (2023) focusing on when and how to use the design thinking process in innovation development, it was found that the steps that lead the implementation of design thinking process occurs in three distinct phases, namely fuzzy front end, development and testing, and commercialization. It has been shown that organisations use design thinking in four design practices: 1) user-centeredness, 2) embracing diversity, 3) visualization, and 4) iteration. This aims to transit from the fuzzy front end to development and testing, and it finally leads to commercializing new products.

Gao & Yu (2023) conducted a study on knowledge exchange of SMEs service innovation using design thinking. It was found that SMEs can use and incorporate design thinking in order to think together and leverage the group's knowledge to achieve service innovation. Also, it demonstrates that the mindset of leaders, executives, and employees is critical to successful design thinking implementations. Importantly, design thinking should be emphasized with executives first, and it should also focus on employee participation. Carella et al. (2023) researched the design thinking concepts for entrepreneurs. The responses to the questionnaire regarding practical participation revealed that entrepreneurs are sensitive to diverging and converging dynamics and to the visualization ability. In addition, they are aware of the benefits and capabilities of design thinking from the early phases of the development to the building of a specific design mindset.

Li, Ho & Yang (2019) conducted a design thinking-based study of the prospect of the sustainable development of traditional handicrafts. It was found that, based on the use of design thinking proposed by Hasso Plattner Institute of Design at Stanford University (2010) in exploring the opportunities of sustainable development of traditional handicrafts, there were 24 “indicators of the sustainable value of handicraft design” and four value dimensions, namely, “material and innovative value”, “handicraft and cultural value”, “empirical and local value”, and “sharing and interactive value”.

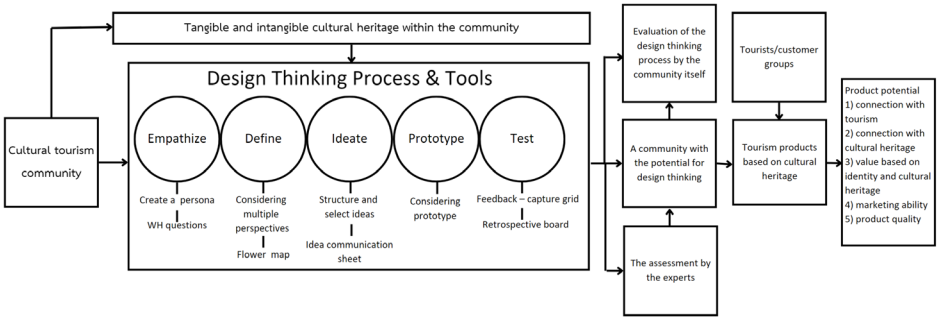
It can be concluded that exploring the sustainable development of handicraft design also forms the sustainable development model of design thinking.

In addition, many research studies also found that design thinking process is an important process and guideline that contributes to innovation development, product design and development, and the development of business models for sustainability from the participation of leaders and people in the organisation (Andrews, 2015; Elsbach & Stigliani, 2018; Geissdoerfer, Bocken & Hultink, 2016).

Conceptual framework used in this research

As for the conceptual framework used in this research, the researchers analysed related documents and research studies by drawing on a design thinking model that is widely used in solving problems, namely the Design Thinking Model proposed by Hasso Plattner Institute of Design at Stanford University (2010).

The five stages of Design Thinking were applied together with the tools of Lewrick, Link & Leifer (2018) to suit community potential. In this research, the communities brought their own cultural heritage, both tangible and intangible cultural heritage to be a question/problem of design thinking. Each step passed the assessments of the design thinking process, including a self-assessment and an assessment by experts who visited the areas to observe as well as creating criteria for evaluating results according to the research objectives. The conceptual framework is shown in Figure 1 below.



» **Figure 1:** *The conceptual framework of this study*

Research Method

In this study, the research procedure was divided into three phases as follows.

Phase 1: Studying community products towards the development of product potential for tourism

In this phase, the researchers studied the format of community products from the case study of two cultural tourism communities: 1) Khlong Suan Mak Ban Nakhon Chum Community and 2) Ban Wang Phra That Trai Trung Community in Kamphaeng Phet Province, Thailand. From the area visits, observation, and group discussion, the researchers analysed the original approaches used in developing their community products that were used to link existing cultural heritage with their community products. In addition, the researchers also synthesised these data into a model that communities used to develop the potential of tourism products based on cultural heritage.

Phase 2: Developing community products using design thinking methods using the cultural heritage capital

After getting the model that was used as a guideline for developing product potential for tourism based on cultural heritage in Phase 1, this guideline was applied into design thinking activities according to the Design Thinking Model proposed by Hasso Plattner Institute of Design at Stanford University (2010).

The five stages of Design Thinking included 1) empathize, 2) define, 3) ideate, 4) prototype, and 5) test. Additionally, the design thinking tool of Lewrick, Link & Leifer (2018) was also employed as a guideline for organising design thinking activities by using people in the communities as a base. The questions/problems were then defined and linked cultural heritage within the community with tourism products in the community. The details of this process are as follows.

1. As for the "Empathize stage", the tools used in organising activities were as follows.
    a. Creating a persona: The researchers created a persona by having the community to brainstorm, draw hypothetical characters of the target group, and identify the characteristics of the target group who were the community's product buyers onto a large sheet of paper, and discuss and summarise the results together.
    b. Asking WH questions: After creating a Persona, the researchers asked the community to ask and answer the WH questions about questions/problems and solutions in developing the products based on cultural heritage. The researchers and the community then discussed and summarised the results together.
2. As for the "Define stage", the tools used in organising activities were as follows.
    a. Considering multiple perspectives: It was a consideration of various perspectives. The community brainstormed to propose ways to use the cultural heritage of the area in connection with the product development by jointly presenting cultural heritage in the community both in tangible and intangible forms from various perspectives. The obtained ideas were then written on a large sheet of paper. After that, they were voted for appropriate cultural heritage, and the results were summarised together.
    b. Creating a flower map: It was a flower map. The community brainstormed and selected only important issues in the product development that were connected on the basis of cultural heritage from various issues. The obtained ideas were then written on five-eight flower petals on a large sheet of paper by jointly making suggestions and selecting. The results were then summarised together.
3. As for the "Ideate stage", the tools used in organising activities were as follows.
    a. Structuring and selecting ideas: The researchers structured and selected ideas. In this stage, the community members were given small pieces of paper, and they were asked to present their ideas through drawing the product. These drawings were then put on the board by classifying the ideas into three parts: 1) solving the question/problem, 2) being interesting although it did not answer the question/problem, and 3) others (i.e., apart from the question/problem). The guidelines and types of products for the development were then summarised together
    b. Making an idea communication sheet: It was idea communication sheet. The community brought the products from the structure and select ideas summary to design a simple sketch, including writing an explanation of the concept and development guidelines. The results were then summarised together.
4. As for the "Prototype stage", the tools used in organising activities were as follows.
    a. Considering prototype creation: It was consideration for creating a prototype. The researchers used the sketches from the Idea communication sheet to create prototype products. After that, the community considered, revised, developed the prototypes with participation, and summarised the results of prototype development.
5. As for the "Test stage", the tools used in organising activities were as follows.

a. Using feedback-capture grid: It was feedback-capture grid. The researchers brought the prototype products to distribute and test for sale. In this stage, the community recorded feedback of tourists on community products, divided into four areas: 1) tourists' preferences, 2) purchasing needs, 3) questions that arise, and 4) suggestions/Ideas. The results were then summarised together.
b. Using a retrospective board: It was a retrospective board. In this step, the community reviewed the design thinking process that took place by brainstorming and presenting issues to the process that had been carried out, divided into four issues: 1) things that were beneficial and needed to be continued, 2) things that would not be continued, 3) things that would like to be done further, and 4) things that were not important. The results were then summarised together.

By organising activities according to each design thinking tool, in addition to the community being able to evaluate the processes that occurred on their own with the Retrospective board, there was also observation by three experts in design thinking. They assessed the design thinking process that occurred in the community in each design thinking tool in terms of participation of people in the community, solving problems and developing ideas of people in the community, and analysing and summarising the overall results from community processes with 5-point rating scale criteria.

Phase 3: Assessing tourist satisfaction towards community products based on cultural heritage

In this phase, the community products developed from the design thinking process were brought to an exhibition and trial sales at the cultural market which was a cultural tourist spot.

The data from a group of 100 tourists were collected using online assessments in order to assess their satisfaction according to five aspects obtained from a synthesis of related documents and research: 1) connection with tourism, 2) connection with cultural heritage, 3) value based on identity and cultural heritage, 4) marketing ability, and 5) product quality.

Results and Discussion

The results and discussion of this research are presented according to the three research objectives of this study.

1. The results regarding Research Objective 1 aiming at studying community products towards the development of product potential for tourism

From visiting the areas to study the patterns and guidelines for creating community products towards the development of product potential for tourism, the researchers chose two communities that were outstanding in developing products for cultural tourism in Kamphaeng Phet Province as follows: 1) Khlong Suan Mak Ban Nakhon Chum Community and 2) Ban Wang Phra That Trai Trung Community.

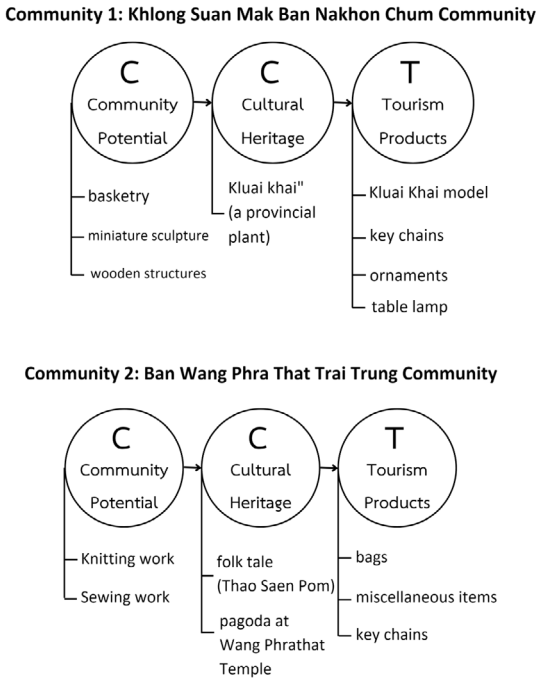
Based on the in-depth interviews with leaders and representatives in each community (10 people of each community) as well as following the process of creating cultural products in both communities, guidelines for developing traditional community products could be summarised. This consisted of taking the potential of the community into account, linking with cultural heritage, and creating tourism products. The researchers named the process that occurred in the communities as CCT Model. The meaning of each abbreviation is as follows.

C stands for Community Potential. It means wisdom, skills, including abilities and efficiency within the community in terms of administration and allocation of resources within the community. It is the starting point and basis of the community development. Various products come from knowledge, abilities, and beliefs that are used to solve basic community problems. The community creates products that are basic to life and are the basis of skills and the potential of the community according to the potential and possibilities of the community in a sustainable way.

C stands for Cultural heritage. It refers to cultural capital that is a bond and has been passed on to the next generation, both in a tangible and intangible forms. It is an important element in expressing the identity of that area, whether it is the form of product styles, customs, traditions, beliefs, places, geography, and so on. They are important “ideal resources” in developing products to connect with tourism based on cultural heritage. It is part of the cultural capital that is applied as inspiration and components in creating product styles under the identity of the area.

T stands for Tourism products. It refers to the development of community product formats to be linked with tourism based on cultural heritage. It is the use of cultural heritage capital as a resource for the development of formats and methods for presenting products according to the potential of the community. It is presented in the form of products for tourism that has the identity of the area linked to tourism that reflects the charm of the way of life, culture, history, and stories. It is something that adds value to tourism products, suitable for buying for use and buying them as souvenirs for tourists.

The CCT Model of these two communities in this present study is shown in Figure 2 below.



» **Figure 2:** *CCT Model*

From the results of the study, it was found that the guidelines for developing cultural products of both communities included the same factors, namely taking the potential of the communities into consideration first. It needed to consider the appropriate skills and work performance of the community to create their community products. In Community 1, it was outstanding in basketry, miniature sculpture, and wooden structures. After the community understood its own potential, there is therefore a connection with cultural capital in that they brought "Kluai khai" (i.e., lady finger banana) which is a provincial plant and is remembered in the provincial motto, to link to the product style for cultural tourism, such as the Kluai Khai model, Kluai Khai key chain, Kluai Khai ornaments, and lamps as provincial souvenirs.

While Community 2 had potential in knitting and sewing work. This led to bridging cultural capital by using the story of the folk tale "Thao Saen Pom" that is well known in Thai folk tales. It is both a legend and a belief that references events from real tourist attractions in the community. It is a miraculous story about a man named “Saen Pom” who was born with an ugly face. There were nodes all over the body. He lived his life by growing eggplant trees. When the daughter of the ruler of Nakhon Trai Trung ate Saen Pom's eggplant, she miraculously became pregnant. After that, the governor of Nakhon Trai Trung gave his daughter to marry Saen Pom. After that, Saen Pom met a magic drum from a monkey in the forest. Saen Pom played the drum and found that he could make any wish. When he played the magic drum, his wish would come true. Saen Pom then asked for a blessing that he would be cured of the nodes all over his body and become a handsome young man. Also, he beat the drum to create the city of Thepnakorn and appointed himself as Thao Saen Pom from then on.

From the story of a famous folk tale, the Thao Saen Pom Shrine, a tourist attraction, was built for tourists to worship and ask for blessings. The community has therefore connected it to cultural tourism products, such as bags, key chains, and various miscellaneous items and has adopted the symbol of the "gong" (i.e., drum) which is a musical instrument that strikes loudly as a symbol.

It was inserted with embroidery in the shape of an eggplant to connect with the story and inserted a picture of the pagoda at Wang Phra That Temple, which is an important tourist attraction in Trai Trung Subdistrict.

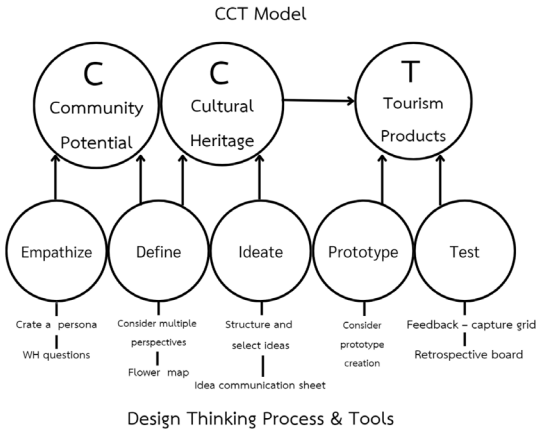
The CCT Model makes it evident that although these two communities had the different potentials and skills of the people in the communities, there were ways to use those potentials to connect with the cultural heritage of their own areas according to their understanding. Additionally, they could use those cultural capitals as inspiration to create cultural tourism products in various forms. This is the patterns and ways of thinking that occur naturally and in the way of the community. The use of the design thinking process helps in making the products more connected and influenced by customer needs according to the concept of Abraham, Howard & Asinyo (2022).

Also, from the community's model, it is also consistent with Cai, Lin & Zhang (2023) about the three steps in which design thinking can be implemented as fuzzy front end, development and testing, and commercialization. In other words, it is about considering problems and planning based on the community's potential, the design and development, the test based on the basis of cultural heritage, and the production and actual selling the products to tourists.

2. The results regarding Research Objective 2 aiming at developing community products using design thinking methods using the cultural heritage capital

Once the researchers obtained guidelines and ways of thinking about creating community products that were linked to the community's cultural heritage, which is the CCT Model, the researchers therefore interspersed it with design thinking activities that consisted of various tools as shown in Figure 3 in order to organise them and ways of thinking in developing community products based on the cultural heritage in their own areas of both communities.

The researchers analysed the results from organising activities with both communities using design thinking tools, following the 5-stage design thinking process, consisting of nine design thinking process tools, divided into nine activities, as shown in Figure 3.



» **Figure 3:** *Bringing the design thinking process to link with the community's CCT Model*

Also, this included participatory observation with the community by three experts in design thinking in order to evaluate the design thinking process that occurred in the community in each activity in terms of participation of people in the community, solving problems, and developing ideas of people in the community. The overall analysis results for each design thinking tool can be summarised as shown in Table 1 below.

From Table 1, the results showed that the overall design thinking process in both communities were at a high level ($\bar{x}$ = 3.76, S.D. = 0.79). The results can be classified according to the five design thinking stags and tools as follows.

As for the Empathize stage, the overall evaluation result was at a moderate level ($\bar{x}$ = 3.35, S.D. = 0.68), and the tool "Creating a persona" revealed at a high level ($\bar{x}$ = 3.63, S.D. = 0.61).

It was observed that the communities understood and analysed a character creation step by step. There were facilitators to stimulate the community and give advice in the process on certain issues. Both communities created fictional characters who were the same group of customers that needed to be taken into consideration, that is, government officials. They were the people with an age range of 30-40 years and above, with a salary of 25,000 - 30,000 baht. They were a group for which the government campaigned to have Thai cultural dress and use cultural products. They had the habit of liking beautiful products that conveyed meaning and had storytelling at a price that was not very high. In addition, in terms of the WH questions tool, the evaluation result was at a moderate level ($\bar{x}$ = 3.17, S.D. = 0.66).

Table 1

The results of the evaluation of the community's design thinking process in order to develop products based on cultural heritage classified by design thinking stages and tools

Design thinking process	**Tools**	**The level of results of the design thinking process for the product development based on cultural heritage**					
		Community 1 Khlong Suan Mak Ban Nakhon Chum Community		Community 2 Ban Wang Phra That Trai Trung Community		The sum of the design thinking processes in both communities	
		$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.
Empathize	Creating a persona	3.80	0.68	3.47	0.52	3.63	0.61
	Asking WH questions	3.33	0.70	3.00	0.59	3.17	0.66
Total						3.35	0.68
Define	Considering multiple perspectives	4.50	0.52	4.67	0.49	4.58	0.50
	Making a flower map	4.27	0.59	4.47	0.52	4.37	0.56
Total						4.46	0.54
Ideate	Structuring and selecting ideas	3.50	0.52	3.75	0.75	3.63	0.65
	Idea communication sheet	3.22	0.67	3.22	0.44	3.22	0.55
Total						3.45	0.63
Prototype	Considering prototype creation	3.80	01.08	04.07	0.80	3.93	0.94
Total						3.93	0.94
Test	Feedback – capture grid	3.96	0.62	3.67	0.56	3.81	0.61
	Retrospective board	3.78	0.83	3.56	0.73	3.67	0.77
Total						3.77	0.65
Total of all aspects		3.79	0.78	3.72	0.79	3.76	0.79

It was revealed that the facilitators must stimulate the communities on many issues that the communities still did not feel comfortable to ask questions about, for example, what the problems were and how to solve the problems. This is because most community members were considerate of community leaders and were careful in asking and answering questions. Most of the questioning and answering occurred from the group of the community leaders who opened the issue.

This makes it necessary to use the facilitators within the activities to help build confidence in the community to be more assertive. This is in line with Jobst et al. (2012) in building confidence, motivation, and the emotional state and expression of community groups and Gao & Yu (2023) in the design thinking of SMEs in that it is necessary to emphasize understanding of design thinking with the executives or community leaders first and focus on the participation of employees or community members.

In this present study, both communities had a consistent answer, namely, wanting to develop community products into tourism products with cultural value. They needed support from the government and related agencies in order to connect cultural capital and create story telling for products. The current problem arose from communities developing products and selecting cultural heritage as inspiration to create their own products without good advice in terms of design. Therefore, this problem should be solved from within the communities by creating various knowledge and promoting it in marketing to make community products outstanding.

As for the Define stage, the overall evaluation result was at a high level ($\bar{x}$ = 4.46, S.D. = 0.54). Regarding the tool "Considering multiple perspectives", the evaluation result was at the highest level ($\bar{x}$ = 4.58, S.D. = 0.50). This is because it is a brainstorming session based on the potential of the community and the cultural heritage that the community should had in connecting together by listening to suggestions and critiques with participation. This is consistent with Lake et al. (2024) who examined current research to understand the value and limitations of teaching design thinking that following a structured learning process, participating in active listening, and focusing on others' perspectives were the most valuable design thinking practices. Moreover, design thinking also encourages collaboration and project framing that emphasizes shared critical analysis.

From the observation results, it was found that both communities were able to carry out the procedures very well and were able to analyse data and present it themselves by offering cultural heritage in the communities, both in tangible and intangible forms from various perspectives, writing it on a large sheet of paper, and voting it together for appropriate cultural heritage. Moreover, the communities had a wide range of opinions. That is, Community 1 selected the outstanding cultural heritage of the community, namely 1) Wat Phra Borommathat Nakhon Chum which is an important tourist attraction of the province, 2) Nopphra traditional music festival, 3) Kamphaeng Phet Historical Park, and 4) Miang, which is an ancient local food of the community, respectively. Community 2 selected the outstanding cultural heritage of the community, which is 1) the folk tale of Thao Saen Pom and 2) the pagoda at Wang Phra That Temple which is important tourist attractions of the community, respectively.

In terms of the flower map tool, the evaluation result was at a high level ($\bar{x}$ = 4.37, S.D. = 0.56). The communities determined together the key development issues that were equally important and removed unimportant issues by brainstorming and writing on flower-shaped paper. The communities could do well by having facilitators to stimulate sometimes. Both communities had identified five consistent product development issues, which could be summarised as follows. First, the products must be connected to the story and culture of the community. Second, the product must be connected to community tourism. Next, the products must be created by the community participating in thinking and being the identity of the community. Fourth, the products must be suitable for marketing and having markets to support it. Finally, the products must be of high quality and attractive to tourists.

As for the Ideate stage, the overall evaluation result was at a moderate level ($\bar{x}$ = 3.45, S.D. = 0.63). The tool "Structuring and selecting ideas" revealed at a high level ($\bar{x}$ = 3.63, S.D. = 0.65). The results from the observation showed that both communities were able to carry out the steps well. The facilitators must stimulate the communities and encourage people in the communities to express themselves in drawing and proposing ideas for developing products linked to the cultural heritage that were selected in the previous process. From the conclusion of products that met the needs of the community, the Community 1 defined their products for linking cultural heritage, consisting of 1) wooden table lamps, 2) handle bags, and 3) key chains of miniature food replicas (i.e., Miang). The Community 2 defined their products, consisting of 1) Thai traditional round-neck sleeveless collar shirts, 2) shoulder bag, and 3) a gong-shaped key chain from the story of Thao Saen Pom. In terms of the tool "Idea communication sheet", the evaluation result was at a moderate level ($\bar{x}$ = 3.63, S.D. = 0.65). The communities were pushed and courage to express themselves by the process. From linking products and cultural heritage in designing the sketch, it was found that both communities still did not feel comfortable to express themselves about painting since they were shy and afraid that it would be beautiful and not the same as what they thought. Therefore, this had to rely on the facilitators to help guide and encourage them throughout the painting.

As for the Prototype stage, the overall evaluation result was at a high level ($\bar{x}$ = 3.93, S.D. = 0.94). By the tool "Considering prototype creation", from the observation, it was found that both communities were able to create product prototypes linked to cultural heritage from the Define and Ideate stages very well, with the facilitators stimulating thinking on certain issues. The Community 1 had graphics work related to the Nopphra traditional music festival and Kamphaeng Phet Historical Park to be used with wooden table lamp products and a handle bag. Also, key chains of miniature food replicas were designed using a local food model (i.e., Miang) to help create a story along with a model "Kluai khai" (i.e., lady finger banana) which was famous fruit of the province. The Community 2 had the story of Thao Saen Pom to convey as embroidery-knitting in the shape of a "gong" (i.e., drum) which is a symbol of a musical instrument that strikes loudly, corresponding to the story of the magic drum of Thao Saen Pom. In addition, there was sewing cloth into the shape of an eggplant and an eggplant flower to represent Thao Saen Pom. The focus was on the products related to the belief in good fortune for users. Both communities participated in improving the sketches continuously and developing the prototypes at least twice until they were suitable. These products are shown in Figures 4-5 below.

» **Figure 4:** *The developed community products of Communities 1 using a design thinking process linked to cultural heritage 1) wooden table lamps, 2) handle bags, and 3) key chains of miniature food replicas (Miang)*

» **Figure 5:** *The developed community products of Communities 2 using a design thinking process linked to cultural heritage 1) Thai traditional round-neck sleeveless collar shirts, 2) shoulder bag, and 3) a gong-shaped key chain from the story of Thao Saen Pom*

From Table 1, as for the Test stage, the overall evaluation result was at a high level ($\bar{x}$ = 3.77, S.D. = 0.65). For the tool "feedback – capture grid", the result was at a high level ($\bar{x}$ = 3.81, S.D. = 0.61). Regarding the observation, it was found that, from organising exhibitions and selling products at the Nakhon Chum Cultural Market, both communities were able to evaluate feedback from tourists and interested parties well by having facilitators stimulating the interviews with buyers sometimes. There were consistent results in both communities that, in terms of tourists' preferences, they liked handicrafts from the communities. However, the tourists would like it to have a lower price than this. Tourists' purchasing needs therefore were on the cheapest products which were the key chains from both communities. There were questions asked directly to the communities about the products' storytelling regarding the origins of the cultural heritage that were conveyed on the products. There were also suggestions regarding the product design and development to be more diverse in terms of color, size, and placement of graphic elements on the products.

In terms of the tool "retrospective board", the evaluation result was at a high level ($\bar{x}$ = 3.67, S.D. = 0.77). From the observation, it was found that the communities could evaluate the design thinking process from the beginning. However, the communities were considerate of each other in writing information on large sheets of paper.

Therefore, the facilitators must help to build confidence in presenting their opinions. The results from the retrospective boards of both communities were consistent in the matter of what was very useful in the process which was the tool in the Define and Ideate steps, especially considering multiple perspectives. That allowed the communities to brainstorm and select cultural heritage. This made them see the missing cultural heritage and create pride in the communities. Both communities would like to proceed design thinking since they found that it was beneficial in developing their future products, especially the Test stage where community leaders and members would like to have sales trials in many areas to collect feedback from buyers and tourists further.

This is consistent with the study conducted by Abraham, Howard & Asinyo (2022) showing that the entire process is connected and influenced by the customers and interaction with customers to solve problems and develop products creatively. Also, this supports Carella et al. (2023) who demonstrate the sensitivity of entrepreneurs to change and awareness of the benefits and capabilities of design thinking in that it is not only as part of product design and development, but it is also with the building of a specific design mindset.

From the results of assessing the community's design thinking process in order to develop the products based on cultural heritage, classified by design thinking stages and tools, the researchers chose nine design thinking tools from the study of design thinking tools by Lewrick, Link & Leifer (2018) and applied them to the communities to create a systematic thinking process and help in making the products more connected

to and influenced by customer needs according to the concept of Abraham, Howard & Asinyo (2022).

3. The results regarding Research Objective 2 aiming at assessing tourist satisfaction towards community products based on cultural heritage

It was found that, after having community products that were jointly developed using a design thinking process linked to the cultural heritage, such products were introduced and brought them to an exhibition and trial sales at the cultural market, which was a cultural tourist spot, in order to disseminate to a group of 100 tourists. The data were then collected using online assessments in order to assess tourist satisfaction according to the five aspects as shown in Table 2 below.

From Table 2, it was found that the results of the tourist satisfaction assessment with the community products that were developed with a design thinking process linked to the cultural heritage base of both communities, overall, was at a high level ($\bar{x}$ = 4.12, S.D. = 0.64). The aspect that revealed the highest satisfaction was connection with cultural heritage ($\bar{x}$ = 4.16, S.D. = 0.55).

This shows that the communities can use design thinking processes to design and develop the products based on cultural heritage. This is in line with Seidel & Fixson (2013) who mentioned about the participation in using design thinking with interdisciplinary groups in that even though each group member has different aptitudes and main occupations, they can work together to create work through the design thinking process.

It was followed by product quality ($\bar{x}$ = 4.15, S.D. = 0.58), linking to tourism ($\bar{x}$ = 4.14, S.D. = 0.72), value based on identity and cultural heritage ($\bar{x}$ = 4.07, S.D. = 0.65), and marketing ability ($\bar{x}$ = 4.05, S.D. = 0.72), respectively.

It was suggested that there should be marketing promotion to make the products more well-known, and the products should be more contemporary.

From the evaluation of all five aspects, it is consistent with Li, Ho & Yang (2019) who studied the use of design thinking in the sustainable development of traditional handicrafts which defined four value dimensions, namely, 1) material and innovative value, 2) handicraft and cultural value, 3) empirical and local value, and 4) sharing and interactive value.

In this regard, the sustainable development of handicrafts or community wisdom products also contributes to design thinking's sustainable development model, business model, product design and development, and various innovations according to the concepts of Andrews (2015), Elsbach & Stigliani (2018), and Geissdoerfer, Bocken & Hultink (2016).

Table 2

The results of tourists' satisfaction assessment towards community products that have been developed with a design thinking process linked to cultural heritage

Five aspects of the assessment	**The product of Community 1**						**The product of Community 2**						**The sum of the assessment of the products of both communities**	
	Wooden table lamp		Handel bag		Key chains of miniature food replicas (Miang)		Thai traditional round-neck sleeveless collar shirts		Shoulder bag		A gong-shaped key chain from the story of Thao Saen Pom			
														
	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.
Connection with tourism	3.82	0.72	3.96	0.70	4.39	0.62	3.80	0.78	4.29	0.50	4.56	0.58	4.14	0.72
Connection with cultural heritage	4.10	0.62	4.15	0.48	4.08	0.45	4.17	0.61	4.25	0.58	4.21	0.54	4.16	0.55
Value based on identity and cultural heritage	3.95	0.63	3.98	0.74	3.81	0.68	4.22	0.60	4.19	0.60	4.30	0.50	4.07	0.65
Marketing ability	3.38	0.73	3.85	0.66	4.51	0.55	4.00	0.50	4.07	0.59	4.52	0.55	4.05	0.72
Product quality	4.13	0.56	4.06	0.54	3.96	0.62	4.04	0.52	4.18	0.54	4.53	0.54	4.15	0.58
Total mean	3.91	0.70	04.01	0.63	4.13	0.64	4.04	0.62	4.19	0.56	4.44	0.56	4.12	0.64

Conclusion

From studying community products towards the development of product potential for tourism on the basis of cultural heritage, the results of area visits and interviews with leaders and representatives in community groups, including following up on the process of creating cultural products of the two communities, which were outstanding cultural tourism communities in the province leads to the CCT Model. From the CCT Model, it was found that the two communities, despite having different potentials and skills of the people in the communities, had ways to use those potentials to connect with the cultural heritage of their own areas according to their understandings.

This is consistent with the Design Thinking Model proposed by Hasso Plattner Institute of Design at Stanford University (2010). According to the five stages of design thinking in the traditional community thinking process, the Empathize and Define stages are consistent with C (Community Potential) which is a stage in studying and understanding the potentials of the communities in various areas and determining perspectives and directions in developing community products. The Define and Ideate steps are consistent with C (Cultural heritage), which is the stage from defining perspectives and creating concepts/ideas linked to cultural capital in their own areas. The Prototype and Test stages correspond to T (Tourism products), which are the stages to create product prototypes linked to cultural heritage and test the market. Table 3 below shows the relationship among the CCT Model, the five stages of design thinking, and design thinking too.

Table 3

The relationship among the CCT Model, the five stages of design thinking, and design thinking tools

CCT Model	The five stages of Design Thinking	Design thinking tools
C: Community Potential	Empathize	Creating a persona
		Asking WH questions
	Define	Considering multi perspectives
		Making a flower map
C: Cultural heritage	Ideate	Structuring and selecting ideas
		Idea communication sheet
T: Tourism products	Prototype	Considering prototype creation
	Test	Feedback – capture grid
		Retrospective board

From Table 3, it can be seen that the Define stage of the five stages of design thinking is a stage that connects C (Community Potential) and C (Cultural heritage) because it defines perspectives and the connection between the potentials of the communities that has with the cultural capital that communities have. This leads to creating ideas together.

Recommendations

This present study employed document research and nine tools/activities in the design thinking stages. However, there are many other design thinking tools used in each stage. Therefore, the recommendation is that the further research can apply and change to other design thinking tools according to the suitability and potentials of the community groups.

Also, the recommendation for the product evaluation section is that the products should be promoted in marketing and publicising the product to be known to tourists before the evaluation. It is because they are the products that are connected to the cultural heritage and are presented in a new way and different from the community's original products. Therefore, there should be the transfer of the concept and the story of the product design and development to tourists in order to create understandings about the connection between cultural heritage and the products.

Funding

The research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

Abraham, I., Howard, E. K. & Asinyo, B. K. (2022) Design thinking in design innovation among small and medium textile enterprises in Ghana. *Journal of Design Thinking*. 3 (1), 49-60. Available from: doi: 10.22059/jdt.2022.344139.1078

Andrews, D. (2015) The circular economy, design thinking and education for sustainability. *Local economy*. 30 (3), 305-315. Available from: doi: 10.1177/0269094215578226

Cai, Y., Lin, J. & Zhang, R. (2023) When and how to implement design thinking in the innovation process: A longitudinal case study. *Technovation*. 126. Available from: doi: 10.1016/j.technovation.2023.102816

Carella, G., Cautela, C., Melazzini, M., Pei, X. & Schmittinger, F. (2023) Design thinking for entrepreneurship: An explorative inquiry into its practical contributions. *The Design Journal*. 26 (1), 7-31. Available from: doi: 10.1080/14606925.2022.2144565

Daksa, M. D., Yismaw, M. A., Lemessa, S. D. & Hundie, S. K. (2018) Enterprise innovation in developing countries: evidence from Ethiopia. *Journal*

of Innovation and Entrepreneurship. 7 (1). Available from: doi: 10.1186/s13731-018-0085-4

Elsbach, K. D. & Stigliani, I. (2018) Design thinking and organizational culture: A review and framework for future research. *Journal of Management*. 44 (6), 2274-2306. Available from: doi: 10.1177/0149206317744252

Fu, X., Pietrobelli, C. & Soete, L. (2011) The role of foreign technology and indigenous innovation in the emerging economies: technological change and catching up. *World Development*. 39 (7), 1204-1212. Available from: doi: 10.1016/j.worlddev.2010.05.009

Gao, B. & Yu, K. (2023) Knowledge exchange in SMEs service innovation with design thinking. *Management Decision*. 61 (7), 2029-2049. Available from: doi: 10.1108/MD-06-2022-0795

Geissdoerfer, M., Bocken, N. M. & Hultink, E. J. (2016) Design thinking to enhance the sustainable business modelling process–A workshop based on a value mapping process. *Journal of cleaner production*. 135, 1218-1232. Available from: doi: 10.1016/j.jclepro.2016.07.020

Goldschmidt, G. & Rodgers, P. A. (2013) The design thinking approaches of three different groups of designers based on self-reports. *Design Studies*. 34 (4), 454- 471. Available from: doi: 10.1016/j.destud.2013.01.004

Hasso Plattner Institute of Design at Stanford University. (2010) *An introduction to design thinking: Process guide.* Stanford, Stanford University. Available from: https://dschool old.stanford.edu/sandbox/groups/designresources/wiki/36873/attachments/74b3d/ModeGuideBOOTCAMP2010L.pdf [Accessed 10th June 2022]

Hofstede, G., Hofstede, G. J. & Minkov, M. (2010) *Cultures and Organizations: Software of the Mind*. New York, McGraw-Hill.

Jobst, B., Köppen, E., Lindberg, T., Moritz, J., Rhinow, H. & Meinel, C. (2012) The Faith-Factor in design thinking: Creative confidence through education at the design thinking schools Potsdam and Stanford? In: Plattner, H., Meinel, C. & Leifer, L. (eds.) *Design thinking research*. Heidelberg, Springer, pp. 35-46. Available from: doi: 10.1007/978-3-642-31991-4_3

Johansson-Sköldberg, U., Woodilla, J. & Çetinkaya, M. (2013) Design thinking: Past, present and possible futures. *Creativity and Innovation Management*. 22 (2), 121-146. Available from: doi: 10.1111/caim.12023

Lake, D., Guo, W., Chen, E. & McLaughlin, J. (2024) Design thinking in higher education: Opportunities and challenges for decolonized learning. *Teaching and Learning Inquiry*. 12, 1-22. Available from: doi: 10.20343/teachlearninqu.12.4

Lawson, B. (2012) *What Designers Know*. New York, Routledge.

Lewrick, M., Link, P. & Leifer, L. (2018) *The design thinking playbook: Mindful digital transformation of teams, products, services, businesses and ecosystems*. Hoboken, Wiley.

Li, W. T., Ho, M. C. & Yang, C. (2019) A design thinking-based study of the prospect of the sustainable development of traditional handicrafts. *Sustainability*. 11 (18). Available from: doi: 10.3390/su11184823

Pisoni, A., Michelini, L. & Martignoni, G. (2018) Frugal approach to innovation: State of the art and future perspectives. *Journal of Cleaner Production*. 171, 107-126. Available from: doi: 10.1016/j.jclepro.2017.09.248

Seidel, V. P. & Fixson, S. K. (2013) Adopting design thinking in novice multidisciplinary teams: The application and limits of design methods and reflexive practices. *Journal of Product Innovation Management*. 30 (1), 19-33. Available from: doi: 10.1111/jpim.12061

Spencer-Oatey, H. (2012) What is culture: A compilation of quotations. *GlobalPAD Core Concepts*. 1 (22), 1-21.

Tschimmel, K. (2012) Design thinking as an effective toolkit for innovation. In: *The XXIII ISPIM Conference – Action for Innovation: Innovating from Experience, 17 – 20 June 2012, Barcelona, Spain*. Manchester, The International Society for Professional Innovation Management (ISPIM).

UNESCO (n.d.) *Historic town of Sukhothai and associated historic towns*. Available from: https://whc.unesco.org/en/list/574/ [Accessed 6th August 2023]

Professional paper http://doi.org/10.24867/JGED-2025-3-017

Designed animation for daily living skill of children with Down syndrome

ABSTRACT

Children with Down syndrome generally have difficulty with daily living skills. Therefore, an appropriate learning approach is needed to train DS children to have daily living skills. The aim of this research is to identify the level of learning visual ability of children with Down syndrome, then explain the parameters of visual content animation as a tool to obtain responses from children with Down syndrome, and to determine the effective animation content to help the independence process of children with Down syndrome. The research method used is a mix method. This research uses an experimental study where the participants are children with Down Syndrome. Data collection methods use interviews, observation and questionnaires. Data analysis using the Wilcoxon Sign Rank test
The results of this research found that Down syndrome children have different characters, levels of learning abilities and interests even though they are the same age and DS children tend to experience problems with independence, especially toilet training. Independent intervention to be used as a learning medium can be done through animation media whose visual content matches their character and preferences. The test results show that there is a significant effect of learning through animated videos on the level of message understanding and toilet training independence in DS children. With the characters, environment, duration, colors, figures in the video that they like, it will further increase their interest in the video so that they can understand the message in the animated video easily.

Ercilia Rini Octavia [1]
Muhizam Mustafa [2]
Dermawan Syamsuddin [3]

[1] Universitas Sebelas Maret, Faculty of Art and Design, Surakarta, Indonesia
[2] Universiti Sains Malaysia, School of The Art, Penang, Malaysia
[3] Binus University, School of Design, Jakarta, Indonesia

Corresponding author:
Ercilia Rini Octavia
e-mail:
erciliaoctavia@staff.uns.ac.id.

First received: 9.5.2024.
Revised: 4.12.2024.
Accepted: 15.1.2025.

KEY WORDS
daily living skills, DS children, animation videos, toilet training

Introduction

Data from the World Health Organization (WHO) estimates that every year there are 3,000–5,000 babies born with Down syndrome, with an estimated one incidence of Down syndrome per 1,000–1,100 births worldwide (Agheana & Duţă, 2015). WHO also estimates that globally, there are currently 8 million people with Down syndrome.

In Indonesia, based on Basic Health Research (Riskesdas) 2010–2018, the incidence of Down syndrome tends to increase. In 2018, 0.41 percent of congenital disabilities were recorded for children aged 24–59 months, and Down syndrome was experienced by 0.21 percent of that age group.

Down Syndrome (DS) is a condition of retarded physical and mental development in children caused by abnormalities in chromosomal development (D'Souza et al., 2020). Based on the research results, there was a gene mutation on chromosome 21, where there was an additional part of this chromosome (Mohamed et al., 2021). People living with Down Syndrome have three chromosomes 21. This excess chromosome is characteristic of Down Syndrome or what is known as Trisomy 21 (Boundy et al., 2023).

Children with DS have distinctive facial features, congenital disabilities, mental retardation, heart defects, lung problems, and widespread infections (Krinsky-McHale et al., 2014).

Children with Down syndrome vary greatly in ability, but the majority show moderate learning difficulties, and some have severe learning difficulties (Agheana & Duţă, 2015). Children with disabilities also experience problems in daily living skills (Auld, Foley & Cashin, 2022). Daily living skills are essential for improved quality of life and autonomous living (Auld, Foley & Cashin, 2022). On average, children with Down syndrome still depend on their parents or other family members to carry out daily life activities (Widyawati & Ardianingsih, 2019). Therefore, an appropriate learning approach is needed to train DS children to have daily living skills.

The development of learning methods linked to technology to overcome problems in children with Down syndrome has been studied by several researchers (Shahid, Law & Verdezoto, 2022). Technology has become something that is greatly needed by all levels of society in all areas of life, including children with special needs (Baldo et al., 2023). The trend is the reason that more research is needed to deeply understand the use and adoption of technology along with their methodology, intervention techniques, and potential in equipping early childhood special needs children to transform them into independent adults (Baldo et al., 2023).

Some existing research focuses on the medical aspects of Down Syndrome, looking at their prevalence, causes, symptoms, diagnosis, medical complications, and overall care management (Agheana & Duţă, 2015; Lukowski, Slonecker & Milojevich, 2020; Morris, Farran & Gilligan-Lee, 2023; Sabeti et al., 2024). Several other researchers use machine learning as an intervention medium for children with DS (Baldo et al., 2023; Porras et al., 2021; Porras et al., 2022; Sabeti et al., 2024). Meanwhile, digital technology has the potential to support children with intellectual disabilities (Constantin & Hourcade, 2018; Tashnim et al., 2017).

Several studies have proposed several teaching methods and materials that can result in more effective learning for children with DS. One of them is the use of electronic media to teach DS children. Research conducted by Agheana & Duţă (2015) shows that there is significant progress in the acquisition of basic mathematics skills in children who use electronic media compared to children who only use concrete objects. The research results also show that teaching using visual learning can improve children's education in coping with Down syndrome if they are exposed to the right conditions that suit their needs. Shahid, Law & Verdezoto (2022) specifically presented a systematic literature review regarding technology support for children with Down Syndrome and adolescents appropriate for the mental age of children considered neurotypical (NT). This synthesis identified several key findings, namely that there is a diversity of technological supports available for children with Down Syndrome that target individual abilities.

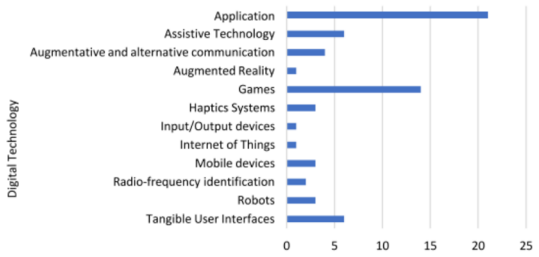
Technological developments also help in overcoming the problems of children with Down syndrome; several studies have used technological interventions to overcome the difficulties of children with Down syndrome (Shahid, Law & Verdezoto, 2022). Augmentative and alternative communication (AAC) is an intervention, method, and technology used to supplement an individual's speech alternatives. AAC ranges from symbol systems using charts, boards, communication books, and individual cards (Foreman & Crews, 1998). The Foreman & Crews (1998) study used Makaton as an intervention technique that was considered more effective with positive results for alternative communication among Down Syndrome. The use of Makaton as a sign language supports visuospatial memory and the ability to reflect iconic components compared to verbal speech.

This field focuses on designing interactive technology, how children can benefit from this technology, and its effectiveness in the child's development process. Technology is increasingly being used to support children with special needs, for example, in the areas of health, education, behavior, and social communication. To measure or evaluate children's interactions with technology, several different methodologies have been studied. Manojlovic, Boer & Sterkenburg (2016) in their paper present a fun interaction, also known as Theraplay, to strengthen the bond between parents and children with Down Syndrome families in the Netherlands. This approach can benefit other children who experience visual and hearing impairments throughout their development (Manojlovic, Boer & Sterkenburg, 2016).

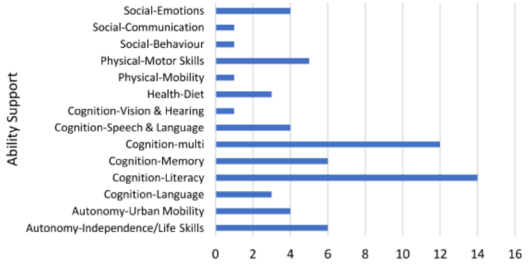
Macias et al. (2020) studied interactions between parents and children with Down Syndrome to explore role-play experiences. After observation, it was discovered that parents, especially mothers of children with Down Syndrome, used directed behavior more often than mothers of children who were developing. The increased use of directed behavior causes children to become easily distracted and divert their attention from the activity they are doing. Macias et al. (2020) used puzzle games to observe the type of directed behavior given and the child's response to the directed behavior. Interaction analysis is used to predict what happens in similar activities involving two people. The result is that excessive use of directed behavior can damage a child's autonomy and independence. The results of a literature review conducted by Shahid, Law & Verdezoto (2022) show that the use of digital technology to support the learning of DS children still needs to be improved, with most applications being used in 21 papers, others under 15 papers (Figure 1).

The results of a literature review conducted by Shahid, Law & Verdezoto (2022) also showed that there were only six papers regarding the types of characteristics of previous research related to independence/daily living skills (Figure 2).

The six previous studies were: Alesii et al. (2013), Costa et al. (2015), Franchi et al. (2016), Gomez et al. (2017), Kramer et al. (2015), Lara et al. (2019).



» **Figure 1:** *Use of Digital Technology for DS Children*



» **Figure 2:** *Characteristics of Research Related to Independence*

The results of the literature review above show that the literature on learning interventions for children with Down's syndrome is still limited, as well as the use of technology to overcome the problems experienced by children with Down's syndrome. To fill the research gap regarding the use of digital technology for learning for children with Down syndrome, this research will examine the impact of using animated learning media on the daily living skills of children with DS. Daily living skills tasks include eating, dressing, bathing, and mobility (Auld, Foley & Cashin, 2022). Daily living skills are essential for improved quality of life and autonomous living (Auld, Foley & Cashin, 2022). In addition, on average, children with Down syndrome still depend on their parents or other family members to carry out daily life activities (de Weger, Boonstra & Goossens, 2021). The use of visual media can facilitate understanding, strengthen memory, foster interest, and establish connections between material content and the real world (da Cruz Netto et al., 2020). Children with Down syndrome have a greater ability to perceive instructions visually. Audio-visual learning is appropriate for DS children because this media can stimulate the senses of sight and hearing (Az Zahra et al., 2021).

Animated videos can help children form good characters, which is reflected in polite words in everyday life (Mashuri & Budiyono, 2020). Based on these problems, there are three objectives to be achieved in this research, namely:

RO1: To identify the level of learning visual ability of children with Down syndrome

RO2: To explain the parameters of visual content animation as a tool to obtain responses from children with Down syndrome

RO3: To determine the effective animation content to help the independence process of children with Down syndrome

Method

Methodology is an important part of any research because it presents and justifies the way the survey is organized and conducted. In this research, the methodology used is mix method research. To be more specific, we used an experimental study where the participants were children with Down Syndrome. The research tool used is qualitative research (initial/final evaluation, interviews and non-participatory observation) using several quantitative research tools as a complement.

The location of this research is in Central Java, Indonesia, which has an area of 32,800.69 km², or around 28.94% of the area of Java Island, Indonesia. Study Population Overall the children who are members of PIK Potads Central Java have 490 children with Down syndrome.

The subject criteria for this research are: 1) Children with Down syndrome 2) Boys and girls 3) Age 7-9 years 4) Resides in Central Java 5) Trisomy 21 Spectrum 6) Having moderate and low mental retardation. Based on these criteria the population in this study were children aged 7-9 years, numbering 75 children. By considering the age of the child, we choose appropriate audio visuals, namely Upin & Ipin videos and Nusa & Rara videos which provide daily living skills education.

Participants

Participants in this study were children with Down Syndrome. Participants were children selected based on certain criteria, namely having an official diagnosis of Down syndrome. Selected participants will be given learning media to investigate whether these children will successfully respond to audio visuals and ultimately learn audio visuals to increase their independence. In this study, children's independence was measured by daily living skills tasks including toilet training (Loue & Sajatovic, 2008).

Procedure

This research follows certain stages. First, semi-structured interviews were conducted to obtain information about the level of learning of visual abilities of children with Down syndrome.

Second, analyze the parameters of animated visual content as a tool to obtain responses from children with Down syndrome, and third, analyze animated content that is effective in helping the process of independence for children with Down syndrome. In the third stage, intervention was carried out, namely testing animated videos to test the ability of children with Down syndrome to understand animated videos about toilet training. This test was carried out in stages over 3 weeks, namely by watching 1 video (first week), 2 videos (second week), and 3 videos (third week).

Educational objectives

In accordance with the research objectives set for this intervention, children must be able to:

1. Understand animation as an assistive medium,
2. Carry out the process of independence in the toilet.

Data collection and analysis

The data collection procedure is carried out with the following steps:

1. In depth interviewing: semi structured interview 1 pediatrician, 1 therapist, team psychologist (Table 1), and 13 parents of children with Down syndrome (Table 2); Observation (Partisipant Quisi): IQ test for 13 children with Down syndrome;
2. Multiple Case Study: 3 series of animated films Ipin Upin and 2 films series Nusa & Rara; In depth interviewing: semi structured interview on 13 children with Down syndrome;
3. Questionaire: Before and after trial to test prototype with Wilxocon Sign Rank tst; 30 Pilot Study respondents; 75 Respondents to test the prototype; Analysis the response.

Results

The results of data analysis in this research are divided into three parts to answer the research objectives. The following is the arrangement:

Identify the level of learning visual ability of children with Down syndrome

To identify the level of visual learning abilities in children with Down syndrome, the method in this research uses in-depth interviews with experts who are competent in their fields, namely pediatricians, therapists, psychologists and parents of children with Down syndrome. Themes that will be identified in this research include the basic abilities of children with Down syndrome (Prena, 2014; Whalen, Schreibman & Ingersoll, 2006), learning for Down syndrome children (Wester Oxelgren et al., 2019), and the interests of children with Down syndrome (Amatori et al., 2022). The results of in-depth interviews with pediatric, therapists, psychologists, and parents of children with Down syndrome to Identify the level of learning visual ability of children with down syndrome are as follows.

Table 1

Conclusions from in-depth interviews with experts

Theme	Aspect	Results
Basic Abilities of Down Syndrome Children	Speech Pathology	The speaking ability of each child with Down syndrome is different, it cannot be generalized based on age
	Audiology	On average, the hearing of children with Down syndrome is normal, except for those with comorbid hearing problems
	Psychology	Understands the feelings of joy and sorrow, is emotional and has a lower IQ than ordinary children
	Occupational Therapy	Having done occupational therapy, toilet training is predominantly a problem of independence
Learning Children with Down Syndrome	Daily Living Skill (ADL)	The milestone for ADL independence is toilet training, so children with Down syndrome need to be trained to be independent.
	Independence Therapy	It is necessary to repeat therapy at home repeatedly so that children with Down syndrome are independent
	Animated Video as Learning Tool	Animated films as an intervention medium have not yet been found specifically for toilet training children with Down syndrome
Interest	Intervention Media	Animated films are an alternative medium for teaching independent toilet training, with the right content
	Screen time & problem behaviors	The need to limit time when viewing animated films
	Media for children's screen time	Hope there is an animated film for toilet training interventions with dishes that children with Down syndrome like

The results of interviews and observations with pediatricians, therapists and psychologists found that each child with Down syndrome has a different character, level of learning ability and interests even though they are the same age. Independence is their problem, especially toilet training, so they need an animated film that they like as a medium for their intervention.

Table 2

Conclusions from the results of in-depth interviews with 13 parents of children with Down syndrome

Theme	Aspect	Results
Basic Abilities of Down Syndrome Children	Speech Pathology	92.3% of children with Down syndrome at home use Indonesian, not all of them can speak it
	Audiology	Another 76.92% of normal hearing suffer from moderate impairment & Sensorineural Hearing Loss (SNHL)
	Psychology	69.2% are worried about the emotions and independence of children with Down syndrome
	Occupational Therapy	53.84% of children with Down syndrome cannot hold a ladle and 46.1% can hold a ladle
Learning Children with Down Syndrome	Daily Living Skill (ADL)	69.2% of respondents chose toileting as the most difficult activity and the second activity was brushing their teeth.
	Independence Therapy	53.84% of children with Down syndrome carry out therapy independently at home under parental supervision using audio-visual via television and smart phone
	Animated Video as Learning Tool	76.92% of respondents wanted animated videos as learning aids and the rest wanted direct learning
Interest	Intervention Media	76.3% independent therapy which is carried out using audio-visual media.
	Screen time & problem behaviors	100% of children with Down syndrome watch animated videos
	Media for children's screen time	69.2% most often use smartphones and the least use televisions Ipin upin and Nusa Rara

These results are supported by observations made by parents of children with DS who found that the basic abilities of Down syndrome children aged 7-9 years cannot be generalized. The abilities of DS children aged 7-9 years are equivalent to children usually 3-5 years old. Parents worry about independence especially toilet training. Parents carry out further intervention through animated videos, via TV and YouTube platforms. Children with Down syndrome concentration is longer when viewing animated videos than other media. Down syndrome children like animated videos because of their cute appearance, main characters in pairs, music and songs, and showing daily activities. Down syndrome children aged 7-9 years are equivalent to normal children aged 3-5 years. Down syndrome children are interested in animated videos (Ipin Upin and Nussa Rara).

Explain the parameters of visual content animation as a tool to obtain respons from children with Down syndrome

The second data analysis was carried out by means of a Multiple Case Study using 10 animated videos (Table 3), namely the Upin and Ipin dan videos (5 series) and the Nussa Rara videos (5 series). Upin & Ipin video links and Nussa and Rara videos are below. Video link is in the attachment.

Conclusion:

Visual Character: Physical characteristics of the cartoon: light brown skin, black hair, slanted eyes (mongoloid), thin lips, big head, short neck (resembling a child with Down syndrome), paired. favorite animal is elephant

Environment: The bathroom colors found are bright; The type of closet that is often found is the squat; The color of the closet found is white; The most common toilet door color is blue.

Table 3

Parameters of Visual Content Animation

Visual Character			Environment	Duration	Narrative
Organs	Face	Clothes			
The skin color of the entire cast is the same, namely light brown The hair color of the entire cast is black The hair size of the entire cast is short The head size equation for all casts is large Similar shape of sickle ears Short neck shape	Round eye shape Eyeball color is black Thin lip shape Pink lip color Sharp nose shape	The types of clothes used are both 2 colors There are different colors for each character pairing	Most of the sets where videos are taken are in the home environment and are more often found in bathrooms	The average duration of the video is around 10 minutes The video duration is quite long because 1 video contains 1 episode	The average number of vocabulary words in the title is 3 words The average number of activities in 1 video clip is 4 activities

Duration: The average length of the film is more than 6 minutes; The average duration of each slide is 11-15 seconds; Pronunciation duration 5-6 seconds

Narrative: The font color used for subtitles is white; The type of font used is bold and small; Number of words per slide 5-8 words

Other elements: Likes music, likes 2D and 3D animation, understands story lines, repetitive (repetition)

Determine the effective animation content to help the independence process of children with Down syndrome

Based on the results of the animated visual content parameters found, an animated visual prototype was then created as follows (Figure 3). The animated visual results were then made into an animated video which was tested on DS children related to toilet training (Table 4).

The test results are explained below:

Table 4

The Results of the Wilxocon Sign Rank Test

Variable	Frequency of Watching Videos	Z value	Asymp Sign
Message Understanding	1 x Watch	-1,437	0,151
	2 x Watch	-2,184	0,029
	3 x Watch	-3,417	0,001
Independence	1 x Watch	-1,955	0,051
	2 x Watch	-3,359	0,001
	3 x Watch	-4,571	0,000

Based on the results of the Wilxocon sign rank test, the following conclusions were obtained:

1. Testing the level of understanding of Down syndrome children regarding toilet training messages
    a. The first test was that children with Down syndrome were given the test treatment by watching an animated video about toilet training once, the result was an Asymp Sign value of 0.151, this means there was no significant difference in the level of understanding of children with Down syndrome regarding the toilet training message in the video.
    b. Testing the two children with Down syndrome who were given treatment by watching it twice, the result was an Asymp Sign value of 0.029, this means that there was a significant difference in the level of understanding of children with Down syndrome regarding the toilet training message after watching the animated video twice.
    c. Testing the three children with Down syndrome who were given the test 3 times, the result was an Asymp Sign value of 0.001, this means there is a significant difference in the level of understanding of DS children regarding the toilet training message from the animated video.

Based on these three tests, it shows that the more often DS children are given the treatment of watching animated videos, the more they will improve their ability to understand the message from animated videos related to their toilet training abilities.

2. Testing the independence of children with Down syndrome in toilet training
    a. The first test for Down syndrome children was given the testing treatment once,

» **Figure 3:** *Animated visual prototype*

watching an animation video about toilet training, the result was an Asymp Sign value of 0.051, this means there is no significant difference in the level of independence in toilet training for Down syndrome children.

b. Testing the two children with Down syndrome who were given treatment by watching it twice, the result was an Asymp Sign value of 0.029, this means that there was a significant difference in the level of toilet training independence for children with Down syndrome after watching the animated video twice.

c. The third test for Down syndrome children was given the test 3 times. The result was an Asymp Sign value of 0.001, this means there was a significant difference in the level of toilet training independence for Down syndrome children after watching the animated video 3 times.

Based on these three tests, it shows that the more often DS children are given the treatment of watching animated videos, the more independence DS children have in carrying out toilet training.

Discussion

To identify the level of visual learning ability in children with Down syndrome

The most common genetic disorders experienced by children with Down syndrome (DS) are neurological deficits and visual impairment (Højberg, Lundbye-Jensen & Wienecke, 2023; Manrique-Niño et al., 2020). The development of these two functions depends on executive control (Manrique-Niño et al., 2020). However, it is not known whether there is a relationship between visual impairment in children with DS and delays in their cognitive development. The purpose of this study is to identify the level of visual learning ability in children with Down syndrome, including the basic skills of children with Down syndrome, how children with Down syndrome learn, and the interests of children with Down syndrome, then carry out evidence-based intervention research for this group.

This study uses in-depth interview techniques with experts and practitioners who are directly related to DS children. The results of this study identified that each child with Down syndrome has a different character, level of learning ability, and interests, even though they are the same age. Basic ability measurements include aspects of speech pathology, audiology, psychology, and occupational therapy. The speech pathology aspect shows that the speaking ability of each child with Down syndrome is different; it cannot be generalized based on age.

Then, in the audiology aspect, it was found that children with Down syndrome had normal hearing, except for those with comorbid hearing problems. The psychological element shows that children with DS understand the feelings of joy and sorrow, are emotional, and have a lower IQ than normal children. Meanwhile, in the occupational therapy aspect, DS children have done occupational therapy, and toilet training is the dominant issue in their independence.

The results of observations involving parents regarding the basic abilities of children with Down syndrome concluded that in the aspect of speech pathology, namely 92.3% of children with Down syndrome at home use Indonesian, and not all of them can speak well. Then, in the audiology aspect, 76.92% of their hearing was normal, while the others experienced moderate impairment and sensorineural Hearing Loss (SNHL). In the psychological aspect, it shows that 69.2% are worried about the emotions and independence of Down syndrome children. In the occupational therapy aspect, it shows that 53.84% of Down syndrome children are not yet able to hold a spoon, and 46.1% can already use a spoon. Based on these results, it can be concluded that the basic abilities of DS children cannot be generalized.

Still, their development is slower than that of children in general, and the skills of DS children aged 7-9 years are equivalent to those of typical children aged 3-5 years.

These results support previous studies, which stated that in children with DS, motor, cognitive, practical, and social skills develop more slowly compared to the development of children in general (Boundy et al., 2023; Morris, Farran & Gilligan-Lee, 2023). After birth, children with DS experience slow growth and maturity (Lukowski, Slonecker & Milojevich, 2020; Morris, Farran & Giligan-Lee, 2023). Furthermore, within a few months, the development of the morphology of the nerves of the visual cortex (where visual information is processed), the size of the cerebellum and brain stem, brain weight, skull size, and visual acuity progressively slow down (de Weger, Boonstra & Goossens, 2021; Manrique-Niño et al., 2020). Eye disorders also limit visual acuity and visual function. These disorders include frequent and severe refractive errors, nystagmus, and slowness of accommodation (da Cruz Netto et al., 2020; Højberg, Lundbye-Jensen & Wienecke, 2023).

The results of interviews and subsequent observations related to DS children's learning in the daily living skills (DLS) aspect show that the milestone for ADL independence is toilet training. Hence, Down syndrome children need to be trained independently regarding toilet training. The aspect of independence therapy shows the need to repeat therapy at home repeatedly so that children with Down syndrome become more understanding and independent.

In the Animated Video as a Learning Tool aspect, it is concluded that animated films can be used as intervention media. Still, we have yet to find a special video for toilet training children with Down syndrome. The results of observations from parents of DS children regarding the ADL aspect concluded that 69.2% of respondents chose toilet training as the most difficult activity, and the second activity was brushing their teeth. In the independence therapy aspect, it was concluded that 53.84% of children with Down syndrome carried out therapy independently at home under parental supervision using audio-visual via television and smartphones. Meanwhile, regarding the animated video as a learning tool aspect, it was concluded that 76.92% of respondents wanted animated videos as learning aids, and the rest wanted to know directly.

Based on the results of the interviews and observations above, it can be concluded that children with DS have difficulty learning in toilet training; independent therapy is preferred to be done at home with parents using audio-visuals and the videos that children with DS like to know for learning are animated videos. To overcome this problem, parents carried out further interventions through animated videos on the TV and YouTube platforms; the result was that DS children's concentration was longer when they saw animated videos compared to other media. DS children liked animated videos because they looked cute, there were people and pairs of characters, there was music, and there were daily activities. DS children were especially interested in animated videos Upin and Ipin.

These results support previous research stating that the basic abilities of children with Down's syndrome are different. Still, children with Down's syndrome have the same problems in their daily living skills, so learning media intervention in the form of animated videos is needed to train their motor and cognitive skills so that they develop optimally, especially to teach them (Boundy et al., 2023; de Weger, Boonstra & Goossens, 2021; Lukowski, Slonecker & Milojevich, 2020). DLS includes three subdomains: personal (taking care of self), domestic (taking care of the home), and community skills (school/community life) (Sparrow, Cicchetti & Saulnier, 2016). So, DLS includes Activities of Daily Living (ADL) and Instrumental Activities of Daily Living (IADLs). ADL refers to more basic self-care tasks (e.g., brushing teeth, dressing, and personal hygiene).

In contrast, IADL refers to more complex skills (e.g., financial management, preparing food, and washing clothes) (Guo & Sapra, 2022). The acquisition of these skills impacts the extent of a person's ability to live independently and independently in their routine living environment (Hong et al., 2015). DLS, when carried out alone, can encourage improved quality of life and reduce dependence on other people (Wertalik & Kubina, 2018).

Based on the findings in this research, learning media is needed to train children with DS to be independent, especially animation media, to train toilet training, which some DS children have difficulty doing.

Explain the parameters of visual content animation as a tool to obtain responses from children with Down syndrome

The development of information and communication technology today is increasingly intertwined with everyday life, from using mobile applications to remotely control lighting at home to tracking health-related problems, socialization applications, fitness applications, and much more (Mohammedi & Augusto, 2021). One of the difficult challenges is that only some systems can meet all individual needs, considering that each user group and stakeholder has their priorities, needs, and preferences. The surge in applications that focus on helping people with various health-related conditions, as well as other applications that aim to improve well-being and lifestyle, is increasing in number. However, not all communities are given the same attention; some community groups with special needs still receive less attention because their percentage is small, so they are less attractive from the market side; this widens the digital gap between several sectors of society (Mohammedi & Augusto, 2021).

Based on the identification of basic abilities, learning methods, and interests in children with DS, ADL problems, namely toilet training, were found. These findings require learning media that are effective and appropriate to the character and interests of children with DS, namely animated videos. The animated videos that children like based on observation results are Upin & IPIN and Nusa Rara. In this sub-discussion, we will explain the findings related to the visual parameters of the animated content in the Upin & IPIN and Nusa Rara videos on the YouTube Channel, which will be used as a tool or medium for making prototypes of toilet training learning videos.

YouTube is an option for sharing video content that is entertaining and useful for society because the system is so easy and reaches many people (Az Zahra et al., 2021). Therefore, YouTube has become a forum for sharing knowledge in the form of learning animation videos, where learning animation videos, there is a Voice Over to explain the animations shown in the learning animation videos; apart from that, there are also animations in the form of illustrations as visuals so that they can be easier for the audience to understand (Az Zahra et al., 2021).

The results of this study found that DS children liked visual characters with physical characteristics such as light brown skin, black hair, slant eyes (mongoloid), thin lips, big heads, short necks (resembling Down syn-

drome children), and pairs. His favorite animal is the elephant. Then, the environmental aspects include the color of the bathroom, which is found to be bright; the type of cupboard that is often seen as squat; the color of the closet is found to be white; and the most common color of the toilet door is blue. Then, in terms of duration, the average duration of the film is more than 6 minutes, the average duration of each slide is 11-15 seconds, and the duration of the pronunciation is 5-6 seconds. In the story aspect, the font color used for the subtitles is white, the font type used is bold and small, and the number of words per slide is 5-8 words. Then others like music, 2D and 3D animation, understanding story lines, and repetition. These results show that DS children like visual characters with physical characteristics that are close to their physical characteristics and environments that tend to be brightly colored.

Based on the findings of these parameters, this research has produced animated learning videos for children with DS. The animated video can be seen at the following link: https://bit.ly/Toilettrainning. This animated learning video for children with DS will be uploaded to the YouTube channel after testing its effectiveness. The results of testing the effectiveness of the learning animation videos are explained in the following sub-discussion.

Determine the effective animation content to help the independence process of children with Down syndrome

In the world of education, the development of information and communication technology in the learning process is increasing (Az Zahra et al., 2021). ICT aims to make the teaching and learning process easier and easier for students to accept. One of the media used in learning is video. The findings of this research show that DS children really like animated videos that match their characters and interests. Based on these findings, this study has created a prototype video for DS children to teach toilet training skills so that DS children can be independent and no longer dependent on other people.

Toilet training is one part of self-development activities, namely self-care activities that are challenging to do for children with Down syndrome. Toilet training is because children with Down syndrome experience motor and emotional problems, which result in difficulty in carrying out procedures for cleaning themselves after defecating. The aim of toilet training for children with Down syndrome is to be able to clean themselves after defecating or urinating. The results of the treatment with animated videos show that learning through animated videos significantly influences the level of message understanding and toilet training independence in DS children. With the characters, environment, duration, colors, and figures in the video that they like, it will further increase their interest in the video so that they can understand the message in the animated video easily. The results of this study support research conducted by Az Zahra et al. (2021), who found that learning with animated videos will further improve children's abilities in daily living skills, namely how to brush their teeth properly.

The self-development program has a central role in assisting students in carrying out self-development for themselves, such as caring for and taking care of themselves, maintaining personal safety, communicating, and adapting to the environment according to their abilities (Auld, Foley & Cashin, 2022). Self-development learning is directed at actualizing and developing students' abilities to carry out self-development for their own needs so that they do not completely burden others (Auld, Foley & Cashin, 2022; de Weger, Boonstra & Goossens, 2021). In the self-development program, there are various aspects that Down syndrome children must master and possess so that each child can live a normal life in accordance with independent functions, including self-care, self-care, self-help, communication, socialization/adaptation, life skills, and fill the free time (Auld, Foley & Cashin, 2022; Zgonec & Bogataj, 2022). Down syndrome children aged 7-9 years in Central Java have different characters, levels of learning abilities, and interests even though they are the same age. DS children tend to experience problems with independence, especially toilet training. Independent intervention to be used as a learning medium can be done through animation media whose visual content is in accordance with their preferences, namely using a forward, simple plot, third person point of view; an optical character with light brown skin color, black hair, slant eyes (mongoloid), thin lips, big head, short neck (resembling a child with Down syndrome), paired; showing the animal character of an elephant as a complement to the main character; bright color; and lasts approximately 5 minutes, and there is happy music.

Conclusion

The results of the treatment with animated videos show that learning through animated videos significantly influences the level of message understanding and toilet training independence in DS children. With the characters, environment, duration, colors, and figures in the video that they like, it will further increase their interest in the video so that they can understand the message in the animated video easily.

Acknowledgment

The author would like to thank the dedication and the parents of Down Syndrome children. We would also like to thank PIK Potads Central Java as an institution

that handles Down Syndrome children for helping with this work. The first author gratefully thanks the Universitas Sebelas Maret for the financial support for this research in the form of a doctoral scholarship.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

Agheana, V. & Duţă, N. (2015) Achievements of Numeracy Abilities to Children with Down Syndrome: Psycho-Pedagogical Implications. *Procedia - Social and Behavioral Sciences*. 186, 38–45. Available from: doi: 10.1016/j.sbspro.2015.04.068

Amatori, S., Sisti, D., Perroni, F., Brandi, G., Rocchi, M. B. L. & Gobbi, E. (2022) Physical activity, sedentary behaviour and screen time among youths with Down syndrome during the COVID-19 pandemic. *Journal of Intellectual Disability Research*. 66 (12), 903–912. Available from: doi: 10.1111/jir.12933

Auld, C., Foley, K. R. & Cashin, A. (2022) Daily living skills of autistic adolescents and young adults: A scoping review. *Australian Occupational Therapy Journal*. 69 (4), 456–474. Available from: doi: 10.1111/1440-1630.12806

Az Zahra, A. A., Audrey, N. W., Ichyana, D. S., Saskianti, T., Pradopo, S., Nelwan, S. C. & Masyithah, M. (2021) Effectiveness of the Use of Manual and Electric Toothbrushes and the Effect of Educational Brushing Teeth with Video Animation on OHI-S Children with Down syndrome. *Indonesian Journal of Dental Medicine*. 4 (1), 6-10. Available from: doi: 10.20473/ijdm.v4i1.2021.6-10

Baldo, F., Piovesan, A., Rakvin, M., Ramacieri, G., Locatelli, C., Lanfranchi, S., Onnivello, S., Pulina, F., Caracausi, M., Antonaros, F., Lombardi, M. & Pelleri, M. C. (2023) Machine learning based analysis for intellectual disability in Down syndrome. *Heliyon*. 9 (9). Available from: doi: 10.1016/j.heliyon.2023.e19444

Boundy, L., Hargreaves, S., Baxter, R., Holton, S. & Burgoyne, K. (2023) Views of educators working with pupils with Down syndrome on their roles and responsibilities and factors related to successful inclusion. *Research in Developmental Disabilities*. 142. Available from: doi: 10.1016/j.ridd.2023.104617

Constantin, A. & Hourcade, J. P. (2018) Toward a Technology-based Tool to Support Idea Generation during Participatory Design with Children with Autism Spectrum Disorders. In: *Proceedings of the 20th International ACM SIGACCESS Conference on Computers and Accessibility, ASSETS'18, 22-24 October 2018, Galway, Ireland*. New York, Association for Computing Machinery. pp. 385–387. Available from: doi: 10.1145/3234695.324099

D'Souza, H., Lathan, A., Karmiloff-Smith, A. & Mareschal, D. (2020) Down syndrome and parental depression: A double hit on early expressive language development. *Research in Developmental Disabilities*. 100. Available from: doi: 10.1016/j.ridd.2020.103613

da Cruz Netto, O. L., Rodrigues, S. C. M., de Castro, M. V., da Silva, D. P., da Silva, R. R., de Souza, R. R. B., de Souza, A. A. F. & Bissaco, M. A. S. (2020) Memorization of daily routines by children with Down syndrome assisted by a playful virtual environment. *Scientific Reports*. 10 (1). Available from: doi: 10.1038/s41598-020-60014-5

de Weger, C., Boonstra, F. N. & Goossens, J. (2021) Differences between children with Down syndrome and typically developing children in adaptive behaviour, executive functions and visual acuity. *Scientific Reports*. 11 (1), 1–15. Available from: doi: 10.1038/s41598-021-85037-4

Foreman, P. & Crews, G. (1998) Using augmentative communication with infants and young children with Down syndrome. *Down's Syndrome, Research and Practice*. 5 (1), 16–25. Available from: doi: 10.3104/reports.71

Guo, H. J. & Sapra, A. (2022) *Instrumental Activity of Daily Living*. Treasure Island, StatPearls Publishing.

Højberg, L. M., Lundbye-Jensen, J. & Wienecke, J. (2023) Visuomotor skill learning in young adults with Down syndrome. *Research in Developmental Disabilities*. 138. Available from: doi: 10.1016/j.ridd.2023.104535

Hong, E. R., Ganz, J. B., Ninci, J., Neely, L., Gilliland, W. & Boles, M. (2015) An Evaluation of the Quality of Research on Evidence-Based Practices for Daily Living Skills for Individuals with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders*. 45 (9), 2792–2815. Available from: doi: 10.1007/s10803-015-2444-3

Krinsky-McHale, S. J., Silverman, W., Gordon, J., Devenny, D. A., Oley, N. & Abramov, I. (2014) Vision deficits in adults with down syndrome. *Journal of Applied Research in Intellectual Disabilities*. 27 (3), 247–263. Available from: doi: 10.1111/jar.12062

Loue, S. (ed.) & Sajatovic, M. (ed.) (2008) *Encyclopedia of Aging and Public Health*. New York, Springer. Available from: doi: 10.1007/978-0-387-33754-8

Lukowski, A. F., Slonecker, E. M. & Milojevich, H. M. (2020) Sleep problems and recall memory in children with Down syndrome and typically developing controls. *Research in Developmental Disabilities*. 96. Available from: doi: 10.1016/j.ridd.2019.103512

Macias, A., Caro, K., Castro, L. A. & Parra, J. F. (2020) Exploring player experience of an augmented puzzle and wearables for studying interactions between parents and children with down syndrome. In: *Proceedings of the 14th EAI International Conference on Pervasive Computing Technologies for Healthcare, PervasiveHealth '20, 18-20 May 2020, Atlanta, Georgia*.

New York, Association for Computing Machinery. pp. 179–187. Available from: doi: 10.1145/3421937.3422020

Manojlovic, S., Boer, L. & Sterkenburg, P. (2016) Playful interactive mirroring to support bonding between parents and children with down syndrome. In: *Proceedings of the The 15th International Conference on Interaction Design and Children, IDC '16, 21-24 June 2016, Manchester, United Kingdom*. New York, Association for Computing Machinery. pp. 548–553. Available from: doi: 10.1145/2930674.2935987

Manrique-Niño, J., Díaz-Forero, A., Velez-van Meerbeke, A., Ramírez-Guerrero, S., Florez-Esparza, G. & Talero-Gutiérrez, C. (2020) Executive function in down syndrome children in Bogotá, Colombia. *Heliyon*. 6 (11), 1–7. Available from: doi: 10.1016/j.heliyon.2020.e05585

Mashuri, D. K. & Budiyono. (2020) Pengembangan Media Pembelajaran Video Animasi Materi Volume Bangun Ruang untuk SD Kelas V. *Jurnal Penelitian Pendidikan Guru Sekolah Dasar*. 8 (5), 893–903.

Mohamed, R. A., Mohamed, E. S. H., Habshy, S. M. & Aly, S. M. (2021) Impact of two different pulmonary rehabilitation methods in children with down syndrome. *Journal of Bodywork and Movement Therapies*. 27, 512–521. Available from: doi: 10.1016/j.jbmt.2021.04.009

Mohammedi, A. & Augusto, J. C. (2021) Using technology to encourage a healthier lifestyle in people with Down's syndrome. *Universal Access in the Information Society*. 20 (2), 343–358. Available from: doi: 10.1007/s10209-020-00721-y

Morris, S., Farran, E. K. & Gilligan-Lee, K. A. (2023) Spatial abilities in Down syndrome: Characterising the profile of spatial skills and models of spatial development. *Cognitive Development*. 66. Available from: doi: 10.1016/j.cogdev.2023.101325

Porras, A. R., Rosenbaum, K., Tor-Diez, C., Summar, M. & Linguraru, M. G. (2021) Development and evaluation of a machine learning-based point-of-care screening tool for genetic syndromes in children: a multinational retrospective study. *The Lancet Digital Health*. 3 (10), e635–e643. Available from: doi: 10.1016/S2589-7500(21)00137-0

Porras, A. R., Rosenbaum, K., Tor-Diez, C., Summar, M. & Linguraru, M. G. (2022) A machine learning-based screening tool for genetic syndromes in children – Authors' reply. *The Lancet Digital Health*. 4 (5), e296. Available from: doi: 10.1016/S2589-7500(22)00047-4

Prena, K. (2014) *Down Syndrome Videogame Preferences*. MA thesis- partial fulfillment. Michigan State University. Available from: doi: 10.25335/ent8-j124

Sabeti, M., Boostani, R., Taheri, B. & Moradi, E. (2024) Image processing and machine learning for diagnosis and screening of craniosynostosis in children. *Interdisciplinary Neurosurgery*. 36. Available from: doi: 10.1016/j.inat.2023.101887

Shahid, N. M. I., Law, E. L. C. & Verdezoto, N. (2022) Technology-enhanced support for children with Down Syndrome: A systematic literature review. *International Journal of Child-Computer Interaction*. 31. Available from: doi: 10.1016/j.ijcci.2021.100340

Sparrow, S. S., Cicchetti, D. V. & Saulnier, C. A. (2016) *Vineland adaptive behavior scales*. 3rd edition. London, Pearson.

Tashnim, A., Nowshin, S., Akter, F. & Das, A. K. (2017) Interactive interface design for learning numeracy and calculation for children with autism. In: *2017 9th International Conference on Information Technology and Electrical Engineering, ICITEE, 12-13 October 2017, Phuket, Thailand*. Piscataway, IEEE. pp. 1–6. Available from: doi: 10.1109/ICITEED.2017.8250507

Wertalik, J. L. & Kubina, R. M. (2018) Comparison of TAGteach and Video Modeling to Teach Daily Living Skills to Adolescents with Autism. *Journal of Behavioral Education*. 27 (2), 279–300. Available from: doi: 10.1007/s10864-017-9285-4

Wester Oxelgren, U., Åberg, M., Myrelid, Å., Annerén, G., Westerlund, J., Gustafsson, J. & Fernell, E. (2019) Autism needs to be considered in children with Down Syndrome. *Acta Paediatrica*. 108 (11), 2019–2026. Available from: doi: 10.1111/apa.14850

Whalen, C., Schreibman, L. & Ingersoll, B. (2006) The collateral effects of joint attention training on social initiations, positive affect, imitation, and spontaneous speech for young children with autism. *Journal of Autism and Developmental Disorders*. 36 (5), 655–664. Available from: doi: 10.1007/s10803-006-0108-z

Widyawati, H. N. & Ardianingsih, F. (2019) Metode Applied Behaviour Analysis (ABA) Bermedia Quiet Book terhadap Kemampuan Daily Living Skills (DLS) Anak Autis. *Jurnal Pendidikan Khusus*. 11 (3), 1–16.

Zgonec, S. & Bogataj, D. (2022) Assistive technologies supporting the independence of elderly adults with intellectual disability: Literature review and research agenda. *IFAC-PapersOnLine*. 55 (39), 129–134. Available from: doi: 10.1016/j.ifacol.2022.12.023

Original scientific paper http://doi.org/10.24867/JGED-2025-3-029

Calibration of the printing process for 3D models using Vat polymerisation and investigation of the mechanical properties of TGM-7 resin

ABSTRACT

With the development of modern technology, three-dimensional graphics (3D) are increasingly making their way into various fields such as design, advertising, packaging, industry and even medicine. Three-dimensional graphic elements can be not only modelled, but also apadted for the three-dimensional printing. However, the quality of the print is highly dependent on the printing method used, technological process and on the properties of the material. In this work, the models were created using 3D graphics software and tested after 3D printing. The new acrylic resin TGM-7, developed by AmeraLabs, was used for the 3D printing. During the testing process, the models were calibrated in order to obtain accurate and high-quality models with fewer inaccuracies or defects in the future and precise connections. During the experiments, a more significant change in dimensions was observed in the lower part of the models, which could have occurred due to the deposition of the polymer. Samples printed at a 45o angle had more accurate dimensions. The mechanism of parameters compensation in the XY and YX axis was demonstrated. During the work, the mechanical properties of the material were also determined, which are important for the many applications such as packaging, advertising items or other products subject to load. The acrylic resin, printed at different angles, exhibited plastic propertie, and samples printed at a 90° angle were better able to withstand dynamic loads, which averaged 206 N. The obtained results were applied to the creation and printing of an advertising model.

KEY WORDS

3D modelling, design, 3D printing, resin, calibration, masked stereolithography, mechanical measurements

Renata Gudaitiene [1]
Vygintas Minkus [1]
Andrius Darulis [2]

[1] Kauno kolegija/Higher Education Institution, Faculty of Computing, Engineering and Technologies, Department of Informatics and Media Technologies, Kaunas, Lithuania
[2] MB Labsamera, Kaunas, Lithuania

Corresponding author:
Renata Gudaitiene
e-mail:
renata.gudaitiene@go.kauko.lt

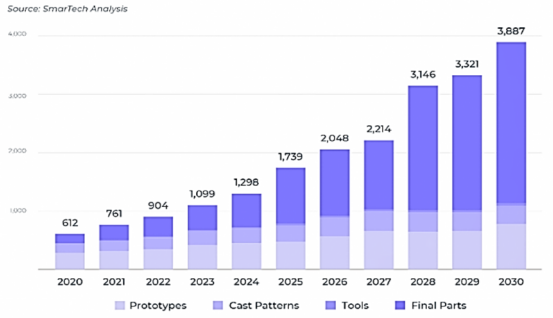
First received: 17.9.2024.
Revised: 21.1.2025.
Accepted: 29.1.2025.

Introduction

With the development of information and multimedia technologies, three-dimensional (3D) technologies are gaining market share (Shahrubudin, Chuan & Ramlan, 2019; Dizon et al., 2018). AMFG (2021) forecasts that by 2030, the use of three-dimensional technology and the revenue generated from 3D printing will more than double, and, as can be seen in Figure 1, not so much in the production of prototypes or parts, but in the production of final goods or their structural accessories. 3D printing is the innovation of this century and, according to Barry Berman (2012), an industrial revolution that can bring original virtual designs into the tangible material world. 3D printing enables the design and production of complex geometric shapes that can be continuously edited, as they do not require any additional moulding and the design ideas are realised through digital tools (Macdonald & Wicker, 2016).

3D printing opens up new opportunities and offers great promise for companies seeking to improve production efficiency. Moreover, this technology has the potential to make important and fundamental changes in the industry

and transform production (Shahrubudin, Chuan & Ramlan, 2019). The application of 3D printing can accelerate the speed of production, especially for small volumes, reducing the time and cost of production (Unifize, n.d.).

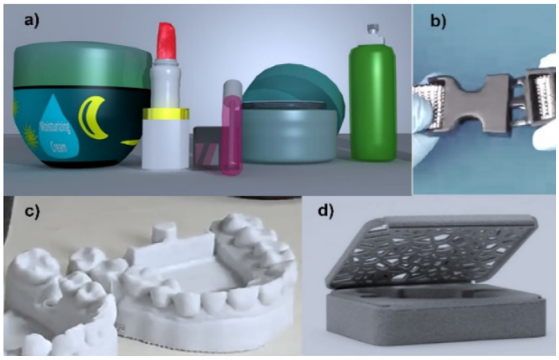


» **Figure 1:** *Revenues from polymers 3D printing in the consumer goods industry in million US dollars (AMFG, 2021)*

A 3D model is a mathematical representation of any three-dimensional object (real or imaginary) in a 3D software environment (Vaira & Linkuvienė, 2013). At the initial stage of turning an idea into a creation, it is important to choose the right 3D printer software. There are many 3D printing software options, but it is important to consider things as follows: ease of use, functionality, compatibility with different file formats and support for a complete additive manufacturing design process. The representatives of Jaycon identify 15 of the most popular 3D printing design software currently available on the market: Autodesk Fusion 360, TinkerCAD, SolidWorks, Rhino3D, SketchUp, Blender, Ultimaker Cura, Autodesk AutoCAD, CATIA, Onshape, ZBrush, FreeCAD, Kreo, Simplify3D, and Autodesk MeshMixer (Jaycon, 2024). Whether it is complex product design or simple 3D objects, the right software can simplify the design process, improve the final product and help achieve the objectives.

Three-dimensional (3D) graphical elements are widely used in many fields, such as architecture, industry (Vaira & Linkuvienė, 2013), medicine (Vaz & Kumar, 2021; Liaw & Guvendiren, 2017), and simple and intelligent packaging (Tracey et al., 2022) as well as in wick design and for advertising purposes (AmeraLabs, n.d.), and in the production of smart 3D structures (Nassar et al., 2018). 3D graphics elements can be successfully applied to 3D printing not only in mass production, but also in the production of single products or prototypes and in the development of educational stands. (Lasec group, n.d.) Some examples of products can be seen in Fig. 2.

3D printing is now useful not only for creating objects with micrometric parameters, but also for creating nanometric structures (Weitzer et al., 2022). So-called 4D technology is also on the way. It is not only possible to obtain a three-dimensional shape, but also to have a variable shape and an object that changes the position of the individual parts (Rieland, 2014). For this purpose, elastic polymeric materials- elastomers- are commonly used (Kuang et al., 2018). Manufacturing a product from such materials can lead to a complex design, which in some cases would be difficult or even impossible to obtain without three-dimensional modelling.

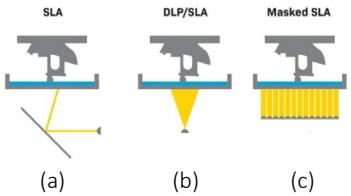


» **Figure 2:** *Examples of 3D models and products (Avid Product Development, 2024; AmeraLabs, 2023): (a) the examples of the 3D models of packaging, (b) the buckle, (c) the printed dentures, (d) the printed box*

In order to make a three-dimensional object three-dimensional and tangible, 3D printing equipment is required. A range of 3D printing techniques are used in this field (All3DP, 2023). Shahrubudin, Chuan & Ramlan (2019) identify and classify the following techniques: binder jetting, directed energy deposition, materials extrusion, materials jetting, powder bed fusion, sheet lamination, and VAT photopolymerisation.

Each printing method has its own characteristics depending on the type of material used, the equipment and the desired result (All3DP, 2023). Currently, the most widely used 3D printing technologies on the market are hot extrusion and resin VAT photopolymerisation (Štaffová et al., 2022).

VAT photopolymerisation is a commonly used 3D printing technique which generally refers to the curing of photoreactive polymers using lasers, light or ultraviolet (UV) light (Low et al., 2017) VAT polymerisation can be performed by different 3D printing technologies (Fig. 3): stereolithography (SLA) and digital light-assisted stereolithography (DLP/SLA) (3DP.Lighting., n.d.), and masked stereolithography (Masked SLA) (Wyss, 2019).



» **Figure 3:** *VAT polymerisation printing techniques: (a) stereolithography, (b) light-flow treatment, (c) masked stereolithography (Wyss, 2019)*

During the initial development of stereolithography, the technology was limited to liquid photopolymers as a raw material. The need to produce robust parts with high mechanical properties and functionality has led researchers to incorporate micro- and nano-sized fillers into the liquid photopolymer for a variety of applications (Chaudhary et al., 2023).

In the case of SLA, the photoinitiator and specific conditions of exposure to UV light influence, as well as any dyes, pigments or other added UV absorbers, have an impact (Stansbury & Idacavage, 2016).

Meanwhile, digital light processing is a stereolithography-like process that works with photopolymers. The main difference in these devices is the light source. Digital Light Processing (DLP) uses a more conventional light source such as an arc lamp with a liquid crystal display panel. It can cover the entire surface of a photopolymer resin vessel in one pass, so it is generally faster than stereolithography (3DP.Lighting., n.d.). The quality of objects can be affected by exposure time, wavelength and amount of energy supplied (quote). Usually, the starting material (resin) is in liquid form and is cured with the help of a polymerizing UV light source. Photopolymerization can produce very high-quality products with good surface smoothness and detail integrity.

An SLA printer can have two types of configurations: bottom-up and top-down (Shahrubudin, Chuan & Ramlan, 2019). In a top-down printer, the first layer is produced on top of a support in the resin, and subsequent layers are cured on top of the lower layers. This technology is still widely used, but the movement of the support along the Z-axis dislodges the resin, and it takes time for the resin to settle which reduces the efficiency of the process. Another type of printer works on the opposite principle: the newly produced layer is placed underneath the previous layers, and photopolymerization with UV light is carried out from below. Since the movement of the support does not move the resin, the surface of the finished structure is always very smooth and the process is faster (FormLabs, 2024a; FormLabs, 2024b).

The main advantages of 3D printing are design flexibility, customisation, waste reduction, rapid prototyping, high precision, tool avoidance and the ability to produce complex structures (Ngo et al., 2018). However, the quality of the print is strongly dependent on the printing method and process used, as well as on the design of the object (Faroze, Srivastava & Batish, 2024).

The main disadvantage is the heterogeneity of 3D printed parts due to defects between adjacent print layers or voxels or polymer relaxation and inhomogeneous monomer conversion in the prints (Štaffová et al., 2022). For this purpose, calibration shapes are printed and their dimensions evaluated (Ameralabs, n.d.).

Difficulties may also arise when trying to fit parts together in joints. In this case, it is important to recalculate and change the dimensions of the objects ready for printing, which is not a straightforward process as some parts of the object may need to be reduced and others enlarged (3D Maker Noob, 2018). Snap-fit joints are a way to connect two different components without using fasteners or permanently joining the parts so that they can be separated later. Once assembled, a snap-fit connector can be either permanent or demountable. There are several different types of joints (cantilever snap fit joints, torsional snap fit joints and annular snap fit joints), but they should all be designed to be easy to assemble by hand (Shields, 2023).

During testing, conversions and calibration of the printing equipment are carried out (3D Maker Noob, 2018). Such test calibration printing and evaluation is particularly important for newly developed or purchased materials. Synthetic polymer resins exhibit a full range of different properties such as polymer fluidity, plasticity, polymerisation and relaxation rates, varying degrees of cure, and resistance to mechanical stresses (Govaert, van der Vegt & van Drongelen, 2019).

Experimental materials and equipment

A new acrylic resin TGM-7 from AmeraLabs was used in this experiment. Table 1 shows the main chemical constituents of the resin.

Table 1
The main chemical constituents of resin

Name of chemical component	CAS Nr.	Concentration
4-(1-okso-2-propenil)-morfolinas	5517-12-4	50-55%
(oktahidro-4,7-metano-1H-indenediil)bis(metilen)diakrilatas	42594-17-2	6-9%
Difenil(2,4,6-trimetilbenzoil) fosfino oksidas	75980-60-8	1-4%

The 3D objects were modeled using Autodesk Fusion 360 software and prepared for printing using the CHITUBOX programme. All samples were printed using a masked SLA printer Elegoo Mars 3 4K. The parameters of the printing process are given in Table 2.

After 3D printing, the samples were washed with isopropanol for 14 min in a wash and cure station Anycubic Wash & Cure plus, dried in the air for 30 min and then additionally polymerized (post-cured) in a standard UV chamber Anycubic Wash & Cure 2.0 (power 25 W) with UV light source of 405 nanometers wavelength.

Determining the strength properties, the tension measurement stand was chosen: the universal 10 kN power testing machine Tinius Olsen H10KT with a 500 N force measurement sensor. Tensile measurements were made according to the ISO 527-5A standard (tensile time 5 min, distance between grips 25 mm).

Table 2

The main printing parameters of resin

Name of producing parameters	Values of parameters
UV spectrum peak	2.62 mW·cm^{-2}
Light intensity	406.3 nm
Exposure time	1.6 s
Motor rotation deviation with respect to the Z axis	1,25 µm
Woxel size	0,035 mm

Results and discussions

Occurrence of defects

The printing process itself is not complicated, but a poorly designed and prepared model can be much more troublesome, leading to defects after printing. When modelling objects, it is necessary to consider both the design and the construction of the future product, i.e. whether the designed object will print and whether the parts will be of the right size and be able to be joined together. Incorrect decisions by the designer can lead to failure, with the object ending up with an uneven surface or being torn apart during printing due to stresses in the material.

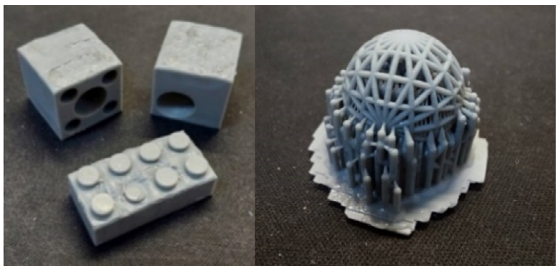
Fig. 4 (a) shows horizontally printed objects that were lifted to a height of 5 mm on supports. This 'run-out' of layers occurs when the supports do not hold the printed layer sufficiently and it begins to fall before the next layer is printed. These defects can be avoided by printing objects flat on the platform, by rotating them at an angle, or by adding more supports of appropriate parameters.

When forming holes, small surface creases may also appear on the sides of the parts. Too few composite supports can also cause the model to wobble, affecting the shape and surface smoothness of the model.

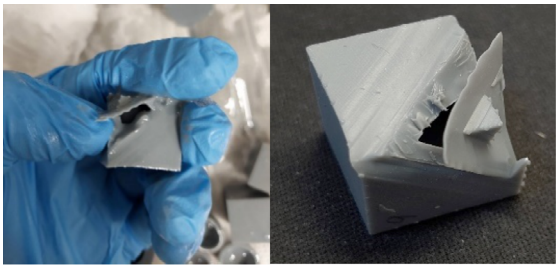
Fig. 4 (b) shows a 20 mm diameter ball on which supports have been placed by hand to support each part of the ball. The supports are visible both externally and internally, connected to each other and from object to object. Printing such balls requires far fewer supports than the shape of the model might suggest, depending on the size of the object and the thickness of the shell.

Sometimes when printing, especially for inexperienced 3D printmakers it happens that for some reason the objects are not printed and remain in the container. This is usually because the supports used could not support the weight of the object or resist the adhesion to the FEP film and fell off. The supports may not hold the object if their contact diameter is too narrow (< 0,30 mm).

In Figure 4 (c), a hollow part was modelled in order to lighten the object and save material. Unfortunately, the void and stresses inside caused the part to tear due to air ingress.



(a)



(b)

» **Figure 4:** *3D printing defects caused by the selection of the wrong supports (a) and design solution (b)*

Study of the parameters of a cube with a hole

In order to ensure the accuracy of the 3D object after printing, it is important not only to select the correct supports during the modelling process, but also to carry out the dimensional refinement and adjustment steps and the calibration process of the machine, which was done in this study. The calibration process is carried out each time a new, untested resin is selected for printing. In this work, a new AmeraLabs acrylic resin TGM-7 was used for research. The quantity and shape of the calibration parts may depend on the shape of the final product to be printed and the shape of the components and their connections. The work started with the modelling of the calibration shapes. Autodesk Fusion 360, a three-dimensional graphics programme, was chosen for the modelling of the figures on a computer. A 30 mm cube was created with the box tool and a circular hole of 20 mm diameter, 30 mm long, was formed horizontally in the centre of the cube (Fig 5, a).

The generated shape was exported to an "stl" format file.

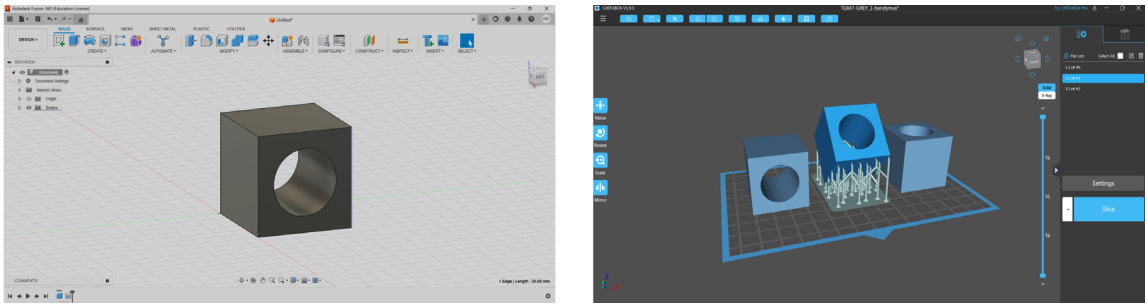
This file type is a common format for 3D printing and Computer-Aided Design (CAD) applications. The resulting file was loaded into the cutting programme CHITUBOX (Fig 5, b). Here, the shapes were copied and rotated to angles of 1-0, 2-45 and 3-90 degrees respectively and prepared for printing to investigate the dimensional change after seating and relaxation of the polymerised resin.

The model printed at 45 degrees did not have a strong contact with the printing platform, so it was lifted to a height of 5 mm from the platform and supports were placed to hold the object in place to prevent it from falling and moving during the printing process (Fig. 6). The supports can be placed automatically or manually.

In this case, the automatic placement was performed and the required parameters have been set (Fig. 6).

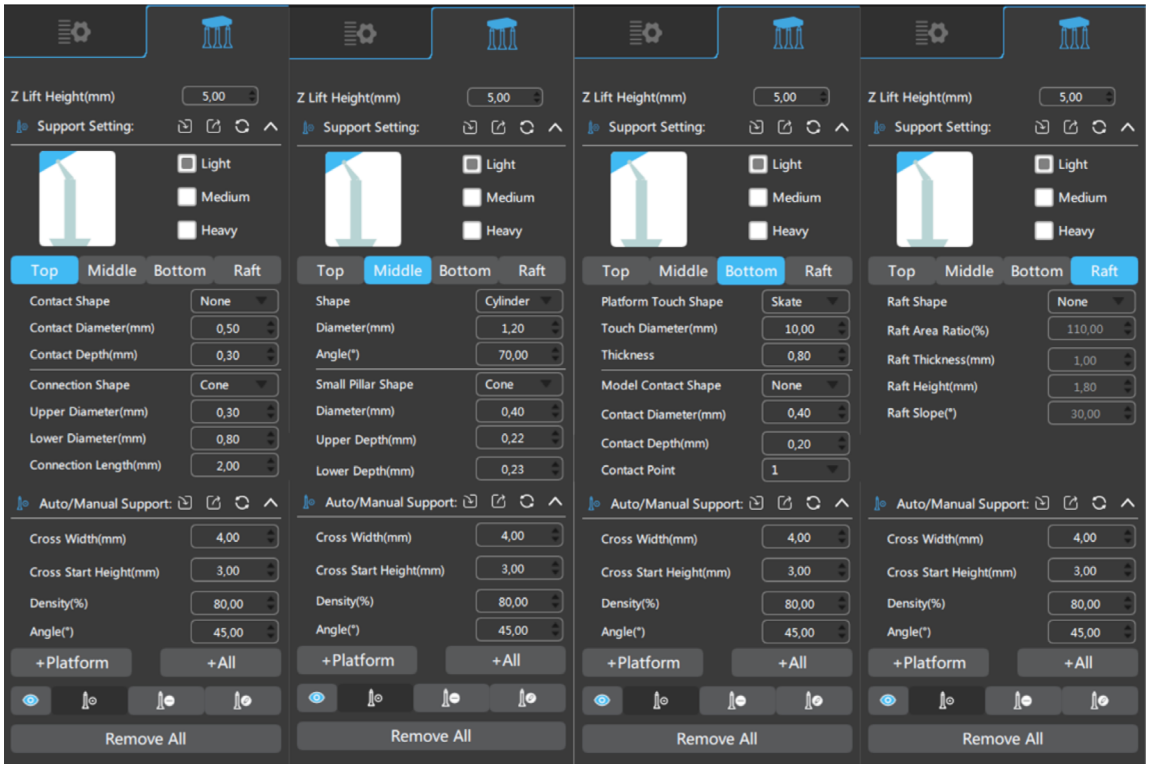
Among the support settings, lightweight supports have been selected and the shape of the base has been changed to a flat shape to better adhere to the printing platform and to make it easier to unhook the printed object.

The shape of the tip contacts was switched off and only the tip itself was adjusted, which was conical in shape with an upper diameter of 0,30 mm and a lower diameter of 0,80 mm. The middle part of the supports is cylindrical with a diameter of 1,20 mm. The diameter of the lower part was 10 mm. The correct selection of the supports is important for the surface shaping of the object in order to prevent them from



(a) (b)

» **Figure 5:** *Object preparation for printing: a) simulated calibration cube in Autodesk Fusion 360, b) cubes (1, 2, 3) ready for printing in CHITUBOX*

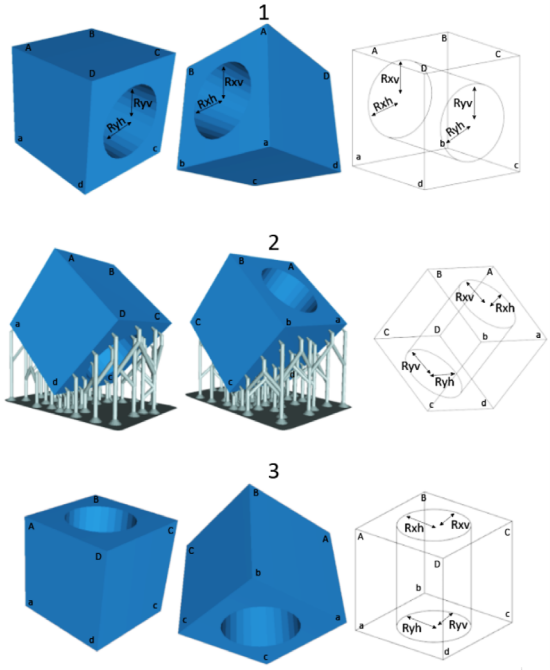


» **Figure 6:** *Support settings: a) top, b) middle, c) bottom, d) base*

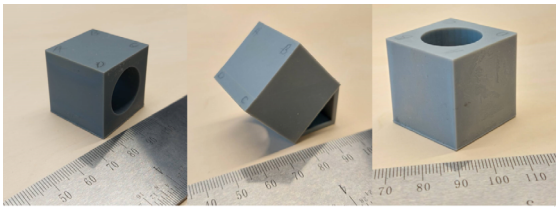
settling during the printing process or separating from the surface after the object has been printed. Once the supports were assembled, the appropriate print settings were selected to best suit the type of resin.

The printed objects were measured with a precision electronic caliper to estimate the overall dimensions of the cones and holes in all axial directions. The printed 3D objects (Fig. 8.) were labelled according to the scheme shown in Fig. 7. For the printing process, 4 bottom layer counts, exposure time 1,6 seconds, bottom exposure time 20 second and 0 transition layer count were set.

After the shapes were prepared for printing, the file was exported from the cutting program in "ctb" format to be recognised by the printer. In order to estimate the dimensions of the edges of the modeled and sharply rotated objects after printing, they were marked with letters, as shown in Figure 7.



» **Figure 7:** *Marking angles and holes in the calibration models*



» **Figure 8:** *Printed models separately (1, 2, 3)*

The printed objects were further hardened by polymerisation with 405 nm UV light to stabilise their parameters. The defects on the models were observed after the curing process was completed.

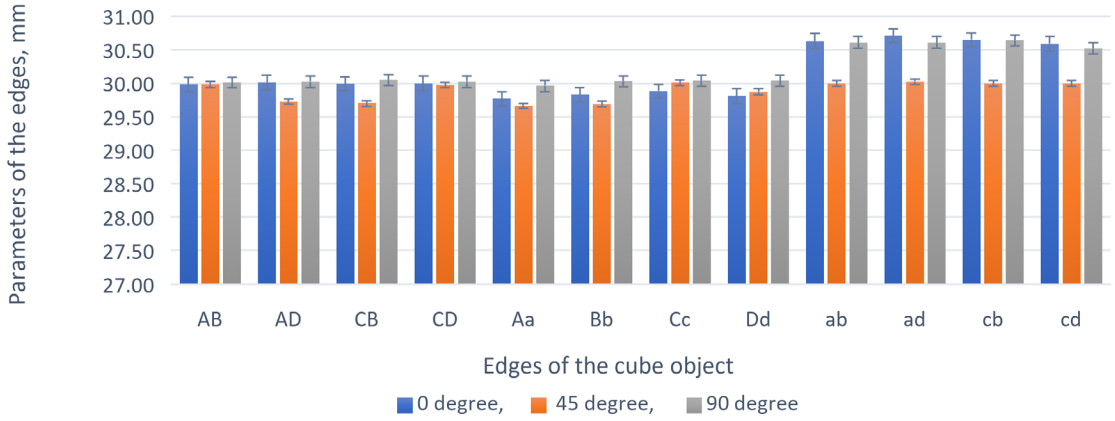
The most noticeable defects were the seating of the first cube figure in the hole during printing, the polymer shrinkage inside the hole, the 'step' effect of the second figure and the blooming of the third printed model.

As can be seen from the diagram (Fig. 9), the largest dimensional changes for the first cube model, printed at a 0 degree angle, were in the vertical axes and at the base. The edges AB, AD, CB, and CD of the first model were smaller than the edges AB, AD, CB, and CD, indicating that the bottom of the model was wider than the top by an average of 0.645 mm, or 2.19 percent of the 30 mm value set for the modeled object. The vertical edges of Aa, Bb, Cc and Dd were also shorter by 0.18 mm (0.59%) than the theoretical set dimension of 30 mm. The second model was reduced in height by 0.19 mm (0.63%). The dimensions of the horizontal edges varied only slightly. Comparing the first and third models, it can be seen that vertically there was a subsidence and the dimensions became smaller than those of the modelled objects, while at the base there was a pronounced widening of the objects by 2% on average. The smallest average change (decrease) in all dimensions was observed in the 45 degree printed object. We think that these changes in the models could have occurred due to the deposition of the polymer in relation to the vertical Z axis, as well as due to the error of the UV light source and the amount of light received through the printed polymer layer.

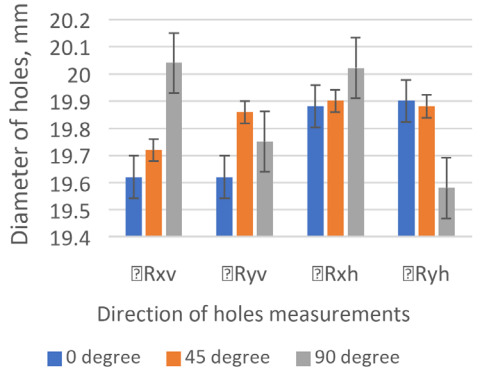
For the same reason, the diameters of the holes in the cobe models also have been changed. Theoretically, the exposure error of the UV source can be compensated through the printing software, but the quality of the software can also affect it.

The hole diameter of the first model decreased more in the vertical Z axis (Fig. 10) than in the horizontal (X and Y) axes, indicating that the hole became slightly elliptical. In the third cube model, the hole at the top of the object remained closest to the hole diameter determined by the modelled object, but at the bottom of the object, the diameter of the hole decreased in both axes, resulting in a conical shape with a smaller diameter at the bottom. The hole dimensions of the cube models printed at 45 degrees also decreased, but the average change was not as large as for the models printed at 0 and 90 degrees and averaged 0,8%.

Thus, a comparison of the three cube models printed at different angles shows that the polymer's yielding properties resulted in all the layers of the object being exposed vertically to the polymer's own weight during printing and seating. The upper parts of the models were narrower than the lower parts, and the edges which were expanded were contracted on the opposite side. In the case of the holes, the cube samples were also observed to sit with respect to the vertical axis.



» **Figure 9:** *Comparison of edges parameters of printed cube models*



» **Figure 10:** *Comparison of holes diameter of printed cubes*

In order to avoid the inaccuracies obtained, the 3D models of the cubes with holes were corrected in the software environment after printing and their dimensions were changed according to the results obtained.

Dimensional accuracy is particularly important when the objects are to be used in more complex constructions or when they are to be combined with each other.

Dimensional errors in the models can also be caused by the temperature of the printing resin (which rises from 23 to about 35 degrees from the start of the process), which affects the flow of the polymer or the quality of the printer screen.

The quality of the screen affects the uniformity of the transmitted light flux. Light intensity at different points can vary by about 20%, so dimensional accuracy can be affected by uneven light flux on the surface, especially if objects are placed in different places during printing, rotated at different angles, or placed at too small distances from each other. In order to obtain the most accurate dimensions of the model after printing, the factors mentioned above should be evaluated and tried to eliminate them as much as possible.

Calibration figure "steps"

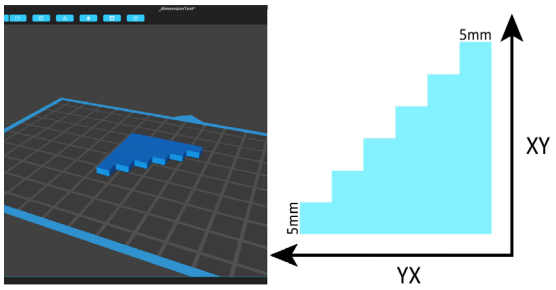
For the second type of calibration, a popular calibration figure "steps" was chosen to see how the polymer sits on average with respect to the X and Y axes. The height of the step chosen for each model was 5 mm (Fig. 11). For the first time, this part was printed 3 times without any compensation (Table 3). After measuring all the shapes, the averages were averaged and fed into a specially designed dimensional compensation calculator. This spreadsheet allows you to immediately see the percentage decrease or increase in the dimensions of a figure, as well as the compensation in millimetres (Table 4).

The averages of the overall results were then fed into the CHITUBOX software in the advanced settings section, as shown in Fig 12. After combining the results obtained for the dimensional compensation and growth of the part, the part was printed 3 more times.

The dimensions of the printed figures were measured and averaged again in the spreadsheet to check the accuracy. As can be seen from the results obtained (Fig. 11), the accuracy of the steps of the part in the XY axis was higher than in the YX axis, indicating that the polymer expanded more in the latter axis.

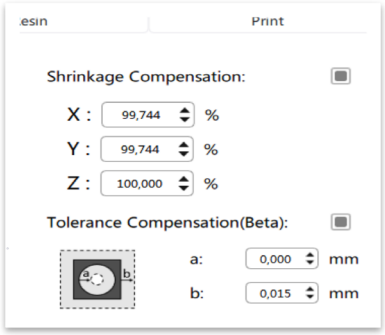
Using compensation, the resulting post-printed dimensions were more accurate and more similar to the modelled shape, as shown. However, the overall average compensation error for the YX-axis had a smaller improvement in performance than for the XY-axis.

These results suggest that the compensation mechanism could work better by specifying different percentages of compensation for the axes. Performing this calibration process with more shapes could lead to even more accurate dimensions, especially for small parts. For the sake of clarity, it should be mentioned that the uniformity of the light flux and the position of the object on the base could have had a small influence on the different relaxation of the polymer in relation to the X and Y axes.



(a) (b)

» **Figure 11:** *Calibration detail "steps" in the CHITUBOX software environment (a) and step measurement diagram (b)*



» **Figure 12:** *Calibration part "steps" print settings based on the overall average of results in the CHITUBOX software*

Table 3

Results of the dimensions of the calibration component 'steps' for different axes

Nominal, mm	Measured, mm		Measured after compensation, mm	
	XY	YX	XY	YX
5	4,94	4,97	4,94	5,00
10	9,99	10,02	9,98	10,02
15	15,01	15,05	15,02	15,03
20	20,02	20,06	20,00	20,03
25	25,03	25,04	25,00	25,00
30	30,02	30,03	29,99	29,05

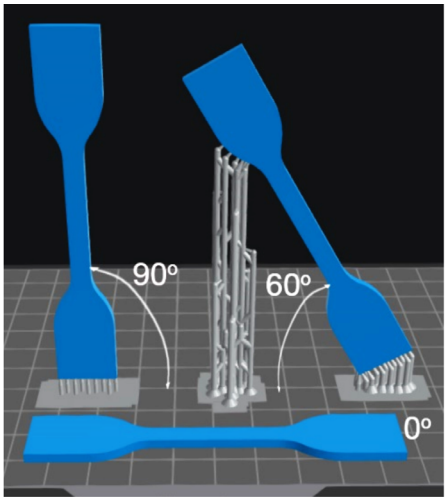
Table 4

Overall average of results of the dimensions of the calibration component 'steps'

Results	Before compensation		After compensation	
	XY	YX	XY	YX
Scale, %	99,70	99,79	99,83	100,18
Compensation, mm	0,026	0,004	0,02	-0,018
Avg. scale, %	99,74		100,006	
Avg. Compensation, mm	0,015		0,0012	

Mechanical measurements

In order to make an effective choice of material, it is important to understand the basic mechanical properties of the resin, how plastic the material is, and how much load it will be able to bear. These properties are essential as they reveal how the resin performs under different conditions, help determine the durability of the material, and the stiffness of the structural elements (Dizon et al., 2018). Therefore, in this work, the tensile strength of the selected acrylic resin TGM-7 was evaluated. The samples for investigation were printed in different angles (Fig. 13).



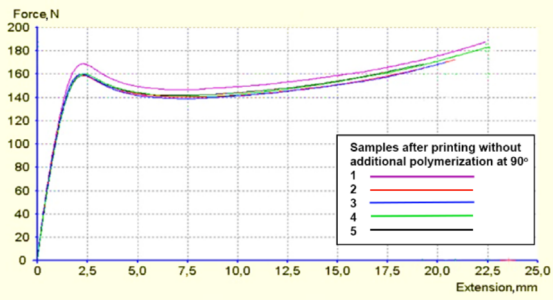
» **Figure 13:** *Samples models in different angles prepared by 3D printing for mechnical measurements*

The tensile properties of the samples are also influenced by the additional exposure to UV light and the orientation of the object at a certain angle. The evaluation of these important properties will allow better informed decisions to be made to ensure optimum performance and durability of printed parts.

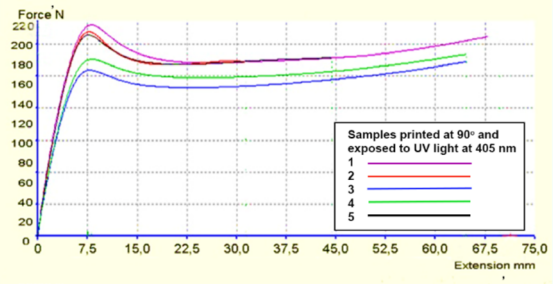
As can be seen from the graphs in Fig. 14, the sample printed at a 90-degree angle (a) without additional UV polymerization was able to withstand an average force of 176.4 N. The study also showed that the additional UV polymerisation gave the samples additional strength and stability. From the second graph (b) we can see that after additional polymerisation with a 405 nm light source, the load capacity of the sample increased to an average of 206 N, which is 14.6%, while some samples reached a maximum load of 220 N. The position of the samples in the curing oven may have contributed to the wider scatter in the measured results.

The maximum stresses of the samples and their stresses at failure were determined by investigating the effect of tensile force on the samples. As can be seen from the graph below (Figure 15), for all three samples, excepting the sample printed at a 90° angle and exposed to UV

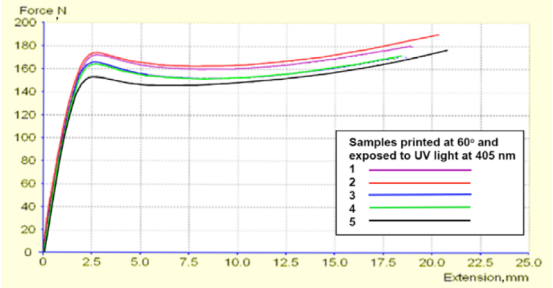
light, the maximum stress value at the necking threshold was lower than at the necking rupture point. This indicates that the material is quite plastic. The sample printed at a 90-degrees and additionally polymerised with UV light showed a higher load resistance. This demonstrates that even a low level of UV polymerisation can affect the mechanical properties of the samples.



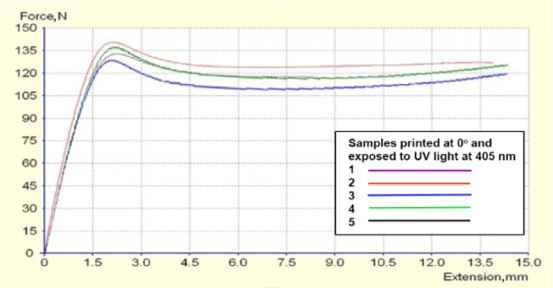
(a)



(b)



(c)

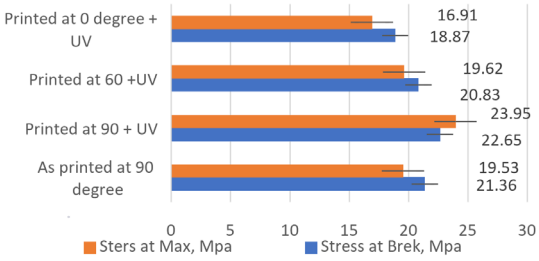


(d)

» **Figure 14:** *The dependence of the tensile force vs the elongation of the samples (tensile speed of samples – 5 minutes, the distance between the holding grips – 25 mm: a) samples after printing without additional polymerization at a 90°; b) samples exposed to UV light (at 405 nm), printed at a 90°; c) samples printed at a 60° and exposed to UV; d) samples printed at a 0° degree and exposed to UV light*

In order to investigate the stability of the sample when rotated by 60-degrees, it was found that the tensile strength of the samples decreased to an average of 177,4 N and was almost identical to that of the samples not additionally cured by the UV light source.

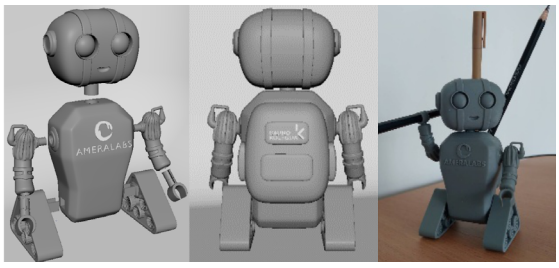
The samples placed on the platform (at 0 degrees) were even less resistant to tensile stress, with an average tensile strength of 132 N. The average elongation of the samples at the fracture limit was almost directly proportional to the change in tensile force to the next one, from 14,3 to 64,7 mm respectively.



» **Figure 15:** *Stresses of the samples at maximum and at break*

Development of the advertising model

Considering the results of measurements before and after calibration and the resistance measurements, an advertising object was created and modeled. It was important to take into account the purpose of the future product and to consider its design, so that the modeled and printed object was not only attractive, but also functional. After the analysis and search for creative solutions, it was decided to create a model of a small robot that would demonstrate the technical possibilities of resin printing and at the same time be useful to the consumer who purchased the product. For that purpose, five variants of the robot were modeled, one opf which is shown in Fig. 16.



» **Figure 16:** *A 3D model of the advertising and printed object*

Furthermore, the print orientation, having a high impact on mechanical properties, is discussed with a particular regard on the residual stress mitigation in future applications, such as 3D-printed cellular bodies.

To demonstrate the effect of calibration on the user, the robot's arms, hands, legs, head, and backpack were printed separately from the body, using different types of connectors and latches, but with preadjustment of detail parts at the joints.

The robot's functionality is manifested through the robot's hands and a modeled backpack. Its hands are sized to fit a standard pencil or thin pen with a diameter of about 7 millimeters. The backpack is designed to be large enough to hold up to 3 pencils or pens, or any other small items such as paper clips, paper clips or stapler pins.

Conclusions and recomendations

Conclusions

During this work, calibration objects were created in the Autodesk Fusion 360 programme and applied to the printing by rotating them at different angles of 0, 45 and 90 for the Chitubox programme. The original AmeraLabs TGM-7 acrylic resin was used to 3D print the models.

After the test printing of objects of different shapes, such defects as surface dripping, "blooming" defect, surface irregularities due to the selection of improperly selected supports, tearing of objects due to the absence of vent holes in hollowed parts in the object were observed. It was observed that filling the voids completely with material results in better product quality than trying to leave the voids unfilled with air gaps. This can make the product heavier, but with a small product it is worth sacrificing the amount of resin for the 3D printing for better final object quality.

After the initial visual quality assessment of the printed figures, measurements were made, and changes in shape were recorded. The real height of the cube-shaped figures decreased by an average of 110 µm. The width of the lower part was larger than the upper part by an average of 340 µm. Based on the results, the height of the objects was increased, and their width was reduced accordingly in the modeled samples.

The difference in the dimensions may be caused by the inaccuracies of the 3D printing equipment and material shrinkage. Some of such inaccuracies can be overcome by adjusting the printing parameters, orientation, and adjusting the design of the model. When the sample was rotated at 45 degrees, a slight expansion of the lower planes was also observed, resulting in the external dimensions of the model being adjusted accordingly. Printing at this angle produced the most accurate dimensions of objects.

After measuring the diameter of the holes, it was observed that the diameter of the holes when the cube-sample is in the vertical position is about 380 µm smaller in the vertical than in the horizontal position (a decrease of 110 µm), and when the printed cube is at an angle or when the hole is in the vertical position, the lower part of the hole diameter is obtained higher than the upper one due to polymer deposition, shrinking and relaxation phenomena.

Measurements of step-shaped samples showed that the overall coefficient of compensation parts can serve to bring the dimensions of the product closer to ideals. However, compensation for XY and YX planes should be done separately to have even greater accuracy in small details. The position of the model on the base and the evenness of the light flux hitting the model can also affect the parameters of the object.

After performing mechanical measurements of the sample's stretching, it was found that the acrylic resin used for the work had plastic properties after printing, and the samples printed at an angle of 90 degrees and polymerized with UV light had a higher resistance to dynamic load.

In the course of this work, applying the results obtained from the conducted research, an original advertising robot model with certain functionality was modeled, prepared for the 3D printing and printed.

Recommendations for 3D printing

Printing hollow objects without holes or with very small holes (< 2 mm) is not recommended, because it is very important to wash off the remaining resin to avoid harm to health, and closed figures do not allow this.

Before 3D printing, dimensional accuracy calibration should be performed and dimensional compensation should be applied in the slicer. If the hole is in a horizontal position, it is necessary to increase the diameter of the hole, especially in relation to the horizontal plane.

Avoid printing figures flat and raised on supports, as this requires significantly more supports than printing at an angle. Also, when printing at an angle, the dimensions of the resulting figures are more similar to the designed model.

When 3D printing samples are at an angle, it is important to place the proper supports so that the object can be printed and the polymer does not deform.

Every now and then, before printing, it is necessary to check the oil lubrication of the motor axis, as insufficient oil will cause vibrations and the object will be printed inaccurately.

If during printing there were figures that were not printed completely, or broke off and fell into the VAT (liquid container), it is recommended not to pour the resin back into the container it is held in, as debris may enter and spoil the remaining resin. It is recommended to use the printer's container clean function to collect loose debris, or use a funnel with a filter when pouring the resin back into its container to keep any debris out.

Acknowledgment

This work was supported by MB Labsamera and Kauno kolegija/HEI.

Funding

The research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

3D Maker Noob. (2018) *3D Printing in TPU - Tips and Tricks*. 3D Maker Noob. [Video]. Available from: https://www.youtube.com/watch?v=ACRh-51hdBxo [Accessed 6th March 2024]

3DP.Lighting. (n.d.) *Digital Light Processing (DLP)*. Available from: https://www.3dprinting.lighting/3d-printing-technologies/digital-light-processing/ [Accessed 6th March 2024]

All3DP. (2023) *3D Printing Technology Guide: The 7 Main Types of 3D Printing Technology*. Available from: https://all3dp.com/1/types-of-3d-printers-3d-printing-technology/#section-vat-polymerization [Accessed 6th March 2024]

Ameralabs. (n.d.) *Resin 3D printing troubleshooting: a comprehensive guide*. Available from: https://ameralabs.com/blog/resin-3d-printing-troubleshooting-a-comprehensive-guide/ [Accessed 6th March 2024]

AMFG. (2021) *5 Ways 3D Printing Can Benefit the Consumer Goods Industry.* Available from: https://amfg.ai/2018/06/08/3d-printing-consumer-goods-industry-5-benefits/# [Accessed 6th March 2024]

Avid Product Development. (2024) *Unlocking Limitless Possibilities: The Incredible Benefits of 3D Printing*. Available from: https://avidpd.com/knowledge-base/what-is-topology-and-why-optimize-it/ [Accessed 15th September 2024]

Berman, B. (2012) 3-D printing: The new industrial revolution. *Business Horizons.* 55 (2), 155-162. Available from: doi: 10.1016/j.bushor.2011.11.003

Chapiro, M. (2016) Current achievements and future outlook for composites in 3D printing. *Reinforced Plastics*. 60 (6), 372-375. Available from: doi: 10.1016/j.repl.2016.10.002

Chaudhary, R., Fabbri, P., Leoni, E., Mazzanti, F., Akbari, R. & Antonini, C. (2023) Additive manufacturing by digital light processing: a review. *Progress in Additive Manufacturing*. 8, 331–351. Available from: doi: 10.1007/s40964-022-00336-0

Dawood, A., Marti, B. & Sauret-Jackson, V. (2015) 3D printing in dentistry. *British Dental Journal*. 219, 521-529. Available from: doi: 10.1038/sj.bdj.2015.914

Dizon, J. R. C., Espera, Jr. A. H., Chen, Q. & Advincula, R. C. (2018) Mechanical characterization of 3D-printed polymers. *Additive Manufacturing*. 20, 44-67. Available from: doi: 10.1016/j.addma.2017.12.002

Faroze, F., Srivastava, V. & Batish, A. (2024) Modelling and prediction of mechanical properties of FFF-printed polycarbonate parts using ML and DA hybrid approach. *Colloid and polymers science*. 302 (12), 1891-1909. Available from: doi: 10.1007/s00396-024-05315-1

FirmLabs. (2024a) *Guide to Resin 3D Printers: SLA vs. DLP vs. MSLA vs. LCD*. Available from: https://formlabs.com/blog/resin-3d-printer-comparison-sla-vs-dlp/ [Accessed 6th March 2024]

FirmLabs. (2024b) *Guide to Stereolithography (SLA) 3D Printing*. Available from: https://formlabs.com/blog/ultimate-guide-to-stereolithography-sla-3d-printing/ [Accessed 6th March 2024]

Gaikwad, S. R., Pawar, N. H. & Sapkal, S. U. (2022) Comparative evaluation of 3D printed components for deviations in dimensional and geometrical features. *Materials Today: Proceedings.* 59 (1), 297-304. Available from: doi: 10.1016/j.matpr.2021.11.157

Govaert, L. E., van der Vegt, A. K. & van Drongelen, M. (2019) *Polymers: From Structure to Properties*. Delft Academic Press. Available from: https://ris.utwente.nl/ws/portalfiles/portal/301365831/Polymers_from_structure_to_properties.pdf [Accessed 6th March 2024]

Jaycon. (2024) *Top 15 Design software for 3D Printing*. Available from: https://www.jaycon.com/top-15-design-software-for-3d-printing/ [Accessed 6th March 2024]

Kuang, X., Chen, K., Dunn, C. K., Wu, J., Li, V. C. F. & Qi, H. J. (2018) 3D Printing of Highly Stretchable, Shape-Memory, and Self-Healing Elastomer toward Novel 4D Printing. *ACS Applied Materials & Interfaces*. 10 (8), 7381-7388. Available from: doi: 10.1021/acsami.7b18265

Lasec group. (n.d.) *3D educational models*. Available from: https://www.laseceducation.com/products/3d-education-models.html [Accessed 6th March 2024]

Liaw, C-Y. & Guvendiren, M. (2017) Current and emerging applications of 3D printing in medicine. *Biofabrication*. 9 (2). Available from: doi: 10.1088/1758-5090/aa7279

Low, Z., Chua, Y. T., Ray, B. M., Mattia, D., Metcalfe, I. S. & Patterson, D. A. (2017) Perspective on 3D printing of separation membranes and comparison to related unconventional fabrication techniques.

Journal of Membrane Science. 523 (1), 596-613. Available from: doi: 10.1016/j.memsci.2016.10.006

Macdonald, E. & Wicker, R. (2016) Multiprocess 3D printing for increasing component functionality. *Science*. 353 (6307). Available from: doi: 10.1126/science.aaf2093

Nassar, H., Markellos, N., Navaraj, W. T. & Dahiva, R. (2018) Multi-Material 3D Printed Bendable Smart Sensing Structures. In: *IEEE Sensors 2018 - Italian National Conference on Sensors, 28-31 October 2018, New Delhi, India*. Piscataway, IEEE. Available from: doi: 10.1109/ICSENS.2018.8589625

Ngo, T. D., Kashani, A., Imbalzano, G., Nguyen, K. T. Q. & Hui, D. (2018). Additive manufacturing (3D printing): A review of materials, methods, applications and challenges. *Composites Part B: Engineering*. 143, 172-196. Available from: doi: 10.1016/j.compositesb.2018.02.012

Rieland, R. (2014) Forget the 3D Printer: 4D Printing Could Change Everything. *Smithsonian Magazine*. Available from: https://www.smithsonianmag.com/innovation/Objects-That-Change-Shape-On-Their-Own-180951449/ [Accessed 6th March 2024]

Shahrubudin, N., Chuan, L. T. & Ramlan, R. (2019) An Overview on 3D Printing Technology: Technological, Materials, and Applications. In: *The 2nd International Conference on Sustainable Materials Processing and Manufacturing, SMPM 2019, 8-10 March 2019, Sun City, South Africa*. Amsterdam, Elsevier. pp. 1286-1296. Available from: doi: 10.1016/j.promfg.2019.06.089

Shields, G. (2023) How to Design Snap Fit Joints for 3D Printing. *PrintPool*. Available from: https://www.printpool.co.uk/articles/how-to-design-snap-fit-joints-for-3d-printing [Accessed 6th March 2024]

Stansbury, J. W. & Idacavage, M. J. (2016) 3D Printing with polymers: Challenges among expanding options and opportunities. *Dental Materials*. 32, 54-64. Available from: doi: 10.1016/j.dental.2015.09.018

Tracey, T., Predeina, A. L., Krivoshapkina, E. F. & Kumacheva, E. (2022) A 3D printing approach to intelligent food packaging. *Trends in Food Science & Technology*. 127, 87-98. Available from: doi: 10.1016/j.tifs.2022.05.003

Unifize. (n.d.) *How to reduce product design & engineering cycle times by up to 75% in 30 days*. Available from: https://www.unifize.com/blogs/how-to-reduce-product-design-engineering-cycle-times-by-up-to-75-in-30-days [Accessed 6th March 2024]

Vaira, Z. & Linkuvienė, D. (2013) *Multimedijos technologijos*. Klaipėda, College of Social Studies.

Vaz, M. V. & Kumar, L. (2021) 3D Printing as a Promising Tool in Personalized Medicine. *Journal of the American Association of Pharmaceutical Scientists*. 22 (1). Available from: doi: 10.1208/s12249-020-01905-8

Weitzer, A., Huth, M., Kothleitner, G. & Plank, H. (2022) Expanding FEBID-Based 3D-Nanoprinting toward Closed High Fidelity Nanoarchitectures. *ACS Applied Electronic Materials*. 4 (2), 744–754. Available from: doi: 10.1021/acsaelm.1c01133

Wyss, J. (2019) Masked Stereolithography 3D Printing. *Diyode*. 29.

Yao, H., Wang, J. & Mi, S. (2018) Photo Processing for Biomedical Hydrogels Design and Functionality: A Review. *Polymers*. 10 (1). Available from: doi: 10.3390/polym10010011

Štaffová, M., Ondreáš, F., Svatík, J., Zbončák, M., Jančář, J. & Lepcio, P. (2022) 3D printing and post-curing optimization of photopolymerized structures: Basic concepts and effective tools for improved thermomechanical properties. *Polymer testing*. 108. Available from: doi: 10.1016/j.polymertesting.2022.107499

Professional paper
http://doi.org/10.24867/JGED-2025-3-041

Possibility of exact realization of silver tones in electrophotographic printing

ABSTRACT

Except for standard CMYK colors in high-quality printed products, designers often choose metallic silver tones. With this method, designers underline important segments and parts of printed publications. Silver applications today are mostly performed with expensive foil printing techniques or lithographic offset printing. However, the development of new Xerox electrophotographic machines has enabled the application of an additional silver toner that achieves a metallic effect of silver tones. In this paper, the possibility of successful realization of silver PANTONE 877C printed with the conventional offset printing (HUBER printing ink series Alchemy) and with silver Xerox emulsion aggregation (EA) toner was investigated. The test used 170 g/m² gloss art printing paper printed on printing press Heidelberg GTO ZP 52 (offset printing conditions) and Xerox Versant 180 (electrophotographic printing conditions). Due to the easier modification of the electrophotographic press conditions (RIP Fiery FS 200), the printing was performed with two screenings (AM and FM distribution of printing elements in a halftone image). Due to the use of different silver pigments, two colorimetric measurement methods (M0 and M3 mode) were also analyzed. Colorimetric analysis (CIE LAB measurements and ΔE2000 color difference) showed that the silver halftones of Xerox EA toner also achieve large color changes ΔE_{mean}>5. However, the PANTONE 877C tone will be better reproduced in full tone (ΔE_{OFF_Xerox} = 4,2) while the rasterization process will achieve higher average tone deviations. By varying the Fiery RIP settings (FM-AM screening), a better imprint will be obtained with FM screening (average difference ΔE_{FM_AM} = 0,64).

Igor Majnarić [1]
Dean Valdec [2]
Đorđe Vujčić [3]

[1] University of Zagreb, Faculty of Graphic Arts, Zagreb, Croatia
[2] University North, University Center Koprivnica, Department of Art Studies, Koprivnica, Croatia
[3] University of Banja Luka, Faculty of Technology, Graphic engineering, Banja Luka, Bosnia and Herzegovina

Corresponding author:
Igor Majnarić
e-mail:
igor.majnaric@grf.unizg.hr

First received: 8.11.2021.
Revised: 17.1.2022.
Accepted: 20.1.2022.

KEY WORDS
printing silver-tone, M0 and M3 measure mode, EA silver toner, silver offset ink, CIE LAB ΔE2000.

Introduction

Printed products to achieve added value, need to be additionally printed with special inks and varnishes. By current representation, the silver print is at the very top option, which, together with gold and white inks, makes up the majority of such effects.

Thus, silver ink use achieves highly reflective imprints (metallic effect) which also has a high coverage (good brightness on darker printing substrates) (Hanisch, 2021).

Traditional printing techniques for creating silver tones are the application of metal foil (cold foil printing process or hot stamping process) and the printing of silver inks using the lithographic offset printing machines. The foil printing techniques achieve an accurate and completely uniform layer of real metalized foil on the print, with a final thickness of 1 to 2 µm.

Thus, a layer of top-quality aluminum (simulates the effect of silver) due to its high reflection creates a high metallic luster (L. Co, 2011).

In offset printing, the silver inks will have to be adapted to the inking and damping unit of a printing press. Thus, pasty lithographic offset inks will have precisely adjusted ink tack and viscosity (40-100 Pa·s) to achieve ink film thickness in a range between 0.5 and 1.5 µm. Although such a silver print is acceptable, it is also characterized by its unevenness (especially on larger printing surfaces) where the effect of reflection is reduced due to the use of small pigment particles (Kipphan, 2001; Majnarić, 2004).

An alternative to lithographic printing is Inkjet digital printing techniques and electrophotography (EP). Thus, in the Inkjet technique, we can be found machines with standard CMYK inks and additional white or silver inks. Thus, ROLAND DGA company in your Inkjet machines integrate fifth channels (5. Inkjet solvent ink) which has the possibility of applying silver ink with metalized pigment particles (L. Co., 2010).

In the electrophotography printing technique, the silver print effect is developed by Xerox company. It is possible with the construction of the Xerox® Iridesse machine, which along with standard CMYK toners, it is possible to use additional toners such as White, Clear, Silver, Gold, and Fluorescent Inks. Silver electrophotographic tones (jobs) can thus be achieved within a few minutes without any waste of pape (L. Co., 2021b).

Theoretical part

Silver inks for offset printing

When we define offset inks, it is important to note that these are inks must have an exactly dynamic viscosity (η). Therefore, depending on the method of preparation of silver and gold offset metallic inks can be distinguished in two forms: one-component inks and two-component inks. In highly productive lithographic offset, one-component inks are generally preferred. They are created by factory mixing: 50% paste (which contains aluminum laminar pigment in a concentration of 90%), 40% one-component varnish (hydrocarbon resin, soy dehydrated oil, aromatic distillate with a low sulfur content), 7,5% polyethylene wax, 2% manganese dryer, and 0.5% antioxidant. Since the gloss effect decreases over time, such inks need to be kept in the original (vacuumed) packaging. The inks must contain resinous binders based on organic hydrocarbons that will achieve the desired viscosity and maintain pH neutrality. Metallic one-component inks must contain dryers (cobalt or manganese salts). Their addition achieves better drying of the print, especially on paper and cardboard printing substrates. Due to the drying of silver offset printing inks, the pH of the damping solution must not be less than 5.5.

In the preparation of the offset printing machine, it is recommended to use buffers that are pH neutral (Hubergroup print solutions, 2020).

In the case of two-component metallic inks, the silver laminar pigments are supplied in the form of a pre-treated paste that is bonded to the binder before the printing process. The pigmented paste is mixed with the binder (carrier component) taking care not to increase ink temperature and change the viscosity (mixing in mixers device maximum of 2-3 minutes to a temperature of 60° C). (Gavran et al., 2015). This avoids the problem of darkening metallic pigments, which allows a higher gloss effect. Although the proportion of pigments in the ink does not change, the main change compared to one-component inks was made in mass share.

Thus, it will contain 50% paste (which contains aluminum pigment laminar in a concentration of 90%), 39.3% two-component varnish (soluble resin in modified phenyl resin, low-viscosity linseed oil, an aromatic distillate with a low sulfur content), 7,5% polyethylene wax, 1,5% manganese dryer, 1% cobalt dryer and 0,7% antioxidants. Thus, a higher content of pigment paste will give a higher metallic luster effect with lower abrasion resistance. Binders in metallic inks (a mixture of resins and oils) are crucial for bonding pigments to the printing substrate and maintaining rheological properties (especially in inks with an extremely high content of metal pigment particles). Rheological stability and prevention of darkening are especially analyzed during the interaction of pigments and binders (Walenski, 1999).

The main characteristic of silver metallic offset printing inks is that they have pigments with a pronounced metallic luster (reflection from the printed surface). Due to their price, silver-tone shades do not contain expensive silver (original elements), but cheaper aluminum and aluminum alloys are added to them as metals for imitation silver. The color tone base is thus made up of pigment particles which are adapted in shape to a laminar sequence (extremely flat particles). Flat aluminum metal particles thus have an average dimensional width ranging from 5 µm to 50 µm, while their height varies from 100 nm to 1 µm. However, in extreme cases, such particles can have up to 10 times larger dimensions. The ratio of thickness and diameter is also known as the shape factor, and it usually ranges in metallic colors in a ratio of 1:50 to 1: 500. The reflection from the printed pigment particles on the paper depends on the detail and morphology of the aluminum pigments. In other words, it depends on surface roughness, particle width and particle length, particle size distribution, and orientation of pigments in the application medium (binders). Important factors include parameters such as the type of aluminum (pure metal or alloys), the method of production, the final treatment of pigment particles, and the viscosity of the binder used.

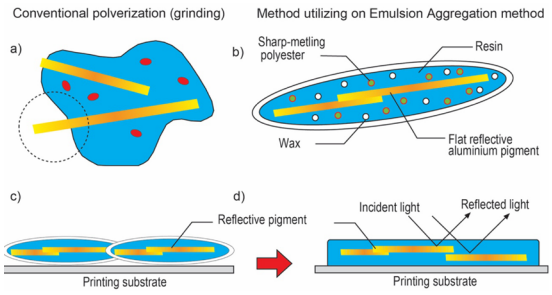
The aluminum used on the ink market can be found in the version: CI Pigment Metal 1, CI No. 77000, and CAS NO. 7429-90-5. In addition to the plate structure, it is characterized by non-resistance in acidic and alkaline media. In other words, exposure to hydrogen ions H^+ and the hydroxyl group OH^- will result in surface degradation and darkening of the imprints. Therefore, it is often found in combination with inert hydrocarbon solvents. The less flat (laminar) structure can be used in the production of all classic types of pasty printing inks, and thus realize the possibility of printing on different printing substrates. Appropriate hardeners must also be added. (Wissling, 2007; Becker et al., 2018).

Due to the characteristic reflection and absorption of aluminum pigments, we achieve a typical silvery metallic luster. The reason for this is the release of bound electrons from aluminum atoms. Such electrons from one ionizing gas which is distributed within the remaining ions and fixed at exact positions within the crystal grid. Due to the interaction with electrons, the external energy (wave of white light) will penetrate the ionizing gas, and thus achieve partial light reflection and partial absorption. Changes in the density of ionizing gases on the aluminum surface will result in a specific dispersion of light in the visible range. Parameters such as refractive indices *n*, absorption *nκ*, reflections *r* (*n, κ*), and melting temperature *Tm* has an important role. In the case of aluminum pigments for printing inks, they are reflection 0.888; refractive index 0,280; absorption 2,91; melting point 1,336 °C (Klain, 2010). Except for the metallic pigments (make up uncoated metal shells), particles of crushed PVD (Physical Vapor Deposition) films can also be found in printing inks and substrates. Such particles are coated with absorption pigments and particles of pigments that are partially or completely oxidized (oxide coating). It is a process used to produce a metal vapor that can be deposited on electrically conductive materials as a thin, highly adhered pure metal or alloy coating. The process is carried out in a vacuum chamber at high vacuum (10–6 torr) using a cathodic arc source after which the foils are crushed at a temperature below the transition temperature to the glassy phase of the polymeric material. The most commonly used polymers are polyethylene terephthalate, polystyrene, and polypropylene The PVD method is now most commonly used to achieve particles with particularly uniform surfaces (Carneiro et al., 2011).

Silver toners for electrophotographic printing

A complete novelty in the printing industry is the generation of metallic tones in the electrophotography (EP) printing technique. During the electrophotographic printing process, each print is made in 6 independent phases: the creation of a layer of charged air (ions) on the surface of the photoreceptor by the action of the corona (phase 1), selective illumination of the photoreceptor to neutralize the previously charged surface of the photoreceptor (phase 2), applying colored and electrostatically charged toner particles to the photoreceptor (phase 3), transferring the toner powder particles to paper due to the action of the transfer corona (phase 4), fix the toner particles by heating and pressing on paper (phase 5) and final cleaning and preparation of the photoreceptor surface for new printing circle (phase 6) (Majnarić, 2015).

To achieve a silver color tone with an expressed shine, in the EP with the possibility of using fast xerographic machines with a new type of toner emulsion aggregation toner. Unlike a standard toner, it will contain: less than 90% polyester resin, 10-20% ceramic powder, 10-20%, aluminum (CAS 7429-90-5), less than 10% waxes (CAS 8002-74-2), less than 10% amorphous silicon (CAS 7631-86-9), and less than 1% titanium dioxide (CAS 13463-67-7). Thus, the final particles of aluminum pigments in the toner must be coated with silicon dioxide or acrylate. The development of such a toner (Figure 1a) was achieved progressively where the problem of the size of the metal laminar pigments (pulverization method of production) was solved by making an emulsion aggregation toner. (Kmiecik-Lowrynowicz, 2003; Diamond, 2001). Thus, with the new silver EA toner, the laminar pigment will be coated with a single fast-melting polyester resin and wax (resin) thus forming a specific oval ellipsoidal shape (Figure 1b). The result is a directed impingement of toner particles on the printing substrate (Figure 1c) which will melt after fusion and form a final imprint of a shell structure with a more visible gloss (Figure 1d). Figure 1 is a schematic representation of the structure of silver toner and its bonding to the printing substrate (L. Co., 2020).



» **Figure 1:** *Structure of Xerox silver toner: a) pulverized type of silver toner; b) emulsion aggregation silver toner; b) silver toner on the printing substrate, d) final silver print (FujiFilm, n.d.)*

Experimental part

The main goal of this paper is to test the variable silver toner cartridge created for the Xerox Versant 180 Press printing machine.

This means that now generation xerographic printing machines can use standard CMYK toner set, fluorescent CMY toner set, and special toners set which include gold toner, silver toner, white toner, and clear (varnish toner) (L. Co., 2021a).

The realization of the test began with the definition of a special printing form dimension 320 x 450 mm. The silver print patch was created with the vector graphics program Adobe Creative Suite Illustrator 2021. In the procedure for the Xerox Versant 180 Press (to recognize the printing form with silver tones) each printing element had to be defined as a spot color called SSilver (PMS PANTONE 877C). The finally printing form contained a halftone wedge from 0 to 100% TV with a step of 5% TV (multiplied by 3 times and positioned in a different position). The used printing machine is connected to an external RIP Fiery FS 200 with which the screen type is varied, ie linear amplitude modulated screening (AM 300 lpi) and frequency-modulated screening (FM 25 µm). The printing was done on matte-coated fine art paper, Maxi Gloss 170 g/m^2. (L. Co., 2021a).

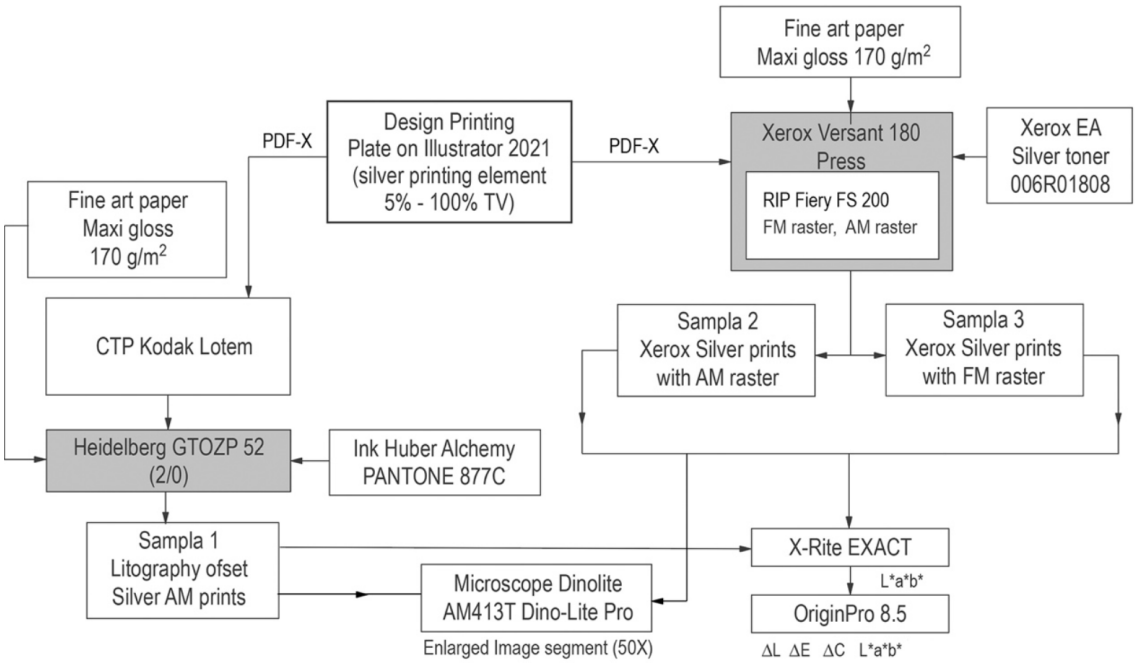
To determine the condition of the electrophotographic printing unit, SCTV reproduction curves were constructed. With SCTV reproduction curves is possible to perform compensation curves (adjust the tone values to the desired curve of the silver lithographic offset print).

For comparison of the achieved effects, the conventional lithographic offset printing was applied (two-color Heidelberg GTOZP 52 printing press). For identical design, a printing plate was created with a Kodak Lotem 400 thermal CTP device.

In the second experiment, an identical printing substrate was used, and a one-component silver offset ink PANTONE 877C was manufactured by germany producer Huber group (series Alchemy). From a printed pile were a choice of 10 imprints, on which a detailed colorimetric and microscopic analysis was performed. For colorimetric analysis, an X-rite eXact spectrophotometer was used to measure the characteristic silver halftone patch (10%, 20%, 40%, 70% TV) and solid silver tone (100% TV) (Gundlach, 2020). When determining the accurate reproduction curve (SCTV compensation curve), the measurement was performed without activating the polarizing filter (standard M0 measuring mode). However, during colorimetric measurements, a polarizing filter was activated, which eliminated the reflection from the printed silver surface (Habekost & Andino, 2016; Mannig &Verderber, 2002). A CIE 3D LAB diagram was constructed from the obtained CIE LAB data, and the differences between light (ΔL), color (ΔE), and chroma (ΔC) were determined. All data is graphically displayed using the Origin 8.5 application. Dino-Lite pro microscope AM413T was used for the visual evaluation of prints. For visual analysis of silver prints elements, we used enlarged images with a magnification of 160 times. Figure 3 shows a schematic diagram of executed experiment (Kipphan, 2001).

Results and discussion

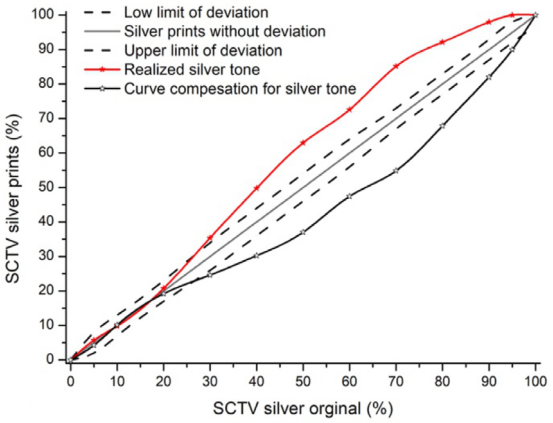
For the creation of silver printing tones, two printing technologies were used: conventional lithographic offset and electrophotography with powder toner. To determine the initial surface coverage (realized with silver dot elements), preliminary densitometric methods were



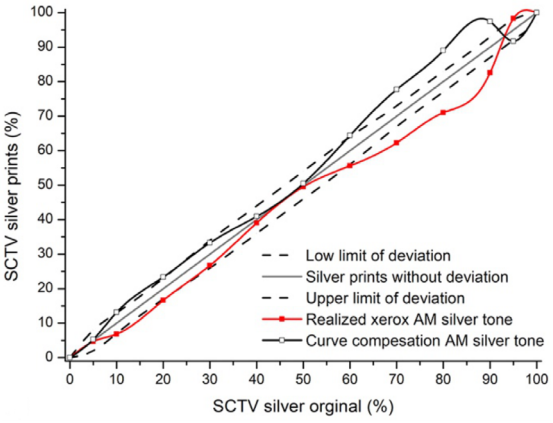
» **Figure 2:** *Schematic diagram of the performed experiment*

used to determination of the tone values (SCTV curve) and comparison from the linear curve was performed.

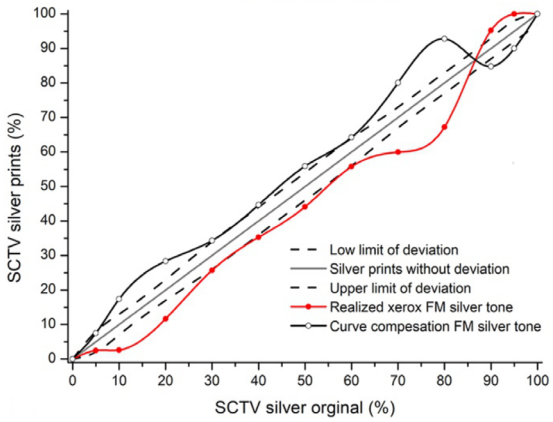
The densitometric settings used during the measurement (eXact spectrophotometer and densitometer) were: filter E, light source D50, standard observer 2°, measuring mode M0. Suggestion for the correction of all tested silver prints and compensation curves is shown in figure 3.



(a)



(b)



(c)

» **Figure 3:** *Realized SCTV curves of reproduction of silver prints: a) Heidelberg GTO; b) Xerox Versant 180 AM screening; c) Xerox Versant 180 FM screening*

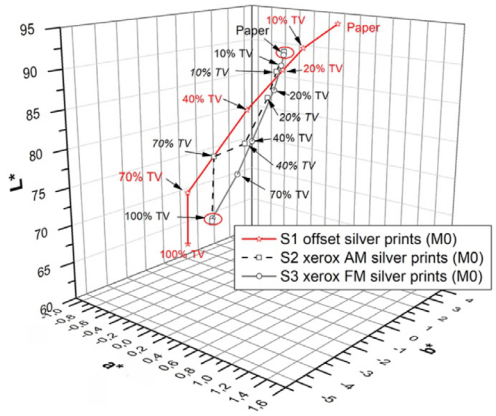
The SCTV offset reproduction curve follows the ideal linear curve up to a surface coverage of 20% TV. After that, a higher dot gain was registered in all measured middle and dark tonal areas (exceeding the allowed tolerance limits ± 4% of SCTV). Xerox AM silver prints have a characteristic curve that is accurately reproduced in the central tonal range (40-50% of SCTV). Low tonal areas have a pronounced dot gain that follows the upper limit of standard tolerance. However, this does not apply to higher tonal areas (70-90% of SCTV). In this segment are reproduced with excessive dot gain. Particularly problematic is the patch of 95% of SCTV that has a negative dot gain and it is necessary to co-correct it. Changing the xerox silver imprint to an FM screening will have the desired effect of achieving an unwanted dot gain.

Thus, the stable part of the reproduction curve will be lost unchanged and will follow the upper tolerance limit (30-60% of SCTV). Low and high coverage of fine dot screen elements will achieve too high dot gain (20%, 30%, 70%, and 80% of SCTV), while the darkest silver screen area (90 and 95% SCTV) will have negative dot gain.

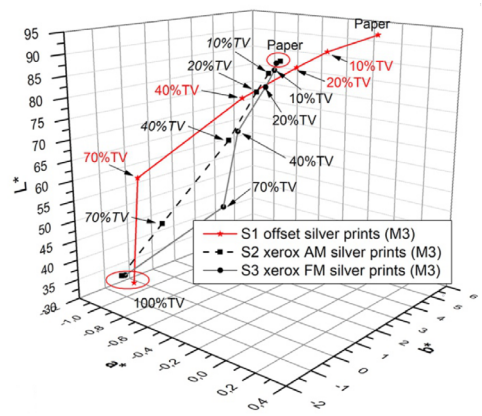
A much more important characteristic of silver prints is the colorimetric value of halftones. An important parameter that affects the realization of silver color images is also a method of screening. For colorimetric analysis of silver toner, two types of screening were used. To eliminate shine from the printed metallic surface, measurement with a polarizing filter (M3 measurement method) is recommended. However, as xerox prints contain very small particles of aluminum pigment, a measurement without the use of a polarizer was also tested (measurement with method M0) (Habekost & Andino, 2016; Mannig & Verderber, 2002). In figure 4. are shown color deviations amplitude modulated (AM) and frequency-modulated (FM) screening in relation to the reference lithographic offset print.

Significant differences in colorimetric measurements were observed from the CIE LAB 3D curves (Figures 4a and 4b). With the activation of the polarizing filter, longer curves along the z-axis (brightness) are achieved. This is especially confirmed by silver tones with higher surface coverage (70% TV and solid tone) where the M3 measurement method better describes the achieved color difference. Chroma of the prints did not experience major changes and the chroma deviation between xerox- offset patch is within the allowed validation tolerances ΔC <2,5. With the M0 measuring mode, light silver tones are somewhat saturated, while activation the polarizer (M3 metering mode) will reduce saturation. After printing in lithographic offset and electrophotography, a slight change in the value of the paper was detected. The reason for this change is the technological process of printing in which the dumping solution is absorbed into the printing medium (lithographic off-

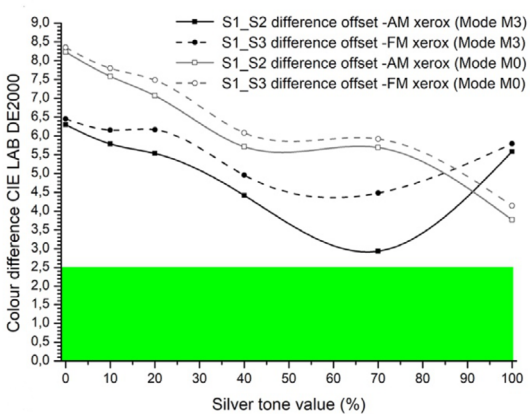
set), while in electrophotography the print is exposed to high heat fuse rollers and required application of ICC profile (color management). With the activation of the polarizing filter (M3 measurement mode) the ΔE2000 color changes of the raster fields of the offset and xerography prints will decrease drastically (Figure 4c).



(a)



(b)



(c)

» **Figure 4:** *Color differences of offset prints and EA silver prints after screening modulation; a) 3D LAB print curvemeasured with M0; b 3D LAB print curvemeasured with M3; c) color change ΔE2000.*

Thus, for xerox prints from the FM screening, the average difference $\Delta E_{M3\_M0} = 1.4$ will be achieved; while the application of AM screening will achieve an average difference of $\Delta E_{M3\_M0} = 1.8$. The exception is full tones. They will display lower color deviations with M0 measurement mode ($\Delta E_{FM100\%\ TV} = 3.8$; DEAM100% TV = 4.5). Experiments show that slightly better prints will be achieved by AM screening (mean $DE_{AM\_FM} = 0.64$). There was a trend of decreasing color changes of silver screening fields due to the increase in the surface coverage of the print.

Realized color differences exceed the maximum of ΔE > 6, and the realized imprints do not match the boundaries of the potential contract proof and validation proof (Kraushaar, 2022). Because of that EP silver tones must be corrected. The reason for this is the need to use a dampening solution (emulsification of the silver ink is performed) which reduces the rheological properties of the offset ink and the silver solid tone of the imprint (Kirchner et al., 2007).

Raster imaging processor (screening device) also affects the achieved results (Figure 5). By image of print sample (enlarging and visually comparing the segment of dimension 2,10 x 1,60 mm), a large difference in the structure of the generated print elements within the silver prints was noticed. Thus, the conventional amplitude raster for offset printing is regular with visible round dot elements (average diameter (d) and circularity (c) of the printed dot in the range of 40% TV is d=195 µm and c=0,97.) This regularity continues in all silver tonal areas (patch) only increased the diameter of the dot elements. Used Fiery amplitude raster has a characteristic linear shape of the print element and is visually noticeable (reproduced) up to 60% of the TV. After that (darker silver tones) are realized as one frequency-modulated screening with different surface coverage in which the structure of the linear print element is lost. Thus, the dark silver tone areas of the AM Fiery raster look identical to the applied FM Fiery raster (small raster elements are the same size but with a different stochastic distribution). This fact confirmed the reason for the small color deviations in the Xerox silver imprints and the impossibility of achieving major color changes by applying different raster settings in the Fiery RIP.

Conclusion

When the machine operator measures a print with a larger number of silver tones (screened patch), it is necessary to activate the polarizing filter (M3 measuring mode) to reduce the color oscillation caused by excessive light reflection. The M3 measurement method has proven to be more suitable for measuring silver prints and allows precise comparison and creation of silver reproduction curves.

» **Figure 5:** *Images of segment silver imprints enlarged 160 times (after experimental printing)*

The initial setup of machines does not give satisfactory values and needs to be corrected. In lithographic offset, it is in the middle tonal areas while in electrophotography with powder toner in the low and high tonal areas. A particularly large correction needs to be made in the 95% TV area. In this case, the EA toner supply should be significantly increased.

In performed testing, the silver tones achieved in digital electrophotographic and offset printing technics have a significant difference. Silver tones generated in the solid patch (PANTONE 877C) will achieve a large color change of ΔEOF_Xerox = 4,2 (mode M0) ΔEOF_Xerox = 5,5 (mode M3). All xerox prints will look darker and with a noticed lower brightness.

Screening process (formation of a halftone silver image) will achieve additional and much higher color oscillations between offset and xerographic prints (ΔEFM_average = 5,70; ΔEAM_average = 5,05). By the variation of the Fairy RIP settings (AM and FM screening), a slight color deviation of the Xerox silver was achieved (ΔEFM_AM = 0,65). Slightly better results (closer silver-tone to offset) will be achieved by using the AM Fiery screening procedure.

Funding

The research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

Becker, M., Reitzenstein, D., Lindl, A. & Plitzko, Y. (2018) *Metal offset Printing Ink with Specular Gloss, and Printing Method*. European Patent Office EP3165578A1 (Patent).

Carneiro, J. O., Teixeira, V., de Carvalho, P. A. L., Azevedo, S. & Mannine, N. (2011) *Current and advanced coating technologies for industrial applications*. In: Makhlouf, A. S. H. (ed.) *Nanocoatings and Ultra-Thin Films*. Sawston, Woodhead Publishing. pp. 414-428.

Diamond A. S. (2001) *Handbook of Imaging Materials.* 2nd ed. New York, CRC Press. pp. 173-180.

FujiFilm. (n.d.) *Gold toner and silver toner*. Available from: https://www.fujifilm.com/fbglobal/eng/company/technology/production/digital/gs.html [Accessed 15th February 2025].

Gavran, M., Majnarić, I., Đaković, D. & Morić, M. (2015) Otiskivanje metalik bojila u litografskom ofsetnom tisku. In: Žiljak Vujić, J. (ed.) *Međunarodni znanstveni skup Tiskarstvo & Dizajn 2015, 27-28 March 2015, Zagreb, Croatia*. Zagreb, FotoSoft. pp.161-171.

Gundlach, M. (2020) *Choosing a Spectrophotometer for Print and Packaging*. Xrite. Available from: https://www.xrite.com/blog/choosing-print-packaging-spectrophotometer [Accessed 15th July 2024].

Habekost, M. & Andino, A. (2016) Metallic Ink Measurement Using the M3 Mode. In: *68th Technical Association of the Graphic Arts Annual Technical Conference, 2016 TAGA, 20-23 March 2016, Memphis, Tennessee*. Chicago, Technical Association of the Graphic Arts. pp. 62-75.

Hanisch, M. (2021) *What makes a cold transfer in sheetfed offset so successful, sustainable, and future-proof*. [Lecture] Conference presentation on Virtual Drupa, 22nd April.

Hubergroup print solutions. (2020) *Technical Information - Alchemy Silver for offset printing*. Available from: https://www.hubergroup.com/it/it/product-finder/tidownload/14M002.ti?-cHash=123e6282a4e62701442503d22aaa477c [Accessed: 15th February 2025].

Kipphan, H. (2001) *Handbook of print media: technologies and production methods*. Heidelberg, Springer.

Kirchner, E., van den Kieboom, G., Njo, L., Supèr, R. & Gottenbos, R. (2007) Observation of visual texture of metallic and pearlescent materials. *Color Research & Application*. 32 (4), 256–266. Available from: doi: 10.1002/col.20328

Klain, A. G. (2010) *Industrial Colour Physics*. Herrenberg, Springer. pp. 65-68.

Kmiecik-Lowrynowicz, G. E. (2003) New EA Toners for High-Quality Digital Colour printing. In: *International Conference on Digital Production Printing and Industrial Applications, DPP2003, 18-21 May 2003, Barcelona, Spain*. Springfield, Society for Imaging Science and Technology. pp. 211-213.

Kraushaar, A. (2022) *Process Standard Digital Handbook 2022*. Munich, Fogra Research Institute for Media Technologies.

L. Co. (2010) *Roland DG Machines – Powered by Eco-Sol MAX: USER'S MANUAL VS-640i*. Roland DG corp. Available from: https://rolanddga.sharepoint.com/sites/dealers/ SupportDocumentation [Accessed 15th July 2024]

L. Co. (2011) *Hot Stamping and Cold Foil Transfer: A Comprehensive Guide for the Graphics Industry*. Fürth, Leonhard Kurz Stiftung & Company.

L. Co. (2020) *Be Brilliant, Xerox® IridesseTM Production Press*. 2018 Xerox Corporation. Available from: https://www.nbm.ie/wp-content/uploads/2022/02/Xerox-Iridesse-Press-Brochure.pdf [Accessed 15th July 2024]

L. Co. (2021a) *Xerox® Versant® 280 Press Let's build a more profitable future*. Xerox Corporation. Available from: https://www.xerox.com/digital-printing/latest/V28BR-01U.pdf [Accessed 15th July 2024]

L. Co. (2021b) *FUJI FILM Business Innovation Digital Imaging Technology Gold toner and Silver toner*. Available from: https://www.fujifilm.com/fbglobal/eng/company/technology/production/digital/gs.html [Accessed 15th July 2024]

Majnarić I. (2004) *Quality of digital prints conditioned by the aging of the printing surface*. MSc thesis. Faculty of Graphic Arts, University of Zagreb.

Majnarić, I. (2015) *Osnove digitalnog tiska*. Zagreb, Grafički fakultet Sveučilišta u Zagrebu. pp. 58-127.
Mannig, J. & Verderber, R. (2002) Improving Metallic Ink Printing through Polarized Densitometry. In: *54th Technical Association of the Graphic Arts Annual Technical Conference, 2002 TAGA*. Chicago, Technical Association of the Graphic Arts. pp. 33-34.
Walenski, W. (1999) *Das Papier buch*. Itzehoe, Beruf and Schule Belz Kg.
Wissling, P. (2007) *Metallic-effect Pigments*. Hannover, Vincentz Network.