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Management, Economics, Business And Marketing (IAC-MEBM)

Innovation Drivers of Low- and High-innovative Manufacturing SMEs

Pedro SOTO-ACOSTA[a], Simona POPA[b*]

[a] *University of Murcia, Department of Business Administration and Finance, Espinardo, Murcia, Spain, psoto@um.es*
[b] *University of Murcia, Department of Accounting and Financial Economics, Espinardo, Murcia, Spain, sp.popa@um.es*

Abstract

This study addresses a notable gap by specifically investigating the drivers of innovation in small and medium-sized enterprises (SMEs) within the manufacturing sector. Consequently, this research contributes significantly by filling the void in the literature concerning the distinctive variables that differentiate low and high-innovative manufacturing SMEs. More precisely, the study delves into the influence of technological, organizational, and environmental factors on the extent of innovation outcomes in manufacturing SMEs. Based on the Technology-Organization-Environment theory, the research employs discriminant analysis to evaluate the innovation levels within a dataset comprising manufacturing SMEs. The findings indicate discernible differences between low and high-innovative firms, particularly in terms of their information technology (IT) knowledge and infrastructure, commitment-based human resources (HR) selection practices, exploitative innovation, and organizational capital. The practical implications derived from the study suggest that companies should invest additional resources in cultivating IT knowledge and infrastructure, implementing commitment-based HR selection practices, and enhancing organizational capital to attain superior innovation outcomes. Furthermore, the identification of exploitative innovation as a significant discriminant variable underscores the efficacy of incremental innovation in SMEs, enabling them to build upon prior exploratory initiatives.

Keywords: Information technology, intellectual capital, environmental dynamism, innovation performance.

1. INTRODUCTION

Innovation and business transformation have been identified as key drivers for responding to the disruptive changes caused by global phenomenon, such as COVID-19, economic crisis, or climate crisis [1, 2]. Extensive research indicates that the ability to innovate is critical for a firm's competitiveness, particularly in uncertain environments, and especially for small and medium-sized enterprises (SMEs) [3, 4]. However, SMEs face more difficulties in pursuing innovation due to resource constraints, limited managerial expertise, less structured procedures, and fewer formalized innovation systems [5]. Therefore, there is a need to advance knowledge on the antecedents that determine the level of innovation in SMEs.

Innovation is a complex phenomenon that develops along three dimensions: products and services, processes, and management or administrative practices [6, 7]. and is driven by diverse factors that may influence the level of innovation. Existing research offers extensive theoretical argumentation about the potential of the information technology (IT) capability to drive significant innovations in business processes, products and services of firms [8].

* Corresponding author.

Besides technological factors, the organizational context has been suggested in literature as relevant for distinguishing between low and high innovative firms [9]. For instance, human resources (HR) practices may result crucial for creating a positive social climate for innovation [6, 10]. In addition, literature suggests that the competitive advantage of SMEs is usually derived from another key organizational factor: intellectual capital. Yet, how intellectual capital influences specific performance indicators of SMEs such as innovation outcomes remains an under-investigated research area [5]. In addition, to be able to extrapolate a climate for innovation to a firm-level, the innovation strategy pursued by companies play a pivotal role.

Furthermore, prior studies suggest that innovation is contingent on environmental factors [11, 12]. In the same venue, firms' ability to innovate may depend on the development of multiple internal capabilities, combining IT, innovation strategy, intellectual capital, but also on the quick response to external pressures such as environmental dynamism.

Drawing on Technology-Organization-Environment (TOE) framework, this study aims to enrich the understanding of the antecedents of innovation from an integrative perspective. To address these issues, the study conducts a discriminant analysis of firms' innovation level based on a dataset of manufacturing SMEs. All regions face similar challenges in delivering sustainable transport solutions to meet their current and future mobility requirements. Transport authorities are aware of the real needs specific to their region but often find it difficult to identify detailed information on targeted solutions that would deliver direct and tangible positive outcomes.

2. THEORETICAL FRAMEWORK AND HYPOTHESES

The TOE framework is a theoretical framework that describes the context of adoption and implementation of technological innovations as consisting of three factors: technological, organizational, and environmental contexts [13, 14]. Technological context refers to the characteristics of the innovation, organizational context describes the characteristics of the organizations, and environmental context implies characteristics of the environment in which the adopting organizations operate. The TOE framework has been widely used to analyze factors that affect the adoption and use of different technological innovations [4, 6, 15].

The importance of IT in promoting innovation in small and medium-sized enterprises (SMEs) has been extensively acknowledged in previous literature. IT can improve information flows within and outside companies, increase business network interconnectedness, and enhance the speed, quality, and flexibility of innovation [16].

IT resources comprise both tangible and intangible resources, with the latter more likely to generate competitive advantages [17]. For instance, some authors suggest that IT infrastructure alone is not a source of competitive advantage as it can be easily copied by other firms [18, 19]. However, intangible resources, such as IT knowledge and skills, can improve the positive impact of IT infrastructure on innovation. This means that firms with higher IT expertise are more likely to adopt IT innovations and adapt them to their specific organizational needs [15, 20]. Thus, we propose the following hypotheses:

- *H1a: IT knowledge is predominant in highly-innovative firms compared to their low-innovative counterparts.*
- *H1b: IT infrastructure is predominant in highly-innovative firms compared to their low-innovative counterparts.*

With respect to the organizational context, previous literature suggests that individuals are key to innovation and collaboration among employees is crucial for driving innovation within a firm [9, 21]. Commitment-based HR practices can create a positive social climate that encourages innovation by promoting flexibility, teamwork, cooperation, and knowledge exchange [6]. Empowering employees in the decision-making process can also have a positive effect on a firm's innovation capability [22]. Accordingly, high-innovative firms are more likely to use commitment-based HR practices, such as selection, incentive, training, and development, compared to their low-innovation counterparts. Accordingly, the following hypotheses are proposed:

- *H2a: Commitment-based HR selection practices are predominant in highly-innovative firms compared to their low-innovative counterparts.*
- *H2b: Commitment-based HR incentive and training and development practices are predominant in highly-innovative firms compared to their low-innovative counterparts.*

Furthermore, in order to extrapolate this climate for innovation from an individual-level to a firm-level, the innovation strategy pursued by the company plays a pivotal role. Innovation strategy has been extensively described in previous literature in terms of exploration and exploitation [9]. Explorative innovation encompasses activities that are oriented toward selection, improvement, and efficiency, while exploratory innovation builds upon search, discovery, and experimentation. Both activities are seen as critical to create firm sustainable competitive advantage, since they enable to enhance firm performance and competitiveness.

When introducing the concepts of exploration and exploitation in the management literature, March [23] argued that they should be viewed as two ends of a single continuum, with unavoidable trade-offs. However, a dominant approach in ambidexterity literature is to conceptualize exploration and exploitation as distinct and separable modes of activity such that firms can choose to engage in high levels of both activities at the same time [24]. In this sense, firms' ability to compete successfully in the long run may, thus, be rooted in their ability to synchronize efforts of exploratory and exploitative innovation [9] and jointly pursue short-term efficiency and long-term innovation [24]. Thus, a highly-innovative firm is one that is capable of both exploiting existing competencies to take advantage of existing market opportunities and, at the same time, exploring new opportunities to meet the challenges of emerging markets. Based on these arguments, we propose:

- *H3a: Exploitative innovation is likely to be more predominant in highly-innovative firms compared to their low-innovative counterparts.*

- *H3b: Exploratory innovation is likely to be more predominant in highly-innovative firms compared to their low-innovative counterparts.*

From a more integrative perspective, intellectual capital has been identified as a critical antecedent of innovation [5, 25]. Intellectual capital can be defined as a set of human, organizational and social intangible resources that the company owns or has access to [5, 26].

There is extensive literature that highlight the role of human capital as the primary antecedent of creativity and innovation [10]. In addition, previous studies identify organizational capital as the infrastructure that allows companies to transform individual knowledge into collective know-how, which remains within the company even when employees leave [27]. However, it is not less true that accumulated expertise tends to become obsolete over time and continuous renewal is required. In this sense, previous studies suggest that social capital enhances the knowledge and capabilities of individuals and companies by improving information access, quality, relevance and timeliness [28]. Based on these arguments, the following hypotheses are proposed:

- *H4a: Human capital is superior in highly-innovative firms compared to their low-innovative counterparts.*

- *H4b: Organizational capital is superior in highly-innovative firms compared to their low-innovative counterparts.*

- *H4c: Social capital is superior in highly-innovative firms compared to their low-innovative counterparts.*

Consistent with the TOE framework and the Contingency Theory, prior studies suggest that firms' innovation strategies and performance are contingent on both internal and external factors [11, 24, 29]. Moreover, the literature agrees on the fact that capabilities development and evolutionary processes are dependent on the external business context [29, 30]. In this sense, environmental dynamism is a source of both challenges and opportunities for innovation [31]. Hence, the following hypothesis is proposed:

- *H5: Environmental dynamism is predominant in highly-innovative firms compared to their low-innovative counterparts*

3. METHOD

3.1. Data and sample

The target population of our study is formed by manufacturing SMEs from Spain with at least 20 employees in order to ensure a minimum firm complexity. The study used a sample of 2000 firms selected randomly from a list of 8,938 manufacturing SMEs with at least 20 employees included in the SABI (Sistema de Análisis de Balances Ibéricos) database.

Data was collected in two stages. First, a pilot study was performed and, following that, a questionnaire was conducted. The survey was administrated between May and June 2018 by using computer-assisted telephone interviewing (CATI) software. In total, a final dataset of 306 valid cases was obtained, yielding a response rate of 15.3 percent, which was comparable to other studies of similar scale. Data was examined for non-response-bias by comparing the characteristics of early and late participants in the study, revealing that non-response bias does not represent a threat for the results obtained.

3.2. Measurement

Measurement items were selected on the basis of a careful literature review. All the variables used in the study were operationalized using multi-item instruments (seven-point Likert scales). A description of the constructs and the associated indicators is provided in Appendix 1.

3.3. Instrument validation

The unidimensionality and reliability of the data set were assessed by different procedures. All constructs met this criterion, suggesting that the items share more variance with their respective constructs than with other constructs. Table 1 also provides an overview of the means, standard deviations, and correlations of the constructs.

Table 1. Descriptives statistics and discriminant validity

Constructs	Av.	SD	Correlation matrix									
			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1. IT know.	4.35	1.48	**0.83**									
2. IT infras.	4.04	1.42	0.69	**0.81**								
3. CHR Sel.	5.44	1.14	0.39	0.40	**0.82**							
4. CHR inc.	4.74	1.23	0.46	0.48	0.66	**0.79**						
5. Exploit. innov.	4.94	1.19	0.41	0.35	0.34	0.38	**0.75**					
6. Explor. innov.	4.12	1.49	0.38	0.33	0.35	0.37	0.60	**0.78**				
7. Human Cap.	4.94	1.15	0.51	0.46	0.49	0.57	0.43	0.41	**0.77**			
8. Organiz. Cap.	4.16	1.53	0.49	0.48	0.43	0.50	0.48	0.49	0.51	**0.72**		
9. Social Cap.	5.43	1.05	0.43	0.45	0.52	0.53	0.43	0.40	0.64	0.49	**0.83**	
10. Env. Dynam.	4.15	1.57	0.24	0.24	0.25	0.30	0.39	0.42	0.31	0.24	0.28	**0.85**

Note: Diagonal values in bold represent the square root of the AVE

Most researchers agree that common method variance is a potentially serious bias threat in behavioral research, especially with single informant surveys. Several steps to control and assess the extent of common method bias, with all these tests suggesting that common method bias is not a serious threat in our study.

4. DATA ANALYSIS

The Two-step cluster analysis was chosen to reveal groupings based on the following constructs: product innovation, process innovation and administrative innovation. This statistical technique has been extensively used to report not readily identifiable groupings and because it allows the importance of each input variable to be identified. The Two-step cluster analysis was conducted for the 306 firms in this study. The log-likelihood criterion and the silhouette coefficient were used for distance measure and compare cluster solutions, respectively. Two clusters were identified, with 148 firms classified as highly-innovative and 158 as low-innovative firms. Differences between the two clusters by the variables of classification (process innovation, administrative innovation, and product innovation) were confirmed through the subsequently conducted ANOVA analyses. Next, the multivariate technique of Discriminant Analysis was used. To suit this type of statistical analysis, a dummy dependent variable composed of the two groups (highly-innovative and low-innovative firms) from the cluster analysis was created. Results for several important statistics (1-the eigenvalue; 2- the canonical correlation; 3-the squared canonical correlation) showed the strength of the discriminant function.

Table 2 presents the significant differences between highly-innovative and low-innovative firms in terms of the predictor variables that best discriminate between the two groups. These specific predict variables are: Exploitative innovation, IT knowledge, IT infrastructure, organizational capital and Commitment-based HR selection practices.

Table 2. Standardized canonical discriminant coefficients and of tests of significant differences between groups

		Classified function coefficients		Test of equality of group means	
Variable	Discriminant function coefficients	Highly-innovative	Low-innovative	Wilks' lambda	F
Exploitative innovation	0.474	3.764	3.023	0.755	98.878
IT knowledge	0.239	0.895	0.603	0.655	79.734
IT infrastructure	0.226	0.694	0.405	0.624	60.558
Organizational capital	0.301	0.495	0.127	0.603	49.500
CHR selection	0.310	4.619	4.110	0.595	40.802
Constant	-	-29.792	-19.426	-	-

In total, 79.7% of the grouped cases were correctly classified, further supporting the power of the discriminant function. Through these analyses, hypotheses H1a, H1b, H2a, H3a and H4b were confirmed, while hypotheses H2b, H3b, H4a, H4c and H5 did not find support.

5. CONCLUSIONS, LIMITATIONS, AND FUTURE RESEARCH

Innovation is highly valued by both academics and practitioners due to its recognized benefits, as it allows companies to explore new markets, enter established industries, and gain a competitive advantage over rivals through innovative products and services. Additionally, process innovation can enhance efficiency and profitability by creating new methods or redesigning existing ones to reduce costs or generate additional revenue [8, 32]. Furthermore, administrative innovation, which focuses on improving management structures, systems, policies, and processes through a top-down approach, is also associated with increased efficiency and effectiveness [33]. However, achieving significant innovation outcomes remains challenging, especially for SMEs, as innovation is influenced by multiple factors rather than a single cause [34].

To gain a more comprehensive understanding of innovation, there is a need to explore its antecedents from an integrative perspective. This suggests that further research is required to better grasp the various factors that contribute to successful innovation. In this sense, this paper builds on the TOE framework to develop an integrative conceptual model that sheds light on the antecedents that may explain the differences between low and high- innovative manufacturing SMEs.

The empirical results reveal that factors have differential effects. With regard to the technological context, the results indicate that low and high-innovative firms can be distinguished in terms of IT knowledge and IT infrastructure. It is important to note that the effect of IT knowledge as discriminant variable is stronger than that of IT infrastructure. These findings provide empirical support for studies suggesting that although both tangible and intangible IT resources

are positively associated with innovation performance, the latter are more likely to generate competitive advantages [8, 17, 19].

Regarding organizational factors, the results suggest that high-innovative firms are more focused towards commitment-based HR selection practices, while the differences between low and high-innovative firms are not significant in terms of other commitment-based HR practices. A possible explanation of this results is that the effect of some commitment-based HR practices on innovation is not direct, but mediated by other factors such as, for instance, social capital [10], e-business use [6], innovation climate [12] or social web knowledge sharing [4]. With regard to innovation strategy, only exploitative innovation is found to distinguish between low and high-innovative firms, being exploitative innovation the strongest discriminant variable in our model. This might be because SMEs are more oriented towards developing exploitative innovations to capitalize on previous exploratory efforts because of their resource constrains.

For the three discriminant variables related to intellectual capital, our results show that only organizational capital distinguishes between low and high-innovative firms. These findings are contrary to previous studies that show that radical and incremental innovation outcomes are higher in SMEs displaying a higher strength of human capital and relational capital. However, our findings may be framed within the stream of research suggesting that, among the three components of intellectual capital, organizational capital is considered to give the greatest benefits for a company, both directly and indirectly [5, 35].

With respect to the environmental context, our findings show that the discriminant effect of environmental dynamism is not significant. A possible explanation of this result is that although dynamic environments may push enterprises to engage in both exploitative and exploratory innovations [36, 37], there is no direct effect on innovation performance. With other words, environmental dynamism may have a direct and significant influence on enhancing the process of innovation but not on the outcomes of innovation. However, such boost of the innovation process is expected to contribute by extension to innovation performance.

The present study provides several important implications for managers. First, the study findings support the idea that innovation is a complex phenomenon explained by multiple factors. In this sense, firms should devote extra efforts to develop IT knowledge and infrastructure, commitment-based HR selection practices and organizational capital because these are crucial for obtaining greater innovation outcomes. Second, our results show that the ability to deploy exploitative innovations is a crucial factor for discriminating low and high-innovative SMEs. The identification of exploitative innovation as a strong discriminant variable highlights that pursuing exploitation has a greater effectiveness than focusing on exploratory innovation in the case of SMEs. Third, although SMEs have to competence within dynamic environments, these firms are not so influenced by the challenges and opportunities posed by the business contexts as their primary focus is on exploitation. Accordingly, rather than introducing radical innovation, the most effective way to be a highly innovative SMEs is though exploitation and incremental innovation, which permits the firm to capitalize as much as possible on previous exploratory efforts.

While the contributions of the present study are significant, it has some aspects which can be addressed in future research. First, the sample used was from Spain. While the findings could be extrapolated to other OECD member countries, in future research, a sampling frame that combines firms from different countries could be used in order to provide a more international perspective. Second, the key informant method was used for data collection. Future studies could consider research designs that allow data collection from multiple respondents within an organization. Third, future research could consider the potential of other unexplored factors such as organizational culture, leadership and open innovation [38]. Fourth, this research takes a static, cross-sectional picture of factors affecting innovation, which makes it difficult to address the issue of how these antecedents and their importance may change over time. A longitudinal study could enrich the findings. These suggestions should be considered in future studies to increase the validity of our findings.

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Appendix A. Instruments of measure

Information technology (IT). Regarding IT in your firm, to what extent do you agree with the following statements? (1-7):

- IT knowledge.

ITC1. Our firm possesses a high degree of ICT expertise.

ITC2. We are very knowledgeable about new ICT innovations.

ITC3. Our firm possesses a high degree of expertise for the development and maintenance of new IT (Web 2.0, wiki, extranets…).

- IT infrastructure.

ITC4. We budget a significant amount of funds for new ICT implementation and maintenance (technical staff, hardware, software…).

ITC5. Our firm use customized software applications.

ITC6. We use computer-based systems that allow our employees to communicate and develop collaborative tasks.

ITC7. We routinely utilize computer-based systems that are integrated with our external stakeholders' IT systems (clients, suppliers…)

Commitment-based HR practices (CHR). In relation to HR practices in your firm, to what extent do you agree with the following statements? (1-7):

- CHR Selection Practices (CHR selection).

CHR1. Internal candidates are given consideration over external candidates.

CHR2. We select employees based on an overall fit to the company.

CHR3. Our selection system focuses on the candidate's potential to learn and grow with the firm.

CHR4. We ensure that all employees are made aware of internal promotion opportunities.

- CHR Incentive and Training and Development Practices (CHR incentive/develop.).

CHR5. Employee bonuses or incentive plans are based primarily on the performance of the firm.

CHR6. Goals for incentive plans are based on business unit or company performance.

CHR7. Salaries for employees in these positions are higher than those of our competitors.

CHR8. Performance appraisals are used to plan skill development and training for future advancement within the company.

CHR9. We provide multiple career path opportunities for employees to move across multiple functional areas of the company.

CHR10. We provide training focused on team-building and teamwork skills.

Innovation strategies (IS). With Regard to innovation in your firm, to what extent do you agree with the following statements? (1-7).

- Exploitative innovation.

ET1. We regularly implement small adaptations to our existing products.

ET2. We introduce improved, but existing, products in our market.

ET3. We improve our provision's efficiency of products and services.

ET4. We increase economies of scales in existing markets.

ET5. Our company expands services for existing clients.

- Exploratory innovation.

ER1. Our firm accepts demands that go beyond our existing products and services.

ER2. We invent new products and services.

ER3. We experiment with new products and services in our market.

ER4. We commercialize products and services that are completely new to our company.

Intellectual Capital (IC). Concerning intellectual capital in your firm, to what extent do you agree with the following statements? (1-7):

- Human Capital.

HC1. Our employees are highly skilled.

HC2. Our employees are widely considered the best in our industry.

HC3. Our employees are creative and bright.

HC4. Our employees are experts in their particular jobs and functions.

HC5. Our employees develop new ideas and knowledge.

- Organizational Capital.

OC1. Our organization uses patents and licenses to store knowledge.
OC2. Much of our knowledge is contained in manuals, databases, etc.
OC3. Our organization's culture (stories, rituals) contains valuable ideas, ways of doing business, etc.
OC4. Our organization embeds much of its knowledge and information in structures, systems, and processes.
- Social Capital.
SC1. Our employees are skilled at collaborating with each other to diagnose and solve problems.
SC2. Our employees share information and learn from one another.
SC3. Our employees interact and exchange ideas with people from different areas of the company.
SC4. Our employees partner with customers, suppliers, alliance partners, etc., to develop solutions.
SC5. Our employees apply knowledge from one area of the company to problems and opportunities that arise in another.

Environment dynamism (ID). Regarding your firm, to what extent do you agree with the following statements? (1–7)
ED1. In a year, our market has changed a lot.
ED2. Our clients regularly ask for new products and services.
ED3. In our market, the volumes of products and services to be delivered change fast and often.

Innovation performance (IP). How would you compare your performance over the last 3 years to that of other firms operating in the same industry in the following areas? (1–7)
- Product innovation.
IP1. The level of newness (novelty) of our firm's new products.
IP2. The use of latest technological innovations in our new products.
IP3. The speed of our new product development.
IP4. The number of new products our firm has introduced to the market.
- Process innovation.
IP5. The speed with which we adopt the latest technological innovations in our processes.
IP6. The updatedness or novelty of the technology used in our processes.
IP7. The rate of change in our processes, techniques and technology.
- Administrative innovation.
IP8. The use of new or improved computer-based administrative applications.
IP9. The use of new or improved employee reward/training schemes.
IP10. The use of new or improved structures such as project team or departmental structures.
IP11. The use of new or improved marketing practices.

An Analysis of the Correlation Between Shopping Benefits, Customer Satisfaction, and Customer Loyalty in Retail Stores

Tareq NAEL HASHEM [a*]

[a] *Marketing Department, Faculty of Business, Applied Science Private University, Amman, Jordan*
t_hashim@asu.edu.jo
ORCID ID: https://orcid.org/0000-0001-9564-931X

Abstract

The study explored the correlation between shopping benefits, customer satisfaction, and customer loyalty in retail stores. A quantitative methodology was utilized. The study included individuals who were retail consumers. A basic random sample of 600 retail store consumers were given questionnaires. After application, the researcher received a total of 493 completed questionnaires. The study hypotheses were accepted based on the results obtained through SPSS. There is a clear connection between shopping benefits (hedonic and utilitarian) and customer satisfaction and loyalty. Furthermore, research has revealed a clear correlation between customer satisfaction and loyalty. The researcher emphasized the importance of carefully selecting the location of a retail store to attract the desired customer base effectively. Employees in retail stores should receive proper training to handle customer interactions effectively.

Keywords: Shopping Benefits, Customer Loyalty, Customer Satisfaction, consumer behavior

1. INTRODUCTION

Customer satisfaction and loyalty are crucial factors that directly and significantly impact a business's growth and profitability in the long run. While some clients will bring in more money than others, it might be expensive to bring in new customers, and you can end up losing more money on the unproductive ones than the lucrative ones. Companies waste a ton of money trying to attract new consumers whose profit potential is uncertain or low, ignoring the steady stream of high-quality clients they lose daily. Considering how crucial it is to attract and keep the proper clients to a company's development and profitability, this position is particularly perplexing. Companies lose out on development and profit opportunities when they don't treat their client connections like the assets they are (Hashem, 2015).

Every company should strive for two things: customer happiness and customer loyalty. In most sectors, customers are getting pickier and have more alternatives than ever before. The Relationship Between Shopping Benefits, Customer Satisfaction, and Customer Loyalty In Retail Stores will be studied in light of the criteria above (Hashem,2010).

Customer satisfaction and loyalty are the most significant factors influencing a company's profitability. Managers are attempting to determine what factors might impact these subjects. "Shopping benefits," among other variables, may impact customer satisfaction and loyalty. This research aims to shed light on this pressing issue, particularly emphasizing retail establishments due to their centrality to the market. This study aims to address the following primary question:

* Corresponding author.

Is there a relationship between the retail store's shopping benefit, customer satisfaction, and customer loyalty?
There are two parts to this question:

1. Do hedonic and utilitarian purchasing advantages correlate with consumer satisfaction?
2. Do the hedonic and utilitarian rewards of purchasing correlate with customer loyalty?

Is customer satisfaction correlated with customer loyalty?

Finding out the relationship between shopping benefits, customer satisfaction, and customer loyalty in retail businesses is the primary goal of this research. Along with the relationship between customer loyalty and customer satisfaction in retail establishments.

2. LITERATURE REVIEW

2.1 Shopping Benefits

Numerous researches show that shoppers may enjoy their shopping . Yuksel (2004) found that emotional shopping experiences increase store time, expenditure, unexpected purchases, and store liking. Product purchases may or may not make shopping joyful. Thus, customers may enjoy a delightful shopping experience without buying. Many shops try to make shopping fun. How store employees handle customers has been studied. The exterior appearance of a shop can also affects its rating (Yuksel, 2004) .

The literature suggests that client perceptions can differ from objective reality. Thus, monitoring customer perception is crucial since it affects consumer assessment and future behavior (e.g. repeat purchases) .

Shop items' advantages outweigh the expenditures and sacrifices involved in their purchasing. According to Bhatnagar and Ghose (2004), shoppers have functional and nonfunctional reasons. Functional motivations involve time, place, and possession. Nonfunctional reasons are those associated with purchasing outlets due to social or emotional values. These motivations are outside storefronts. Shopping for convenience means saving time or money and being motivated by utilitarian motivations. Recreational customers choose closed malls and department stores for their typical shopping because of nonfunctional considerations. Consumers with nonfunctional solid demands choose outlets where friends and coworkers may see them. Consumers evaluate numerous aspects when choosing a retail format for goods purchases. Considerations include convenience, selection, quality, return policies, special services, credit, and perceived hazards.

Different customers gain differently from these characteristics. (Bhatnagar& Ghose,2004). Store image is a significant component in consumers' shopping location choices and a retailer's long-term profitability. Store image is "how the shopper perceives the store, partly by its function." Two generally accepted elements of shop image: first, the image is a mix of functional and psychological characteristics. Secondly, it is based on customer perceptions, not reality." Thus, a customer's view of a retail store is based on internal and exterior indicators and physical attributes. By comparing expectations with perceived performance, a consumer's conscious cognitive and unconscious affective processes are considered to be involved. The setting of a shop may attract customers, encourage repeat purchases, and bring them back. Store surroundings have long attracted and persuaded clients (Burns& Neisner, 2006). A store's atmosphere can influence a purchasing choice more than the product itself and affect customer satisfaction. Music, color, and lighting are all interconnected in a store's environment and affect customers. Consumers see a store's surroundings holistically, not individually. These are atmospherics. Definition of store atmospherics: The way a consumption environment evokes emotions in clients, motivating them to remain, browse, and buy or discourage them. Environmental design elements like atmospherics attract attention, convey a store's image and service quality to potential customers, and elicit emotional responses (Burns& Neisner, 2006). According to research, positive emotions routinely increase the desire to stay in retail locations. Positive emotions are also associated with faster decision-making, lower decision time, more buying propensity, more purchases, and higher spending (Burns& Neisner, 2006).

2.2 Customer satisfaction

A person's sentiments of pleasure or disappointment from comparing a product's performance to expectations is called satisfaction (Kotler & Keller, 2021). Such a formulation shows that performance and expectations determine satisfaction. If the performance meets expectations, the consumer is satisfied; otherwise, they are unsatisfied. If performance exceeds expectations, customer satisfaction is high. Dissatisfied clients may leave and spread bad word of mouth. Although happy clients are more loyal and share goodwill. Therefore, organizations should prioritize keeping good clients above acquiring and creating new ones to replace those that depart. Many theories explain

consumer satisfaction and discontent, but the expectation disconfirmation hypothesis is the most popular (Hashem, 2015).

Many companies now prioritize customer satisfaction to increase repeat business and favorable word-of-mouth, boosting long-term profitability. Companies spend millions measuring customer satisfaction attribute-by-attribute to better manage it. Research on customer satisfaction and loyalty has advanced significantly in recent years (Donio', et al., 2006). Customer satisfaction has several definitions (Dimitriades, 2006). Researchers have claimed that consumer satisfaction is different for tangible objects and service experiences. Because services are intangible and perishable, and production and consumption cannot be separated, this separation is necessary (Hashem,2018).

The significance of client satisfaction for consumer product manufacturers and merchants is well-established. Customer satisfaction is a major component in repeat purchases. Consumer satisfaction with a shop increases the likelihood of a return (Söderlund,2006). Customer satisfaction research has focused on expectations, perceived performance, and satisfaction as a confirmation/disconfirmation paradigm. Consumers expect particular things during exchange contacts, such as a visit to a store, based on past experiences, others' experiences, marketing pictures, etc. These expectations are contrasted to performance throughout the trade . Comparison of expectations and perceived performance leads to consumer satisfaction (confirmation or positive disconfirmation) or discontent (negative disconfirmation) (Burns& Neisner, 2006). According to Burns and Neisner (2006), satisfaction cannot be fully grasped without the emotive dimension. Empirical evidence supports affect's relevance. The emotive reports of customers are strongly predictive of satisfaction, maybe more so than cognitive judgments.

She found that emotional reports predict service purchases more than goods purchases. Since store experiences are service-centric, emotional evaluations should also impact consumer satisfaction. The function of emotion in retail shop evaluation is well-known. Customer satisfaction has typically been seen as a cognitive construct where consumers compare perceived performance to expectations (Donio', et al., 2006). According to Expectancy Customer satisfaction is measured by the gap between expectations and perceived performance. The subjective disconfirmation model and confirmation/disconfirmation model both believe that the discrepancy between expectations and performance affects satisfaction.

Donio', et al. (2006) suggests customer loyalty may stem from satisfaction. Recent years have seen significant improvement in research on consumer satisfaction and loyalty. The most popular conceptual models of loyalty start with the idea that satisfied consumers would buy or want to buy things again.

It is believed that retaining existing customers is more profitable than attracting new ones, and customer satisfaction is a key factor in fostering long-term partnerships.

2.2.1 Customers' satisfaction factors

Zeithmal and Bitran (2003) say product or service attributes and quality perceptions affect consumer satisfaction. Customers' emotional responses, attributions, and equitable views affect satisfaction.
Product and service aspects affect consumer satisfaction. Resort hotel characteristics may include the pool area, proximity to golf facilities, restaurants, room comfort and privacy, staff helpfulness and courtesy, room price, and so on.
Consumer Emotions: Customers' emotions may also impact product and service satisfaction.
Pre-existing emotions might be steady. The purchasing experience might also evoke certain emotions, affecting customer satisfaction. Happiness, joy, ecstasy, and warmth increased consumer satisfaction. Negative emotions including grief, regret, and wrath decreased client satisfaction.

2.3 Customer Loyalty

Most organizations created, tested, and deployed customer loyalty strategies in the early 1980s. The efforts share a goal. They all aim to keep clients longer and boost sales and profits. Over the past 20 years, customer loyalty has changed. Due to market shifts that make it harder to create long-term consumer connections, these tactics will need significant adjustment in 2005 and beyond.

Customer loyalty strategy started as tactical programs. Frequent flier programs were the first broad attempt to convince customers to buy one brand in a category. These projects began as promotions but grew into long-term plans few marketers could have predicted. Over numerous years, a customer loyalty theory arose. The theory held that acquiring new customers costs more than retaining existing ones. This simple notion grabbed on quickly among marketers and became a common concept in all business cases supporting the creation and testing of future customer loyalty-building tactics (Duffy, 2005).

Many firms studied customer-focused thinking to enhance customer loyalty and retention. The debate of customer loyalty programs begins with how much consumers mean to the firm and how they deserve special

attention. However, greater execution of the main product or service should provide much of that exceptional value and care. The company's senior management, not simply the marketing VP, must embrace customer loyalty. Unfortunately, marketers start making concessions early on and focus on what they can do for consumers rather than what they should (Hashem,2010). Today, marketers want to know how to establish customer loyalty. Loyal clients buy more and switch less due to pricing. Loyal clients are a powerful marketing force, promoting positive word-of-mouth and referrals. These partnerships are the finest kind of promotion there is. Sales improve when loyal consumers buy more things and more often. Finally, loyal consumers are cheaper to service since they know the product and need less information (Joudeh, et al.,2020) . Customer loyalty is tough to define. There are three methods to assess loyalty: behavioral, attitude, and composite. (Bowen & Chen, 2001). Behavioral, attitudinal, and composite views have been used to describe customer loyalty. The behavioral perspective of "purchase loyalty" targets recurrent purchase behavior based on client purchase history. Past acts are emphasized here, not future ones. No other loyal behaviors like price tolerance, word of mouth, or complaint behavior can be understood. Focusing on conduct may overstate loyalty. Behavioral assessments of loyalty use persistent, repetitive buying activity as an indicator (Dimitriades, 2006). The attitudinal approach provides a broader knowledge of loyal conduct. Psychological brand commitment may not necessarily cause repeat purchases, which is a concern with the behavioral method.

Söderlund (2006) defined customer loyalty as the relationship between an individual's attitude toward a brand, service, store, or vendor and recurring consumption. Literature identifies three customer loyalty concepts:

1. Loyalty is an attitude that can lead to a relationship with the brand.
2. Loyalty is mostly demonstrated via behavior.
3. Individual attitudes moderate buying.

As an attitude, loyalty leads to a brand relationship. True brand loyalty requires a strong “attitudinal commitment” according to researchers. This is a continual positive view of the brand purchased. People might be asked how much they enjoy, feel devoted to, recommend, and have favorable beliefs and sentiments about the brand compared to rival brands. The strength of these views predicts brand purchase and recurrent patronage.

Ajina et al. (2023) described loyalty as a dedicated, emotional brand-consumer relationship. The bond will be stronger when household or buying group members support it and when consumption is tied to communal identity.

Mainly shown behavior shows loyalty. Though contentious, this view is best supported by statistics. The debate arises because loyalty is defined mainly by past purchases and not by consumer incentives or company commitment (Donio', et al., 2006).

Repeat purchase loyalty results from repeated satisfaction, which weakens brand commitment. The buyer repurchases the same brand since finding an alternative is not worth the time and effort. A functionally equivalent portfolio brand will be purchased if the regular brand is out of stock or unavailable.

Business success depends on client loyalty as recruiting new consumers is far more expensive than maintaining existing ones. Many writers believe that devoted consumers are a competitive advantage and that secure and collaborative buyer-seller relationships increase customer retention. Customer profitability and cost-revenue streams vary, according to several writers. The company has been advised to aggressively create successful client connections and eliminate unproductive ones. Customer loyalty has long been used in customer behavior (Donio', et al., 2006).

Satisfying choice-based clients won't guarantee loyalty. client satisfaction leads to client loyalty, which boosts corporate profits by spending more, repeating purchases, and promoting the firm (Burns& Neisner, 2006). Improved customer loyalty and retention can boost earnings by 25% or more.

2.4 Relation between Customer Satisfaction and Customer Loyalty

Customer satisfaction and loyalty are key to long-term sustainability. Other variables often modify the relationship between satisfaction and loyalty. Given other factors, the relationship strength might be smaller or stronger. Commitment and demography influence the relationship between satisfaction and loyalty. In addition, a recent customer satisfaction study found that the relationship between satisfaction and loyalty varied by research technique and assessment. The following conceptual backdrop justifies the research strategy and data analysis methods used in this study. (Bowen & Chen, 2001). The connection between satisfaction and loyalty has two crucial levels, high satisfaction levels lead to increased loyalty, whereas low satisfaction levels lead to decreased loyalty (Dimitriades, 2006).

3. HYPOTHESES

HO1: There is no relationship between shopping benefits (hedonic & utilitarian) and customer satisfaction.
HO2: There is no relationship between shopping benefits (hedonic & utilitarian) and customer loyalty.

HO3: There is no relationship between customer satisfaction and customer loyalty.

4. METHODS AND MATERIAL

4.1 Methodological Approach

The current study was conducted using a quantitative methodology. This particular methodological strategy was determined to be highly appropriate for current research due to its ability to gather primary data from a larger sample size.

4.2 Population and Sampling

Population of study consisted of customers of retail stores. Total of (600) questionnaires were distributed on customers of retail stores as a simple random sample. The reason or choosing the random sample is attributed to its ability to be more representative of the population since they eliminate the selection bias and give an unbiased estimate of the population characteristics. After application process, researcher was able to retrieve (493) properly filled questionnaire.

4.3 Data Analysis

The study revealed that a significant proportion of participants (57.6%) were male and fell between the age bracket of 40-50 years (34.9%). Furthermore, the survey revealed that a significant proportion of participants possessed a Bachelor degree (50.7%), while their income fell within the range of $2000 to $3000 (34.7%).

4.4 Descriptive Analysis:

Mean and standard deviation were used to describe attitudes toward the study variables as well as the reliability test

Table 1. Descriptive Analysis

	N	Minimum	Maximum	Mean	Std. Deviation	Cronbach Alpha
Shopping Benefits	493	1.00	5.00	4.037	.977	0.938
Satisfaction	493	1.00	5.00	3.864	.962	0.939
Loyalty	493	1.00	5.00	3.828	1.023	0.94

It was discovered that there are favorable views towards the aforementioned questions, as their averages above the mean of the scale (3).

The reliability of the scale was assessed using Cronbach's Alpha, and all results exceed the standard threshold of 0.70.

5. HYPOTHESES TESTING

HO1: There is no relationship between shopping benefits (hedonic & utilitarian) and customer satisfaction.

Table 2. Test of Hypothesis (1)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.884[a]	.782	.781	.45004

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	356.319	1	356.319	1759.263	.000[b]
	Residual	99.447	491	.203		

	Total	455.766	492			

Coefficients

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	.347	.086		4.024	.000
	Benefits	.871	.021	.884	41.944	.000

The hypothesis mentioned above was tested using linear regression analysis, which showed a strong positive correlation (r = 0.884) between the independent variable and the dependent variable. The independent variable explains an additional 78.2% of the total variability in the dependent variable. It is worth noting that the F value is statistically significant at the 0.05 level, suggesting a relationship between shopping benefits (hedonic & utilitarian) and customer satisfaction.

HO2: There is no relationship between shopping benefits (hedonic & utilitarian) and customer loyalty.

Table 3. Test of Hypothesis (2)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.804[a]	.647	.646	.60856

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	332.964	1	332.964	899.069	.000[b]
	Residual	181.838	491	.370		
	Total	514.802	492			

Coefficients

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	.429	.117		3.678	.000
	Benefits	.842	.028	.804	29.984	.000

The hypothesis mentioned above was tested using linear regression analysis, which showed a strong positive correlation (r = 0.804) between the independent variable and the dependent variable. The independent variable explains an additional 64.7% of the total variability in the dependent variable. It is worth noting that the F value is statistically significant at the 0.05 level, suggesting a relationship between shopping benefits (hedonic & utilitarian) and customer loyalty.

HO3: There is no relationship between customer satisfaction and customer loyalty.

Table 4. Test of Hypothesis (3)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate

1	.829[a]	.688	.687	.57238

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	353.943	1	353.943	1080.362	.000[b]
	Residual	160.859	491	.328		
	Total	514.802	492			

Coefficients

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	.423	.107		3.967	.000
	Satisfaction	.881	.027	.829	32.869	.000

The hypothesis mentioned above was tested using linear regression analysis, which showed a strong positive correlation (r = 0.829) between the independent variable and the dependent variable. The independent variable explains an additional 68.8% of the total variability in the dependent variable. It is worth noting that the F value is statistically significant at the 0.05 level, suggesting a relationship between customer satisfaction and customer loyalty.

6. CONCLUSION

According to the findings of the study, shopping benefits have the ability to influence the wants and feelings of consumers regarding their purchases, as well as to achieve a high degree of pleasure and loyalty. In addition, the research study discovered that the advantages of shopping contributed to an increase in the level of happiness experienced by customers in retail areas. The user's shopping experience was improved as a result of the elimination of impediments that would slow down the process of making a purchase. This, in turn, contributed to a reduction in the amount of time spent waiting or the requirement to await payment. One of the factors that has led to the increased degree of customer loyalty is the high level of customer satisfaction. The following recommendations were made by the researcher in the current study, taking into consideration the debate and conclusion of the results:

1. In order to attract the people, you are trying to attract, the location of the retail business should be carefully selected.

2. Employees working in retail establishments should receive training in order to maintain appropriate interactions with consumers.

3. The price of the product needs to be proportional to the quality of the product.

4. In order to boost the level of happiness and loyalty that customers have, it is important to encourage them to purchase by providing them with perks.

5. It is recommended that more research be conducted in order to investigate additional factors that play a role in customer happiness and loyalty.

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Can Non-Fungible Tokens Enhance Audiences' Purchase Intention for Popular Concert Tickets? The Moderating Role of Fans and Nonfans

Chun-Ming CHANG [a*], Tun-Wen YAO [b], Jo-En WANG [c]

[a] *Department of International Business, Ming-Chuan University, Taiwan, chunming@mail.mcu.edu.tw*
[b] *Department of International Business, Ming-Chuan University, Taiwan, 880120@gmail.com*
[c] *Department of International Business, Ming-Chuan University, Taiwan, grace.wang336@gmail.com*

Abstract

Non-Fungible Tokens (NFTs) has become a viral trend for technology, design, economy, and business. From the aspect of marketing, NFTs can be used to promote brand awareness and purchase intention. Yet, researchers have paid limited attention to understand how can NFTs be used to enhance customers' purchase intention. Based on cognitive-affective-conative model, we proposed a research model to understand the effect of celebrities' NTF strategy on audiences' intention to purchase popular concert tickets. Data collected from 387 protentional customers of pop concerts. The results reveal that celebrity identification exerts significant effect on purchase intention, while emotional value and self-enhancement have positive impacts on celebrity identification. The moderation effect test further reports that transactional value has a stronger influence on celebrity identification for fan group. The discussion of results is provided.

Keywords: Non-Fungible Tokens (NFTs), Prchase Intention, Idenitfication, Perceived value, Fans and Nonfans

1. INTRODUCTION

As the rapid development of information technology, non-fungible tokens (NFTs), the digital assets representing unique ownership of each item based on the blockchain-enabled technology (Urom et al., 2022; Zhong and Hamilton, 2023), have become a major economic phenomenon with a tremendous growth of market volume in the past years (Colicev et al., 2023). According to a recent survey, the sales of NFTs in 2021 have reached up to 40 billion USD in sales (Find, 2024). The importance of NFTs might facilitate the development of next generation web (web 3.0) (Colicev et al., 2023).

Although NFTs provide an investment option for online users (Urom et al., 2022), from the marketing perspective, NFTs can be utilized to raise brand awareness and attract customers to purchase brand products to create brand value in the pre-purchase, purchase, and post-purchase stages (Colicev et al., 2023). Many firms, such as Nike and Adidas, have used NFTs to promote their physical products (Colicev et al., 2023). Given that NFT is a new concept, it is then importance to understand how a firm/brand can increase customers' purchase intention by using NFT as a firm's effective marketing strategy in the early stage of NFT application.

While NFT has received a lot of attention from researchers, their studies mainly focused on the NFT sales and market (e.g., Urom et al., 2022; Zhong and Hamilton, 2023), little research has been done to examine how NFTs can

* Corresponding author.

be used to enhance purchase intention. To fulfill this knowledge gap, we aim to explore the effect of celebrities' NTF strategy on audiences' intention to purchase popular concert tickets. This is because popular music (e.g., Korean popular music) has played a vital role in the global market (Kang et al, 2021). The revenue of the concerts held by the famous celebrities in China has reached up to RMB 14.6 billion and more than 20 million have participated in the concerts in 2023 (InfoTimes, 2024). Some celebrity in Taiwan (e.g., aMei) has lunch limited NFT to serve as the gift for the audiences who have purchased the ticket of concerts (Bnext, 2022). The Sony Music, Waner Music, and Universal Music Group also tended to use NTF to lunch unique digital products (iThome, 2022). Therefore, it is suitable for use to propose a model to understand how can use NFTs to promote consumers' purchase intention in the context of popular concerts.

We employed the cognitive-affective-conative model (Bagozzi, 1992; Oliver et al. 1997) as our theoretical base to construct the research model to identify the factors affecting audiences' decision for purchasing pop concert tickets. In the model, we argued that perceive value could be used to reflect cognitive evaluations about NFT attributes and it will influence customers' affective response. In this study, celebrity identification is treated as customers' phycological response resulted from cognitive assessment, which in turn affects purchase intentions. In addition, we argued the fans and nonfans may impact the relationship between perceived value, celebrity identification, and purchase intention, based on Kang et al. (2021).

The remainder of the study is structured as follows. Section 2 presents the theoretical background and hypothesis. Section 3 describes the research methodology, while section 4 details the data analysis and results. Section 5 presents a discussion of our results.

2. THEORETICAL BACKGROUND AND HYPOTHESIS

2.1. Celebrity identification and purchase intention

According to social identity theory (Tajfel and Turner, 1979), identification captures the aspect that an individual view himself/herself as a member of s specific social group and may thus imply emotional involvement with the group (Dholakia et al., 2004). This also indicates that identification represents the strength of the relationship between an individual and the social group he/she belongs to (Martínez-López et al., 2017). From the perspective of affective component of social identity, identification is similar to the concepts of attachment or affective commitment (Dholakia et al., 2004). Based on Hu et al. (2017), we define celebrity identification as audiences' psychological attachment and social bonds with the celebrities.

Identification has treated as a vital factor motivating an individual's behavioral intention (e.g., Dholakia et al., 2004; Hu et al., 2017). This is because favorite relationship could increase members' trust for others in a social group and may thus motivate people to conduct a specific behavior by reducing uncertainty concern (Luo et al., 2016). Past research also argued that audiences' identification with the celebrities will enhance their behavioral intention to follow the celebrities (Kang et al., 2021; Um & Jang, 2020). Therefore, we infer that the increased celebrity identification will enhance audiences' purchase intention for concerts of the celebrities.

H1: Celebrity identification is positively related to purchase intention.

2.2. Perceived values of NFTs and celebrity identification

Perceived value refers to one's overall evaluation about the ratio of customer input and the benefit he/she receives (Oliver and DeSarbo, 1988; Zeithaml, 1988). Perceived value is a complex concept that can be divided into a variety of dimensions to reflect the trade-off between benefit and sacrifice components (Chuah et al., 2017). In general, perceive value can be divided into three types: functional, emotional value, and social value (Chuah et al., 2017; Liu et al., 2021; Sweeney and Soutar, 2001). Functional value reflects the utilitarian benefits that can satisfy customers' demands, while emotional value refers to customers' felling or emotion (e.g., enjoy and excited) resulted from product/service usage (Chuah et al., 2017). Social values represent one's perception about positive feedback from others in a social group (Liu et al., 2021; Sweeney and Soutar, 2001).

In the NFTs context, researchers argued that NFTs as the promotion product may carry symbolic benefits for customers because of the nature of rarity and uniqueness (Colicev et al., 2023). In the study of Zhou et al. (2022), they also found that providing rewards for customers is an effective strategy for enhancing their positive emotion and perception of self-enhancement (the perception of being respected and recognized the importance to the firm). Thus, we consider that customers may obtain emotional value and self-enhancement when they receive NFTs as

reward from the celebrity. In addition, NFT is the digital asset that is transferable and tradable in the online NFT market. The audiences may thus receive value of money by selling their NFTs. Transaction value, one's perception about the comparison between perceived benefit and actual price (Debey et al., 2020), in this sense is included in the research. Finally, although a firm can offer functional benefits for customers to purchase physical products using NFTs it issues, in this research, such benefits are not bundled with NFTs. Thus, functional value is excluded in the model.

In the context of virtual communities, members' identification with social groups is determined by the extent to which their needs can be fulfilled by the social groups (Dholakia et al., 2004; Hogg & Abrams, 1988). Dholakia et al. (2004) further found that purpose and entertainment values are the predictors of members' identification with social groups. Therefore, it is reasonable for us to expect that value perceptions may impact audiences' identification with celebrities.

H2: Transactional value is positively related to celebrity identification.
H3: Emotional value is positively related to celebrity identification.
H4: Self-Enhancement is positively related to celebrity identification.

2.3. The moderating role of fans and nonfans

Past research found that the level of fandom for characters, sports, and celebrities will affect one's motivation, identification, and behavioral intention (Janicke & Raney, 2015; Kang et al., 2021; Kim and Chalip, 2004). In the study of Kang et al. (2021), they revealed that the level of identification with celebrities and intention to participate in celebrities' social campaigns will be higher for fan group than nonfan group, implying that identification with celebrity may exerts a higher effect on purchase intention. In addition, past research found that fans exerted greater enjoyment and higher identification with a character (Janicke & Raney, 2015). Another study further report influencer playfulness will impact satisfaction, which in turn affects commitment to influencer in the social media context. Since identification is akin to the concept of commitment (Kim and Baek, 2022), we may expect that emotional value may have a stronger effect on celebrity identification for fan group than nonfan group.

Moreover, fans generally establish strong parasocial bonds with celebrities through frequent interactions (Kang et al., 2021). From the aspect of interpersonal justice, people usually expect that they can be treated with politeness, dignity, and respect by others within social interactions and the level of interpersonal justice perception may determine the development of exchange relationship in thee-customer service context (Turel et al., 2008). Accordingly, we may propose that self-enhancement may exert a higher influence on celebrity identification for fan group than nonfan group. In addition, the standpoint of relationship development asserts that people tend to focus on the economic benefit in the beginning of relationship development (Hsu et al., 2007). Thus, transactional value may exert stronger effect on celebrity identification for nonfans.

H5a. The influence of transactional value on celebrity identification will be stronger for nonfan group than fan group.
H5b. The influence of emotional value on celebrity identification will be stronger for fan group than nonfan group.
H5c. The influence of emotional value on celebrity identification will be stronger for fan group than nonfan group.

Based on the abovementioned theories and arguments, the conceptual model that we propose is depicted in Figure 1.

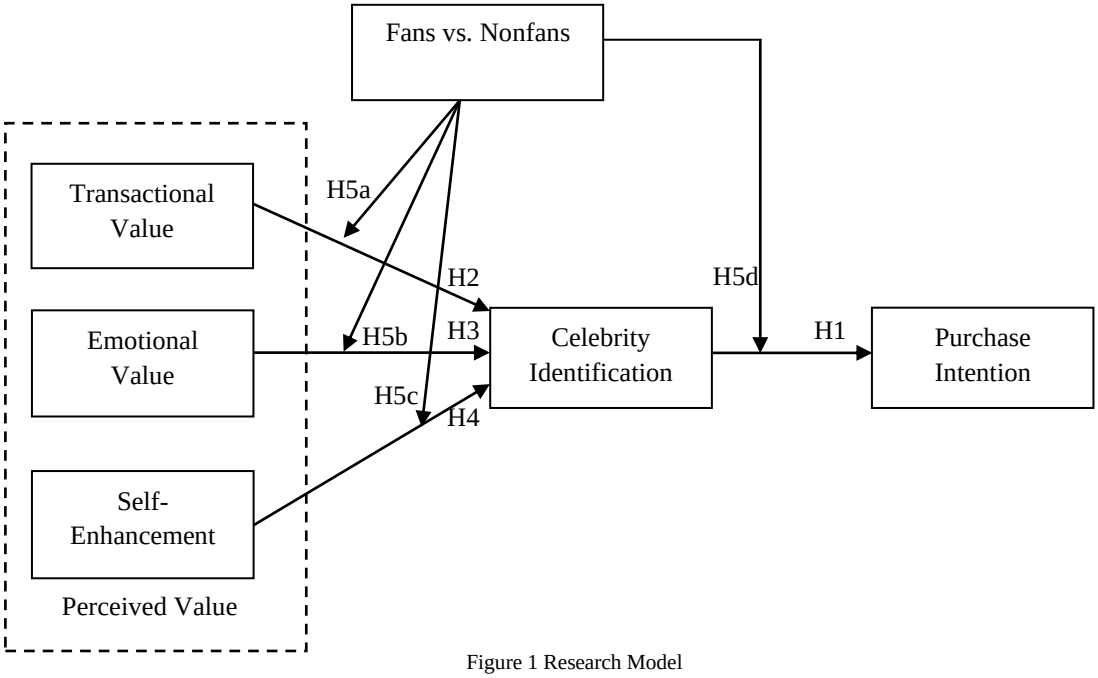

Figure 1 Research Model

3. RESEARCH METHODOLOGY

3.1. Measurement development

All the scale items were adapted or developed based on prior studies and modified based on the research context of this study. We conduct pilot test by inviting 15 undergraduate and graduate students to provide comments on the questionnaire content and structure to ensure the content validity. A few questions with ambiguous wording were modified based on their feedback (Shiau et al., 2020). A five-point Likert scale ranging from "strongly disagree" (1) to "strongly agree" (5) was used to measure all items.

3.2. Data collection

Since NFT is a new concept, it is difficult to recruit sufficient respondents who has received NFT as a reward when they purchased pop concert tickets. Similar to Wang et al., (2021), this study invited the audiences with high willingness to purchase pop concert tickets randomly using social media to be our respondents to represent the potential customers' opinion about the NFT as a marketing strategy. Based on Wang et al., (2021), we further asked the participant to review the NFT concept and understand the scenario that NFT will be the gift for the respondents if they purchase the pop concert ticket in the future for several minutes. A total of 378 participants joined in the survey.

4. DATA ANALYSIS AND RESULTS

We employed the partial least squares (PLS) approach to evaluate the measurement and structural model. Specifically, we use multiple group method to test the moderating role of fans and nonfans. In this study, we conducted data analysis using the software of SmartPLS 4.0 (Ringle et al., 2024).

4.1. Measurement model test

To assess he adequacy of the measurement model, we conducted tests of reliability, convergent validity, and discriminant validity. As shown in Table 1, all the values of composite reliability (rho_a and rho_c) are well above the recommended level of 0.70, indicating the adequate reliability. Moreover, Table 2 reports that the factor loadings

are greater than 0.7 and the values of average variance extracted (AVE) exceed threshold value of 0.5, suggesting the acceptable convergent validity (Fornell and Larcker, 1981). Table 2 also reveal that all the values of the square root of the AVE exceed the correlation shared between a construct and other constructs in the model. Therefore, discriminant validity of the model is adequate (Fornell and Larcker, 1981).

Table 1 Measurement items statistics

Variable	Item	Factor Loading	CR (rho_a)	CR (rho_c)	AVE
Transaction value (TV)	TV1	0.935	0.931	0.950	0.865
	TV2	0.936			
	TV3	0.918			
Emotional value (HV)	HV1	0.926	0.935	0.953	0.835
	HV2	0.921			
	HV3	0.897			
	HV4	0.910			
Self-Enhancement (SV)	SV1	0.926	0.919	0.948	0.859
	SV2	0.940			
	SV3	0.916			
Celebrity Identification (CIY)	CIY1	0.863	0.891	0.924	0.754
	CIY2	0.907			
	CIY3	0.876			
	CIY4	0.825			
Purchase Intention (PI)	PI1	0.897	0.919	0.948	0.860
	PI2	0.951			
	PI3	0.933			

Table 2 Correlations and the square root of the AVE of latent variables

Variable	Transaction value	Emotional value	Self-Enhancement	Celebrity Identification	Purchase Intention
Transaction value	**0.930**				
Emotional value	0.850	**0.914**			
Self-Enhancement	0.781	0.794	**0.927**		
Celebrity Identification	0.625	0.665	0.658	**0.868**	
Purchase Intention	0.448	0.511	0.442	0.722	**0.927**

Note(s): Diagonal elements (in shade) are the square root of the average variance extracted (AVE).
Off-diagonal elements are the correlations among constructs

4.2. Structural model test

To determine the significance of paths in the structural model, we used the bootstrapping resampling method with 5,000 samples to generate t-values. As shown in Figure 2, celebrity identification significantly affects purchase intention (β=0.722, t=21.917), supporting H1. The results emotional value and self-enhancement are the predictors of celebrity identification (β=0.328, 0.326; t=3.607, 4.413, respectively). Thus, H3 and H4 are supported. However, transaction value exerts insignificant effect on celebrity identification (β=0.092, t=1.024), indicating H2 is not supported.

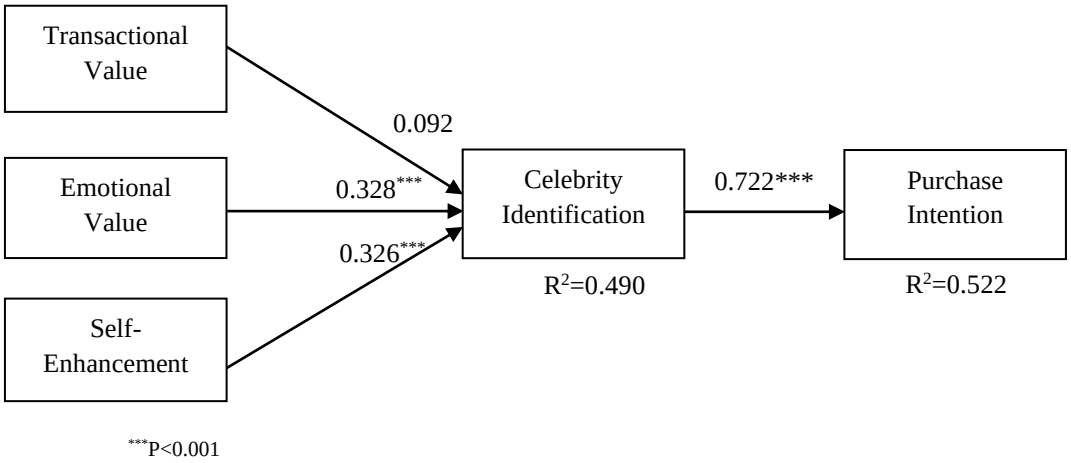

Figure 2 Results of Structural Model Test (Full Sample)

4.3. Moderating effect test

Finally, we used a multigroup method to evaluate the differences in the relationship between perceived value, celebrity identification, and purchase intention between fan group and nonfan group. Unlike Kang et al. (2021) that used self-report measurement item to classify the respondents into fans and nonfans based on the level of fandom, this study used the time of participants become the fans of the celebrity in social media. The respondents of this study were asked to indicate the time they have followed the celebrity they like using the social media (e.g., Facebook, Instagram, or twitter). We may thus yield 105 cases as nonfans because they did not follow the celebrity, while 273 cases were classified into the fan group because they are the fan of the celebrity in the social media.

We then employed a permutation test with 1,000 permutations to compare the standardized path coefficients for the sub-groups, following Schlägel and Sarstedt (2016). The results of MICOM analysis also further reveal that partial measurement invariance is established, indicating that it is suitable to use a multigroup analysis to compare the path coefficients proposed in the model (Schlägel and Sarstedt, 2016). As shown in Table 3, the results posit that transactional value has a stronger influence on celebrity identification for fan group, while no significant difference can be found for the impacts of emotional value and self-enhancement on celebrity identification, and the effect of celebrity identification on purchase intention across both groups. Thus, the results show that H5a is supported, whereas H5b, H5c, and H5d are not.

Table 3 Results of path Coefficient comparisons for fans and nonfans

Relationship	Nonfans	Fans	Difference	P-value of difference
Transactional value→Celebrity identification	0.398	-0.037	0.436	0.021*
Emotional value→ Celebrity identification	0.128	0.387	-0.259	0.210
Self-Enhancement→ Celebrity identification	0.271	0.365	-0.094	0.586
Celebrity identification→ Purchase Intention	0.708	0.671	0.037	0.579

*P<0.05

5. DISCUSSION

Our results indicate that celebrity identification significantly affects purchase intention. The findings confirm the perspectives of past studies (e.g., Dholakia et al., 2004; Hu et al., 2017; Kang et al., 2021; Um & Jang, 2020) that identification is a vital predictor of behavioral intention. Moreover, our results reveal that emotional value and self-enhancement exert positive effects on celebrity identification. The results confirm the importance of value perception on the formation of identification, as suggested by prior literature (Dholakia et al., 2004; Hogg &

Abrams, 1988; Zhou et al., 2022). However, transactional value does not have significant influence on celebrity identification. The results of moderating effect test show that the influence transactional value exerts a positive and stronger influence on celebrity identification for nonfans. The results demonstrate the importance of transactional value for the members with lower social relationship in a social group (Hsu et al., 2017). Additionally, although our results report that emotional value and self-enhancement exert stronger effects on celebrity identification for fans than nonfans, the difference in these path coefficients between the two groups are insignificant. The results implies that emotional value and self-enhancement are the critical factor enhancing celebrity identification for fans and nonfans. Finally, contrary to our expectation, our results report that celebrity identification have a greater effect on purchase intention for nonfans than that for fans, although the difference in the path coefficient between the two groups are insignificant. This result implies that additional factors, such as celebrity attractiveness, performance, or status, may impact audiences' behavioral intention (Chmait, et al., 2020). Further studies may integrate these factors into the model to test their impacts.

Basically, our study makes several contributions to the existing literature. First, this study employs cognitive-affective-conative model to uncover how to use NFTs to promote customers' purchase intention. Our results also reveal the moderating effect of fans and nonfans. The findings may offer useful insights to existing literature on NFTs. These findings also provide some useful directions for organizations to increase customer purchase intention using NFTs as their marketing strategies.

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Engineering, Robotics, IT and Nanotechnology (IAC-ERITN)

Air Temperature Prediction for Mediterranean Sea Region using Deep Learning

Ihsan ULUOCAK[a*]

[a] *Cukurova University, Ceyhan Engineering Faculty,Adana, Turkiye, ihsanuluocak@gmail.com **

Abstract

Presently, air temperature (AT) stands out as the foremost pivotal climatic parameter. It serves as a precise gauge for delineating global warming and climate change, impacting various spheres including the environment, hydrology, agriculture, and fisheries. Ensuring the accuracy and timeliness of AT forecasts holds paramount importance as it furnishes crucial insights fostering credibility in future planning endeavors. This research advocates for the adoption of advanced methodologies such as Long Short-Term Memory (LSTM) neural networks and Gated Recurrent Unit (GRU) models to forecast AT trends one month ahead specifically for the Mediterranean Region. Reanalysis-derived monthly AT data spanning from 1940 to 2023 are employed for this purpose. The efficacy of the predictive models is assessed through diverse statistical metrics such as Mean Absolute Error (MAE) and coefficient of determination (R2), alongside visual analyses. Ultimately, this study offers a comprehensive exploration and assessment of deep learning techniques in projecting air temperature variations within the Mediterranean region over the ensuing 15 years on a monthly basis.

Keywords: Mediterranean, Air Temperature, LSTM, GRU

1. INTRODUCTION

The remarkable surge in global temperatures witnessed over the last century, commonly referred to as global warming, is primarily attributed to the emission of greenhouse gases from the utilization of fossil fuels. Global warming denotes the gradual elevation in Earth's temperature observed since the pre-industrial era, predominantly instigated by human activities such as fossil fuel combustion. These anthropogenic activities have led to an increase in greenhouse gases within the Earth's atmosphere, impeding the escape of solar heat reflected from the Earth's surface back into space (Marzouk, 2021). Since the onset of the Industrial Revolution, particularly since the 1960s, the global climate has experienced a significant warming trend primarily due to heightened concentrations of greenhouse gases resulting from industrial operations. For example, in comparison to the period between 1850 and 1900, global surface temperatures surged by 0.99 degrees Celsius from 2001 to 2020 (Nita, 2022).

* Corresponding author.

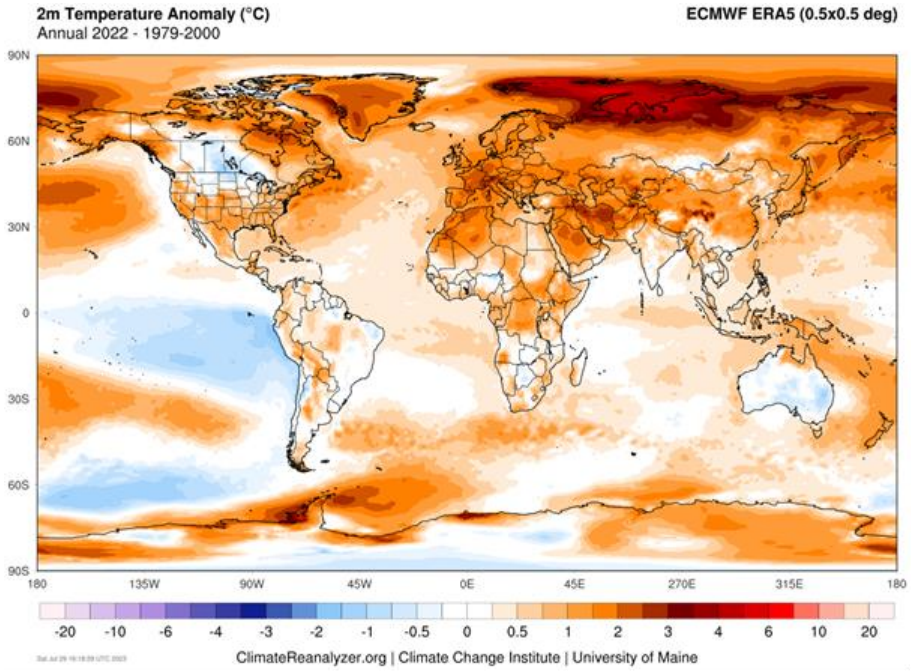


Fig. 1. Temperature Anomaly of 2022

Among meteorological variables, temperature is widely regarded as exerting the most significant influence on the evolving climate of Earth and its surrounding environment (Alomar et al., 2022). Notably, strong correlations exist between air temperature (AT) and various climatic parameters, encompassing humidity, wind speed, precipitation, atmospheric pressure, soil temperature, and solar radiation. Moreover, AT plays a pivotal role in influencing evapotranspiration, a crucial factor in water resource management and agricultural planning (Alomar et al., 2022; Kabbilawsh et al., 2020). Consequently, the accurate and timely prediction of AT holds paramount importance for meteorologists and researchers engaged in meteorological applications. Precise AT forecasting is indispensable for facilitating economic activities, natural resource management, agricultural scheduling, and public health concerns (Akdi & Ünlü, 2021). Particularly in nations reliant on agriculture-based economies, the demand for highly accurate weather forecasting has escalated in recent years. Nevertheless, weather prediction has become increasingly intricate owing to the dynamic nature of weather patterns. Furthermore, conventional mathematical and statistical methods may prove inadequate for estimating air temperature accurately. Consequently, there has been a surge in the adoption of deep learning techniques to enhance weather forecasting endeavors. Deep learning methodologies offer efficient learning processes and have demonstrated efficacy in conducting successful weather forecasting studies. For example, Zhang and Dong (2020) introduced a large-scale temperature forecasting method based on the Convolutional Recurrent Neural Network (CRNN) model for the mainland of China. Uluocak (2023) compared various AI models such as ANFIS, MLP, with deep learning to predict solar radiation values in Türkiye. Ozbek et al. (2021) used an LSTM neural network for one-step-ahead AT prediction in the Eastern Mediterranean cities of Türkiye. In conclusion, in this study, future forecasting of AT time series data using 2 different deep learning models is explored. Real-time monthly AT data measured between 1940 and 2023 at the Mediterranean region.

2. MATERIAL&METHOD

2.1. Data

The monthly AT data collected between 1940 and 2023 are taken from project ERA5 lead by ECMWF (European Centre for Medium-Range Weather Forecasts). The used data combines past short-range weather forecasts with observations through data assimilation. The process mimics the production of month-to-month weather forecasts, which use an analysis of the current state of the Earth system as their starting point. The analysis is a physically consistent blend of observations with a short-range forecast based on the previous analysis from 2m level of the surface.

2.2. Location

The Mediterranean region features a diverse geography that encompasses a range of landscapes, climates, and natural features. At its core lies the Mediterranean Sea, which connects to the Atlantic Ocean via the Strait of Gibraltar to the west and the Red Sea through the Suez Canal to the east and bordered by Europe to the north, Africa to the south, and Asia to the east and 21 countries with nearly 500 million population. The region is renowned for its Mediterranean climate, characterized by hot, dry summers and mild, wet winters, moderated by the sea. The Mediterranean region is also home to several mountain ranges and plateaus, including the Pyrenees separating France and Spain, the Alps along the northern coast, the Apennine Mountains in Italy, the Atlas Mountains in North Africa, and Taurus Mountains among others. The mentioned area is within 30 N-46 N, 0E 30E coordinates.

2.3. LSTM

LSTM (Long Short-Term Memory) networks are a type of recurrent neural network (RNN) architecture designed to overcome the limitations of traditional RNNs in capturing long-range dependencies in sequential data. At the heart of LSTM networks are memory cells, which are capable of storing information over long periods. These memory cells enable the network to retain information for extended durations, facilitating learning from sequences with long-term dependencies.

LSTMs employ special mechanisms known as gates to regulate the flow of information within the network. These gates consist of sigmoid activation functions that output values between 0 and 1, determining how much information should be allowed to pass through. During training, LSTM networks learn the parameters of their gates and memory cells using optimization algorithms like backpropagation through time (BPTT). By adjusting these parameters, the network effectively captures and utilizes long-range dependencies in sequential data. In summary, LSTM networks utilize memory cells and gates to control the flow of information, enabling them to effectively capture long-term dependencies in sequential data such as time series.

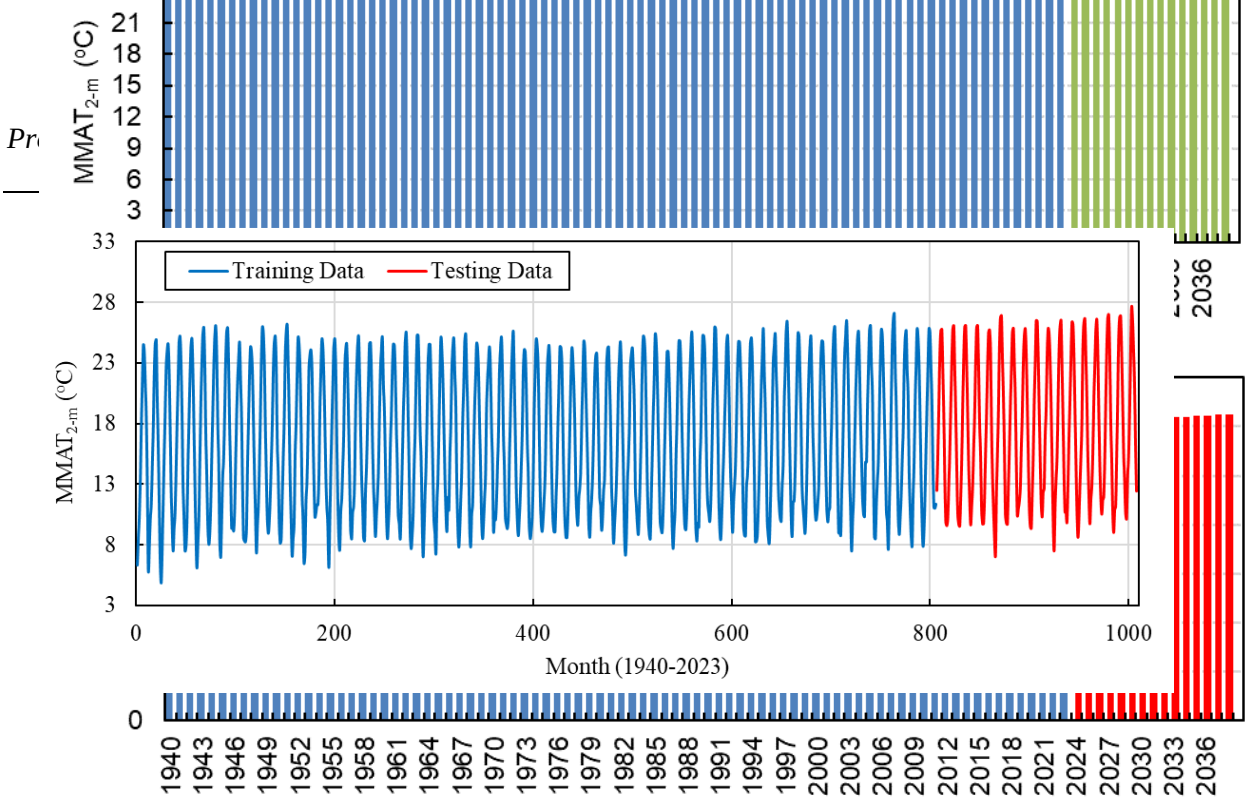
2.4. GRU

A GRU is a type of RNN that is designed to be used in lieu of the traditional LSTM or RNN networks. The GRU architecture, which was first proposed by Cho et al. (2014), has been widely utilized in various language processing applications. The LSTM memory cell is offered in a condensed form by GRU, which frequently achieves comparable performance but has the benefit of being faster to compute. An altered gating mechanism is designed to allow it to perform better long-term dependencies analysis than the traditional RNNs without the over-computing of LSTM. Compared to the LSTM architecture, the GRU architecture has fewer gates. Like LSTM, GRU is effective on long-term dependencies in sequential data such as time series.

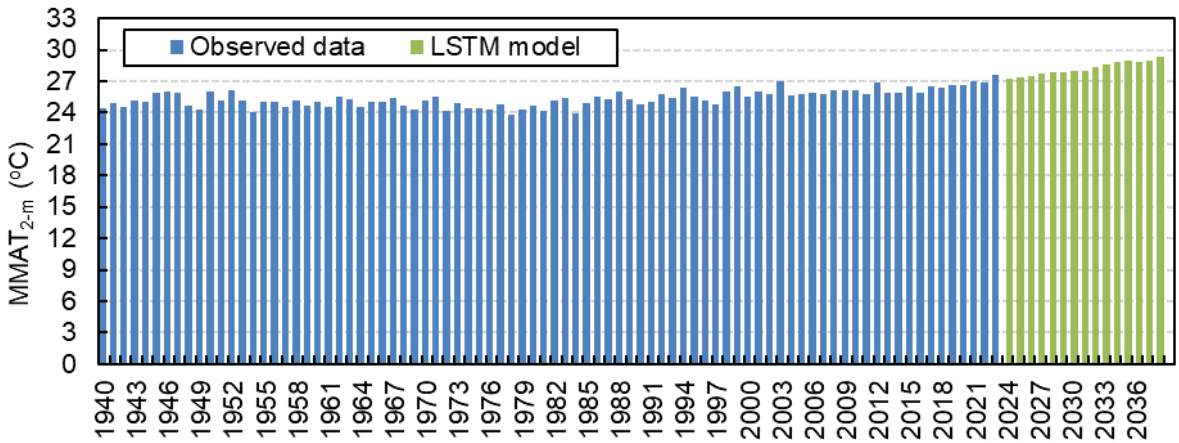
3. RESULTS & DISCUSSION

The time series forecasting approach adopted in this study involves employing a statistical model to anticipate future values of a time series by leveraging past outcomes. This entails developing a univariate modeling study rooted in preceding time series data for the variable under examination. Within time series analysis, past known data serves as the input variable in the model, while the corresponding value of the variable in the subsequent time step serves as the output. This methodology entails univariate modeling, which accounts for the inherent periodicity within the data. A key advantage of univariate modeling lies in its ability to utilize historical data points and their patterns to forecast future outcomes without necessitating additional information or observations.

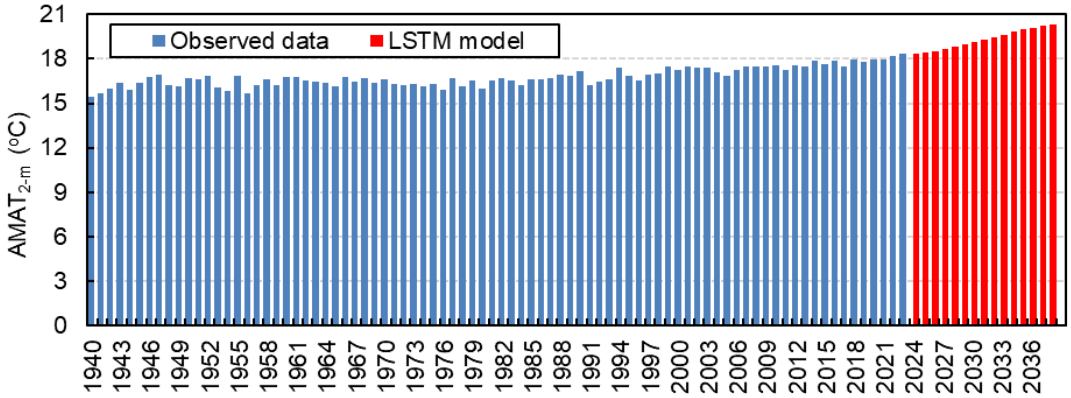
The Figure 2 illustrates the training (806 months) and test (202 months) data, along with observed monthly air temperature values ($MMAT_{2\text{-}m}$) for the Mediterranean region, intended for use in GRU and LSTM models. Initially, a total of 1008 months of air temperature data were partitioned into two sets for testing and training procedures. For all simulations proposed across both cities, a training dataset comprising 806 data points (80% of the entire dataset) spanning from January 1940 to April 2008 was utilized to train the models. The remaining 202 months of observation data, covering May 2008 to December 2023 (20% of the entire dataset), constituted the testing dataset used for model validation and to prevent overfitting. The X-axis of the Figure 2 represents the data points, while the Y-axis denotes air temperature.



collected measurement data indicates that the one-step ahead time-series training algorithm is predominantly



The objective of this study is to analyze authentic surface temperature data from the Mediterranean Region and evaluate the accuracy of the resulting model in predicting future values. Figure 3 displays forecast data for the Mediterranean annual mean air temperature ($AMAT_{2\text{-}m}$) over a 180-month period from January 2024 to December 2038, generated by LSTM and GRU models. Overall, the findings indicate that these models demonstrate the capability to forecast future air temperature values within the time series data. According to the forecasts, it is expected that monthly air temperatures will steadily increase over the next 15 years. Projections from the LSTM and GRU models suggest that the observed annual mean surface air temperature, reaching a peak of 18.32 C^{o} in 2023, will rise to mean values of 20.32 C^{o} and 18.76 C^{o} by 2038, respectively.



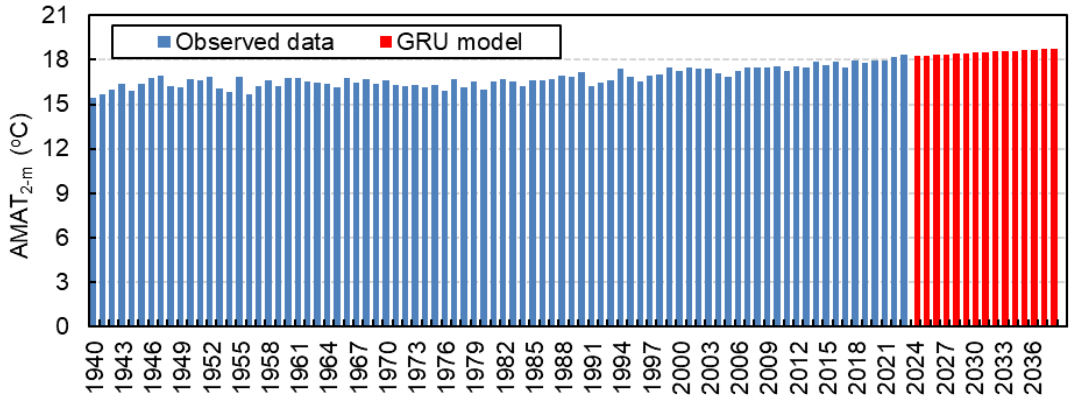


Fig. 3. Annual Mean Surface Air Temperature Observed Data and 2024-2038 Projection

Figure 4 illustrates the trend of the annual highest surface air temperatures ($MHAT_{2\text{-}m}$) in the Mediterranean Region's time series data spanning from 1940 to 2038. Projections indicate a rising trajectory in the yearly peak surface air temperature values for the Mediterranean Region until 2038. Specifically, forecasts derived from LSTM and GRU models indicate an increase from the highest recorded maximum value of 29.27 C° in June 2023 to 27.95 C° in June 2038.

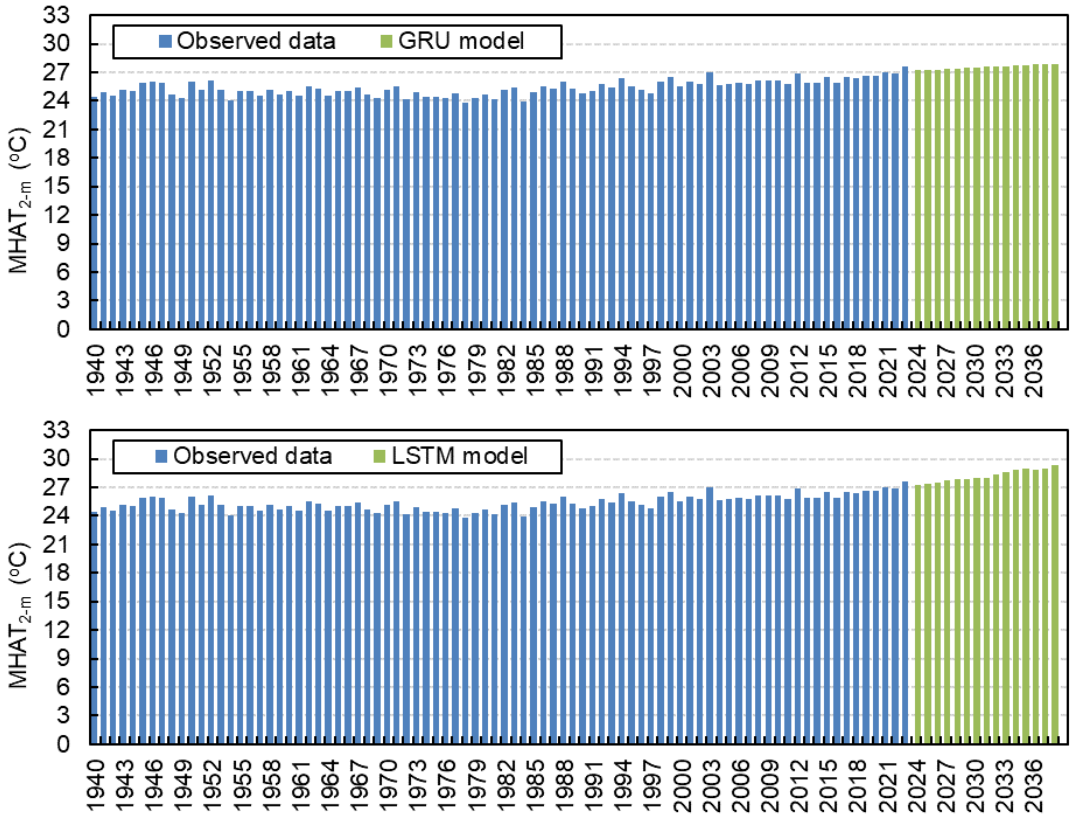


Fig. 4. Annual Highest Surface Air Temperature Observed Data and 2024-2038 Projection

4. CONCLUSION

This research employs advanced deep learning techniques to predict monthly air surface temperatures in the Mediterranean Region. Through a comprehensive analysis, the study offers valuable insights into the characteristics of the associated time series data. Its primary aim is to identify patterns, trends, and seasonal variations within the data to facilitate future value predictions based on historical and present observations. Various time series models tailored for temperature forecasting are developed and compared to assess their predictive capabilities.

The empirical results underscore the efficacy of the proposed LSTM and GRU deep learning models, which demonstrate satisfactory performance in forecasting air temperature. During testing, these models achieved an RMSE of 0.7185 C^o and an R^2 of 0.9864. Comparative analysis with models from previous studies indicates that the mean surface air temperature is anticipated to decrease within the range of 20.32 Co and 18.76 Co by the year 2038. These projections signal potential devastation to the Mediterranean Sea's ecosystem if preventive measures are not implemented.

Acknowledgements

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Impact of Ethylene Glycol on Photovoltaic performance of Cu_2ZnSnS_4 Thin Film Absorbers for Promising Solar Cells

Samed ÇETİNKAYA[a*]

[a] *Mersin University, Vocational School of Technical Science, Department of Medical Services and Techniques, University Street, Mersin, Türkiye, Email:samedcetinkaya@mersin.edu.tr)*

Abstract

In this study, the effect of Ethylene Glycol (EG) additive on the structural, morphological, optical, and electrical properties of CZTS thin films was investigated. It was observed that the morphology and characteristic properties of CZTS thin films improved with increasing EG additive concentration. Raman analysis revealed the formation of CZTS thin films with phase purity, excluding binary and/or ternary compounds. When the EG concentration of 0.5%, spherical structures with dimensions of 1-2 microns were observed on the film surface. Additionally, it was determined from the obtained results that these surface features positively contributed to the IPCE efficiency measurements. Accordingly, the highest IPCE efficiency was calculated as 8.36%. Finally, it was interpreted that the optical absorption measurement results estimated between 1.42 and 1.48 eV were in line with literature values.

Keywords: Ethyl cellulose, CZTS, Solar cell, Additives, IPCE efficiency

1. INTRODUCTION

Among the next-generation absorber materials, Cu_2ZnSnS_4 (CZTS) compound stands out as a promising alternative absorber layer in solar cell applications. Although, its theoretical efficiency being 32.2% [1], the highest laboratory efficiency achieved for CZTS compound to date remains at 12.6%[2]. This situation the necessity for further research on this material. The CZTS is a p-type quternary compound semiconductor with a kesterite crystal structure. Each component of the CZTS compound is abundant in the Earth's crust (Cu: 50 ppm, Zn: 75 ppm, Sn: 2.2 ppm, S: 350 ppm) and has lower toxicity [3], [4], [5]. CZTS compound has a direct bandgap of 1.4-1.6 eV and a high absorption coefficient of 104 cm-1. These properties make it a suitable candidate for absorber layers in solar cells. Additionally, this compound is cost-effective and environmentally friendly as it does not contain toxic or expensive elements such as Selenium (Se) or Cadmium (Cd) used in current commercial solar cells [6]. Research on CZTS thin films has increased in recent years. Studies have been conducted on CZTS thin films and solar cell applications using various methods such as physical vapor deposition (PVD)[7], [8], [9], [10], electrochemical deposition (ECD) [11], [12], sol-gel spin coating[13], [14]. In addition to these, studies using other solution-based methods are also available [15], [16]. The disadvantages of physical vapor deposition techniques, such as high cost, complex equipment requiring high temperatures, and difficulty in large-scale coatings, are well known [17]. Liquid phase deposition techniques are relatively cheaper and suitable for use with a wider variety of substrates with larger surface areas. Furthermore, films produced by these methods exhibit quality] comparable to those obtained by physical methods [18].

* Corresponding author.

Various methods have been attempted to increase the efficiency of existing commercial solar cells. Among the most effective methods is additive. Generally, additive is used in solution-growth methods to control the growth mechanism, particle size, crystal structure, conductivity, and surface morphology of films [19], [20]. The efficiency of thin film solar cells is directly related to the surface morphology, and additive with appropriate additives is often the best way to enhance this efficiency. Among the commonly used organic additive materials in the literature, Ethylene glycol (EG) has been reported to improve the surface morphology of thin film solar cells, induce significant changes in particle growth dynamics (size), and consequently increase cell efficiency [21]. To the best of our knowledge, there are no reports investigating the effect of the EG on CZTS thin-film based solar cells. In this study, for the first time in the literature, the effect of ethylene glycol on the quantum yield, morphology, optical, and structural properties of CZTS thin films containing inexpensive and environmentally friendly elements was investigated.

2. EXPERIMENTAL DETAILS

Copper zinc tin sulfide (CZTS) thin films were applied onto soda lime glass (SLG) substrates previously coated with molybdenum using the sol-gel spin coating technique. The substrates underwent a thorough cleaning process involving sequential ultrasonic treatments with detergent, nitric acid solution (at a ratio of 1:4), acetone, and ethanol, each lasting for 10 minutes, as detailed in our previous research [20].

A solution comprising copper (II) acetate monohydrate (0.3 M, 98+%), zinc (II) acetate dihydrate (0.3 M, 99.99%), tin (II) chloride (0.3 M, 98%), and thiourea (1.2 M, 99.0+% from Sigma Aldrich) dissolved in 2-methoxyethanol (20 ml, 99.8% from Sigma Aldrich) was prepared. To this solution, 2.5 ml of diethanolamine (DEA) was slowly added as a stabilizer under stirring conditions. The mixture was stirred at 45 ºC and 850 rpm for 1 hour to ensure complete dissolution of the metal compounds. Subsequently, the resulting solution was divided into six beakers, and ethyl cellulose dissolved in 2-methoxyethanol (from Sigma Aldrich) was added to each beaker at intervals of 0.1% ranging from 0.1% to 0.5% and also 0.75%.

The CZTS films were deposited onto substrates by spin-coating at 3000 rpm for 30 seconds, followed by drying at 175°C for 10 minutes on a hot plate to obtain the desired film thickness. This process was repeated 10 times. The deposited films were then annealed at 500°C for 2 hours in a quartz tube under 1 atm pressure. The structural and morphological properties of the samples were examined using Raman spectroscopy (Confocal Raman spectrometer, Witec alpha 300 with a 532 nm light source) and scanning electron microscopy (FEI, Quanta FEG 250).

Incident Photon-to-Current Efficiency (IPCE) measurements were conducted in order to investigate the photovoltaic properties of pure and the EG doped CZTS films. IPCE measurements were conducted using a monochromatic light source consisting of a 150 W-Xe lamp and a monochromator interfaced with a computer controlled by the homemade LabVIEW program.

3. RESULTS AND DISCUSSIONS

3.1. Structural results

The Raman spectroscopy serves as a highly effective tool for discerning subtle changes due to its sensitivity to vibrational signals, which are influenced by factors such as the crystal structure, and chemical bonds. ZnS, $Cu_{2x}S$, and Cu_2SnS_3 exhibit X-ray diffraction patterns refer to CZTS due to their similar zinc blend-type structures (Fig. 1).

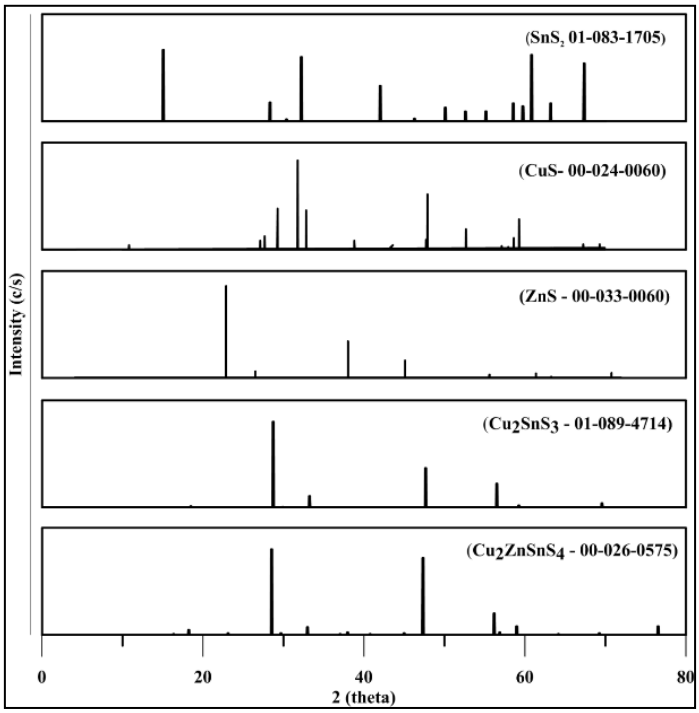


Fig. 1. The Raman analysis of binary or ternary (ZnS, Cu2xS, Cu2SnS3) and Cu2SnZnS4 compounds.

In order to determination phase purity, identify potential secondary or ternary phases, Raman spectroscopy analysis was conducted on EG-doped CZTS thin films within the 200–600 cm-1 range (Fig. 2.). From the Fig. 2., It is observed that with an increase in the amount of additive, the characteristic peaks (at 333 cm^{-1}) begin to sharpen, indicating enhanced crystallinity. Also, a peak was observed at 420 cm^{-1}, the labelled in the EG-0.50%. This peak arises from MoS_2 compound formed due to the highly sulfur pressure during the sulfurization process of the molybdenum-coated glass substrates used as the underlayer for both doped and undoped CZTS thin films.

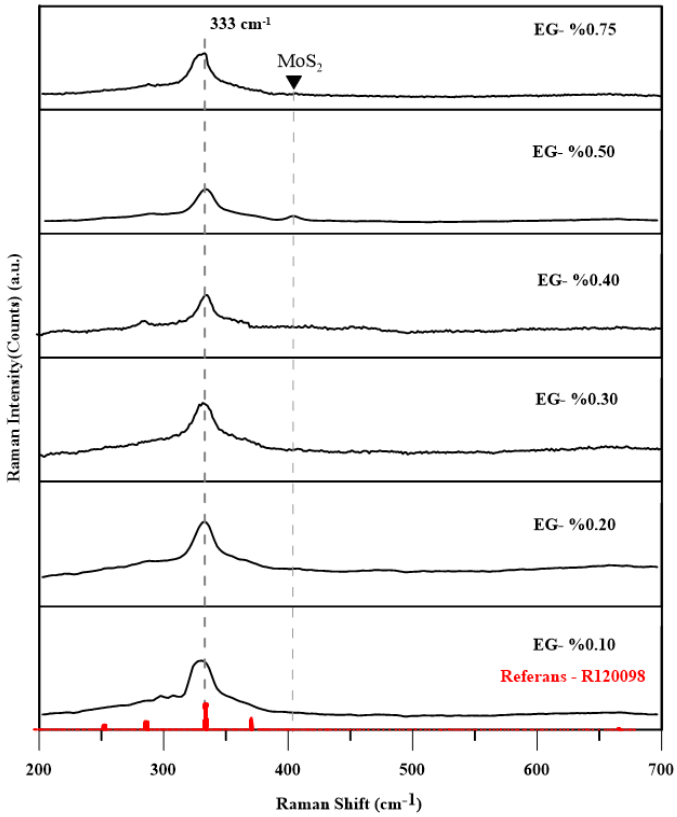


Fig. 2. Raman analysis graphs of CZTS thin films for EG additive

The thicknesses of CZTS films produced in the literature generally range from 1.5 to 2.5 μm. In this study, the thickness of the produced the EG doped and undoped of CZTS films was measured to be an average of 1.0 ± 0.1 μm. Thus, this causes for sulfur penetration underneath the molybdenum layer have been resulted by the formation of MoS2 for the EG-%0.50. In the sample labeled with the EG-0.75, it is observed that the Raman Peak shifts to the higher wavenumber. This shift can be interpreted as an indication of improved crystallization and an increase in particle size, which is clearly evident in the FESEM micrographs.

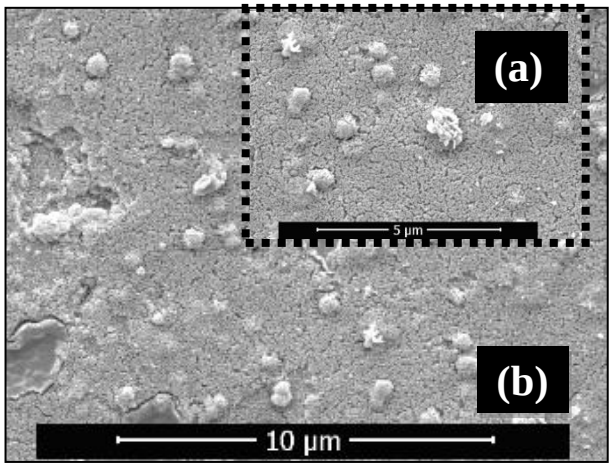
EG is reported by researchers to be commonly used as a surfactant in the sol-gel storage method to regulate hydrolysis reactions in absorber layers of solar cells [22]. In the sample labeled as EG-0.40%, an additional CZTS peak is observed compared to other samples. This can be interpreted as the effect of the ethylene glycol ratio on the sol-gel reactions. According to the Raman analysis results obtained, it is observed that there are no secondary phases in the produced doped CZTS thin films. As show in Fig. 2, a vibrational peak at 333 cm^{-1} is evident in the samples. This observation suggests the presence of the kesterite crystalline phase in the CZTS, possibly accompanied by other binary and/or ternary secondary phases. The peaks closely match the reference Raman spectra of the CZTS, thus providing confirmation of the CZTS phase formation [20].

3.2. Surface morphology

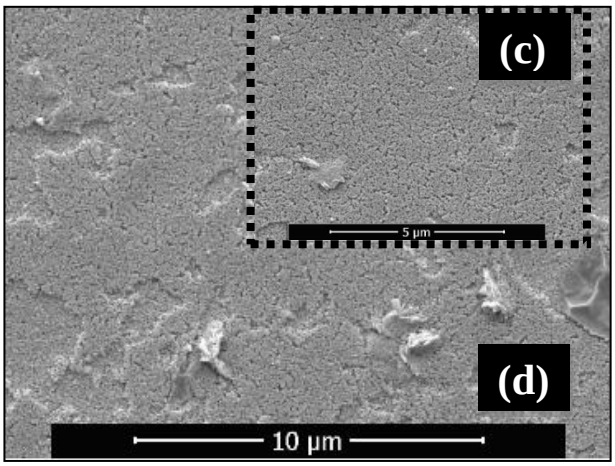
FESEM micrographs of ETS-doped CZTS films deposited by using different concentrations of ethylene glycol (EG) given in Figure 3. The FESEM micrographs demonstrate a surface morphology consisting of crack-free CZTS aggregates with dimensions of approximately 1 μm, which form with the increase in the concentration of the EG additive. It is observed that an increase in the amount of the EG in the solution leads to an increase in particle size.

Also, this change may affect the IPCE efficiency. Generally, a crack-free and dense film can positively affect the electrical conductivity, whereas discontinuities and irregular morphologies act as barriers to electron transmission since electrons are transmitted from the surfaces of the films [23]. These changes in the morphology of the films can be attributed to their effect on the reaction kinetics of the EG. The EG is an organic liquid containing carbon, hydrogen, and oxygen. Because of high viscosity and boiling point of EG, its facilitates the controlled formation of the reaction

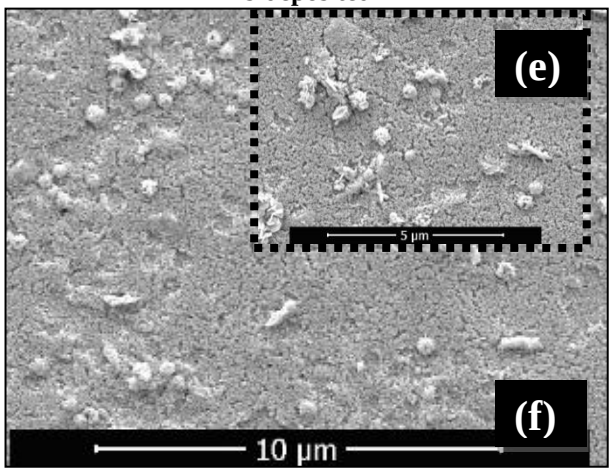
by assisting in the hydrolysis of the alcohols used in the sol preparation stage. In the literature, the EG has been reported by researchers to be used in sol-gel experiments for cases where the sol needs to be stable, viscosity needs to be high, and thin film formation needs to be controlled [24], [25], [26].



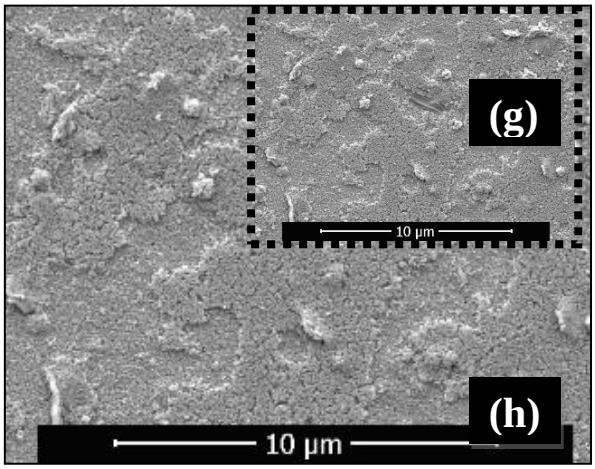
(a) X20.000, (b) X10.000 Mag.
As-deposited



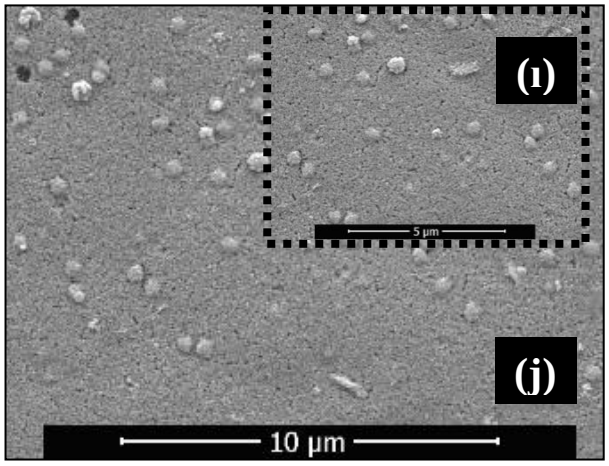
(c) X20.000, (b) X10.000 Mag.
EG - % 0.10



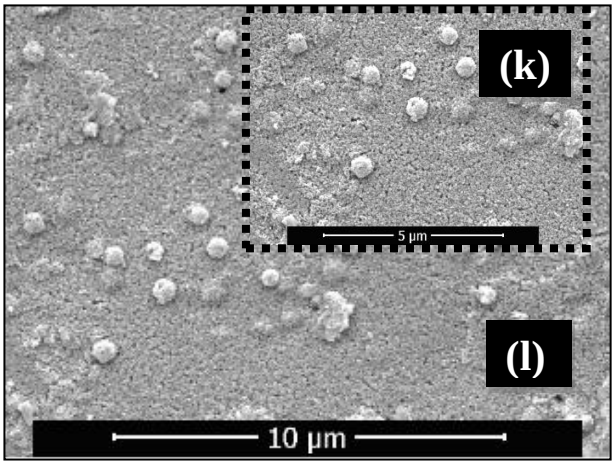
(e) X20.000, (f) X10.000 Mag.
EG - % 0.20



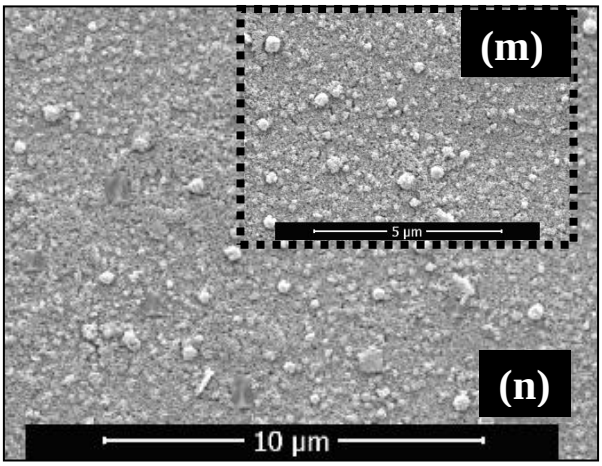
(g) X20.000, (h) X10.000 Mag.
EG - % 0.30



(ı) X20.000, (j) X10.000 Mag.
EG - % 0.40



(k) X20.000, (l) X10.000 Mag.
EG - % 0.50



(m) X20.000, (n) X10.000 Mag.
EG - % 0.75

Fig. 3. (a-b) SEM microimages of undoped and (c-n) EG-doped CZTS thin films at various magnifications.

3.3. Incident photon-to-current efficiency (IPCE) characteristics

External Quantum Efficiency (EQE)-also referred to as Incident Photon to Charge Carrier Efficiency (IPCE)-is defined as the efficiency of converting incoming photons on a photoactive material into electron-hole pairs. The IPCE curve provides information about recombination losses and absorption efficiency within the material[6].

Table 1. IPCE yield results versus the EG doping concentration (%).

Doping concentration (%)	0.10	0.20	0.30	0.40	0.50	0.75
IPCE (%)	1,04	5,43	5,10	7,44	8,36	3,63

IPCE curves of the EG-doped CZTS thin films are given in Fig. 4. When we compare EG-doped films with undoped CZTS film, we can see that the efficiency increases (Table 1.). According to SEM micrographs of films doped with EG, it is observed that CZTS particles are approximately 1 µm in size with a doping concentration of the EG - 0.50% and they are formed in spherical shapes covering the surface. According to the IPCE graph, it can be interpreted that the surface properties, particle sizes, and band gap of the EG-0.50% sample influence the highest efficiency obtained [27]. Additionally, it is well-documented that EG is utilized to control particle sizes and surface properties in dye-sensitized solar cell structures [26], [28].

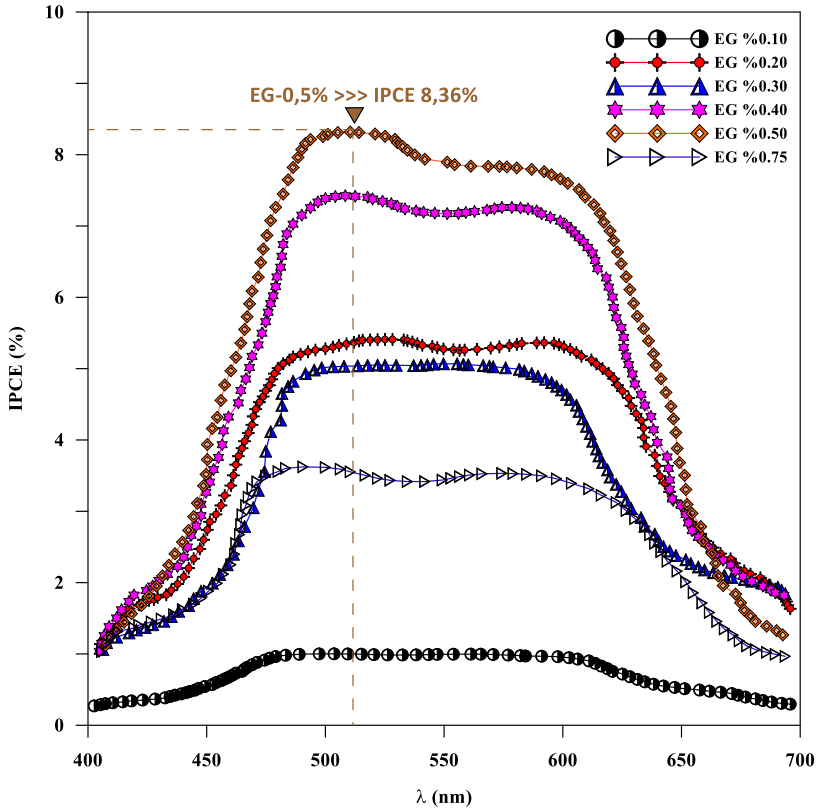


Fig. 4. IPCE curves of EG-doped CZTS thin films.

The highest IPCE value of 8.36% was obtained from the EG-0.50 sample. The wavelength corresponding to the highest efficiency value on the IPCE graph is approximately 532 nm. This wavelength represents the energy of the highest intensity light. According to the IPCE curves, it can be concluded that the EG-doped CZTS thin films can efficiently convert monochromatic light in the range of 480 - 640 nm into photocurrent. As results of the SEM and the IPCE analysis, it has been noted that the EG has a positive impact on the CZTS thin films, an area that has not yet been extensively studied.

3.4. Absorption behavior

The band gap values of EG doped and undoped CZTS films are given in Table 1. The CZTS compound has a direct band gap ranging from 1.4 eV to 1.6 eV, also exhibits p-type semiconductor behavior [29], [30]. According to the estimated E_{gap} values given in Table-1, the EG-doped CZTS has suitable band gap values for a solar cell application.

Table 2. The EG doping concentration versus Eg (eV) values of EG-doped CZTS films

Doping concentration (%)	Estimated Energy Band Gap
0.10	1.47 eV
0.20	1.46 eV
0.30	1.46 eV
0.40	1.48 eV
0.50	1.45 eV
0.75	1.42 eV

As seen in the Table 2, there is no proportionality between the increase in the doping concentration and the energy band gaps. The band gap of a material is influenced by its crystal structure, grain size, and chemical composition. It is observed that the band gap value of EG-doped CZTS thin films is dependent on their surface properties. It can be

interpreted that as the grain size begins to increase the band gap value decreases. As mentioned in previous sections, with additives can affect the structural and morphological properties of the material.

Consequently, it has been observed that the optical band gap value can be easily controlled via additives which are a cheap and simple technique.

4. CONCLUSIONS

Dense and crack-free the EG-doped CZTS thin films were deposited on molybdenum-coated SLG substrates by using sol-gel spin-coating method. The effect of EG-doping on the structural, morphological and optical properties of the films has been investigated in detail. Firstly, as a result of Raman analyses, it was observed that there were no binary and/or secondary phases. Thus, the formation of the films, phase purity and crystal quality were controlled and confirmed. Increasing the concentration of the EG can reduce the cracks and surface roughness of the films, as interpreted from FESEM images. The IPCE results of the films were changed from 1.04% to 8.36%. The highest IPCE efficiency was obtained at the EG-0,50%. Finally, according to the optical results, the E_{gap} values were estimated to be between 1.42 and 1.48 eV depending on the EG concentrations. According to the results, it can be interpreted that EG is a suitable an additive for achieving uniform and continuous of surface morphology and high-efficiency CZTS thin-film solar cells.

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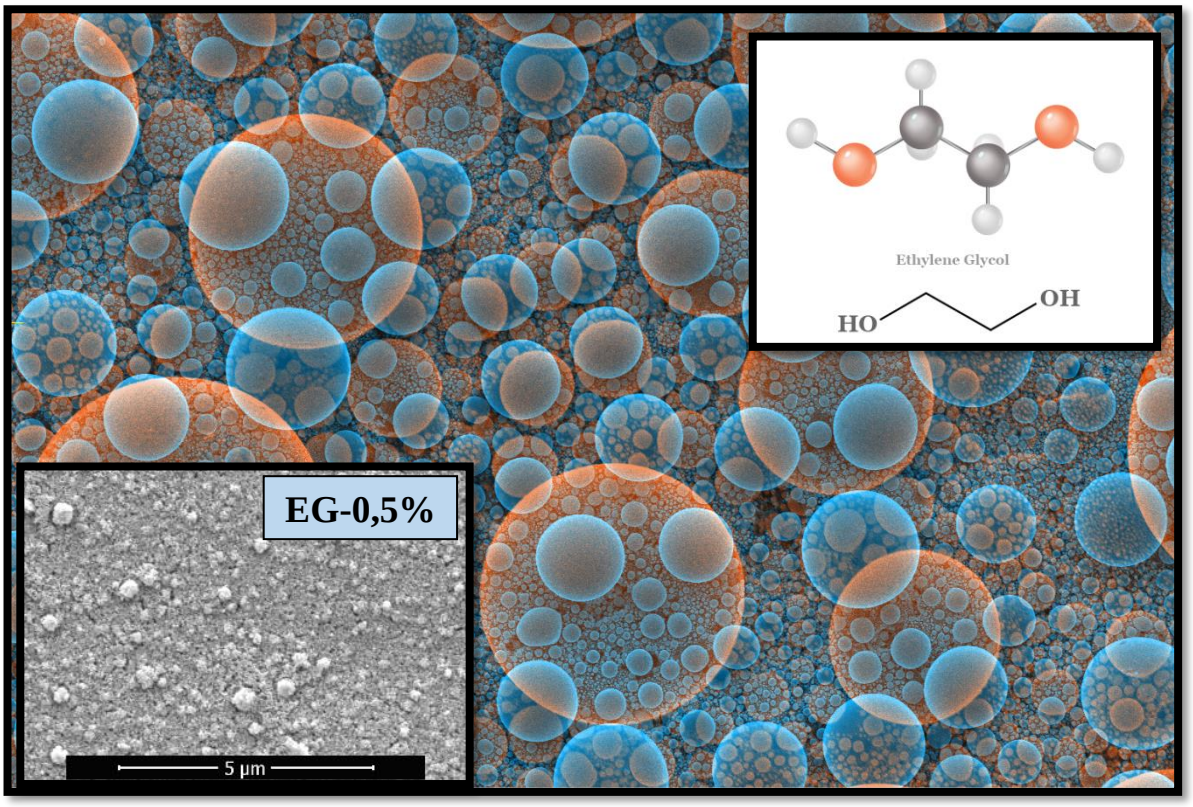
Appendix 1

GRAPHICAL ABSTRACT



Intelligent Classification of Object Locations in Buildings

Łukasz JABŁOŃSKI[a], Paweł GBURZYŃSKI [b], Janusz ZALEWSKI [c*]

[a] *State Academy of Applied Sciences, Department of Informatics, 06-400 Ciechanów, Poland*
[b] *Vistula University, Faculty of Computer Engineering, 02-787 Warsaw, Poland, p.gburzynski@vistula.edu.pl*
[c] *State Academy of Applied Sciences, Department of Informatics, 06-400 Ciechanów, Poland, janusz.zalewski@pansim.edu.pl*

Abstract

This work focuses on the development and implementation of an intelligent classification system for the location of objects inside buildings. The paper presents engineering basics and the process leading to the creation of the final finished product. In the first stage, an analysis of the existing devices and machine learning algorithms for classification are outlined. It is presented step by step, including the process of implementing the interface and the functional part of the application. Then the focus is on preparing a classification algorithm that will allow for determining the location of an object. In order to try to increase the accuracy of the classifications there were machine learning techniques used. A number of tests and experiments were carried out to assess the effectiveness of the created software. Results show that the proposed solution allows determining the location of objects with sufficient accuracy.

Keywords: intelligent classification, smart buildings, machine learning

1. INTRODUCTION

Classification of the location of objects in buildings refers to the process of identification and assigning categories to various objects or elements inside a building based on their specific location in space. This is an important issue in the field of technology location, intelligent building systems, as well as in areas such as indoor navigation and resource management systems. In the context of intelligent buildings, classification of the location of objects allows monitoring the position of various devices and infrastructure elements, such as sensors and HVAC devices (Heating, Ventilation, and Air Conditioning), or even people. This allows better management of energy usage, lighting or air conditioning depending on the presence of people and the needs of the specific building zones. Position classification is also used in system security and access control. Identifying the location of objects can help monitoring and controlling access to various areas in the building, which is especially important in places where strict security control is required, such as offices or laboratories.

1.1. Review of technologies and techniques applied in locating objects

Various localization technologies are used for locating objects, usually based on vision systems or wireless technologies. The most popular of them are well described in [1]:

- RFID technology uses radio signals to communicate between RFID readers and tags placed on objects. Readers receive signals from tags, identifying objects based on unique identifiers.

* Corresponding author.

- BLE is a low-voltage wireless communication technology that allows for tracking objects using devices equipped with BLE modules, such as smartphones or transmitters.

- UWB technology using short radio pulses to measure distance between devices, which allows precisely determine the location of objects.

- WiFi systems used to locate objects based on WiFi signals from portable devices (such as smartphones or laptops) that are received by WiFi multiplexers.

Multiple other technologies are used as well. For example, Bluetooth Beacons are small devices that emit Bluetooth signals that are received by applications on smartphones or other devices, enabling locating users in buildings. Motion sensors, such as accelerometers, gyroscopes and magnetometers, can be used to track the movements of objects in space. Ultrasonics, which involves the use of ultrasonic waves to measure distances between objects and ultrasonic sensors, can be used in systems indoor locations. Video cameras and computer vision devices for image analysis and identification of objects in space can be used in video surveillance systems. Positioning based on visible light uses diodes emitting light visible to the human eye, flashing in a specific pattern. Location detection is done using cameras in smartphones.

Object position classification techniques can be divided into direction-based techniques, and distance based [2]. Direction-based location estimation techniques, also known as angular techniques, use information about the direction in which an object receives or emits radio signals, to determine its position in space. These techniques include, among others:

- ADOA (Angle Difference of Arrival): ADOA involves measuring angular differences between the direction where signals from an object come from and the direction they come from received by different receiver antennas. This technique is particularly useful in systems with high precision antennas.

- DOA (Direction of Arrival): DOA is the determination of the direction from which the radio transmitter signals are coming. DOA is applied in advanced multiplexing antenna systems.

- AOA (Angle of Arrival): AOA involves measuring the angle at which a radio signal reaches the receiver. This technique is particularly useful in location systems indoors, where the signal may be reflected from various surfaces, and the angle measurement allows precisely determine the location of an object.

Each of these techniques has its advantages and limitations. Choosing the right technique depends on specific application requirements such as location accuracy, implementation costs and immunity to interference. In many cases, especially in advanced systems location, various techniques are used simultaneously to obtain the most precise results.

1.2. Algorithms used to estimate the location of objects

Location estimation is the process of determining the position of an object in space based on available data. There are many algorithms used in different environments and contexts. The most frequently used methods of locating objects include: k nearest neighbors, support vector machine, tree-based classification methods and neural networks.

The k nearest neighbors (kNN) algorithm is a regression algorithm used to predict values and classify how individual data will be grouped. In the context of object position classification it can be used to classify data based on similar data training in a specific location. The advantage of kNN is the ability to adapt to change conditions, simplicity of implementation and the ability to handle non-linear data sets. The disadvantage of this solution when high accuracy is required is the need to enter a large amount of data, and the efficiency of this algorithm depending on the distance measure and the selected k value.

Support Vector Machine (SVM) involves classification based on the determined n-dimensional hyperplane of features, which clearly classifies a given class of data. SVM works effectively in high-volume space dimensions. In the case of object location classification, where objects can be described by multiple features or parameters (e.g. geographical coordinates, altitude, temperature), SVM can deal well with this kind of data. The upside of this solution is that SVM tends to minimize the risk of overfitting (overfitting to training data), which is especially important in the case of limited number of samples that are often available in position classification tasks.

Methods based on classification trees (decision tree learning) consist in using diagrams created on the basis of division into classes of observations of similar features. A decision tree consists of a root and nodes. It is in every node that condition is checked and, based on it, a decision is made to select the next one node in the tree. The

advantages of decision trees include their readability and simplicity, as well as the ability to deal with missing data. Compared to other techniques of machine learning, they require less computation. The disadvantage of decision trees, however, is that it is susceptible to overfitting and instability, especially when working with imprecise data.

Neural networks are a subset of machine learning and a group of algorithms that function to find hidden connections in datasets by imitating the way human brain acts. The network consists of many highly connected data processing elements called neurons, which work together in parallel to find a specific pattern. Neural networks are able to "learn" from examples based on large amounts of data training sessions. To avoid incorrect results and abnormal network behavior neural network training data must be carefully selected.

1.3. Work objective

The aim of this work is to organize a network of wireless modules whose task is to collect signals from the transmitters and determine the received signal strength indicator. Transmitter attached to the tracked object is to send a small packet identifying it every certain time, as well as the metadata along with the strength of the received signal. These data are then transferred to the main device connected to one of these modules that determines location of the object that sent the signal.

A machine learning algorithm can be used to estimate the location trained on a data set containing RSSI (Received Signal Strength Indicator) along with their corresponding actual locations. After appropriately retrained, the model can predict the location of new object, based on the received signal power measurements.

It is necessary to present the location estimation results to the user with a graphical interface that allows to map the building and display the tracked positions of objects and wireless modules in the network. The interface shall be easy to use for operation and functions. In addition to visualizing the positions of objects, the user should be able to configure devices on the network for possible parameter adjustments. In particular, the running system should solve the following problems:

- Take into account obstacles such as walls, furniture and other electronic devices that may interfere with RSSI signals.
- Take into account different RSSI measurement values depending on the distance from the transmitter, because these changes are not always linear or constant, which can make it difficult to be precise in distance estimation.
- Use a machine learning algorithm that is resistant to learning noise and fluctuations in training data as real patterns, as this situation may lead to overfitting and low ability to generalize to new data. Overfitting in machine learning occurs when a model fits too closely to training data, resulting in insufficient generalization of new, unknown data. This means that the model is too complex for the quantity available data and starts "learning" specific training cases instead of general patterns.

The rest of the paper is organized as follows. First, we present the hardware and software platform set up for this research. This is followed by a description of the configuration of the platform for experiments. Next, the classification process is outlined, including the classifier training, and finally, experiments are presented and conclusions are drawn.

2. HARDWARE AND SOFTWARE PLATFORM

2.1. Configuration of hardware modules

The device proposed for use in the project is a communication module Olso7 radio station created by Olsonet Communications (Nepean, Ontario, Canada). A block diagram in Fig. 1 presents interfaces through which communication with other modules is possible.

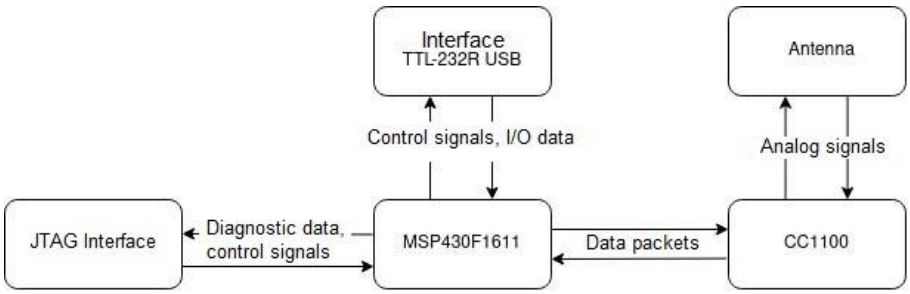


Fig. 1. Configuration of a data acquisition and processing unit

The equipment consists of the following components:

- MSP430F1611 microcontroller from the MSP430 family from Texas Instruments. It is A 16-bit, low-power RISC microcontroller that is commonly used in applications such as embedded systems, sensors, controllers etc.
- CC1100 radio communication module from Texas Instruments. This is an arrangement enabling wireless communication on various frequencies.
- JTAG interface allowing programming and running programs on a microcontroller.
- TTL-232R USB interface enabling communication between the device and UART interface and the computer.

The CC1100 module in the equipment is a module used for wireless communication on frequencies below 1 GHz. It supports 315, 433, 868 and 915 MHz, which can be defined by the circuit connecting the module to the antenna.

2.2. Operating software

The hardware uses the PicOS operating system [3]. This is a system designed for devices with low memory and limited resources. In PicOS, instead of handling interrupts or callbacks the finite state machine model is used along with a global stack shared between threads. This allows for the reduction of memory used while simplifying the problem of synchronization and concurrency. The entry point of each program is *fsm_root()*, which is the equivalent of a standard *main()* function. Each program starts its work with the above-mentioned function after each startup or reset.

The structure of each *fsm()* is similar to the switch structure known from other programming languages and control flow in this structure is almost identical. The difference is that instead of the normal condition in each statement, the state checked is the present program status. If the set of instructions for a given state completes its operation and does not proceed, a switch will be called (which causes a transition to another state) or release (freeing processor resources) until the above-mentioned procedures are called or reached the last line of code in a given *fsm()*. The program thread will go into the state of waiting for the next event happening.

TARP (Tiny Ad-hoc Routing Protocol) is a communication protocol used in PicOS as part of wireless communication between devices. Its special feature is minimalism and the lack of layers typical of other protocols, so it can be successfully used in devices with limited resources and requiring real-time response. Each packet is sent in broadcast mode. Whether the device that receives a given packet consumes it, forwards or simply rejects is dependent on rules that can be customized. The packets are chained together and verified one by one. Negative verification results in packet retransmission. In addition to deciding whether to push a packet to an application, policies can modify the contents of packets before passing them back to the network [3]. An example of a policy used in TARP is the maximum hop count between devices in the network, affecting behavior when duplicate packets appear, and configuration of the packet route optimization.

3. DESCRIPTION OF A SOLUTION

3.1. System structure

As part of this work, a system for classifying the location of objects was created (Fig. 2) consisting of transmitters, an input gate, a network of intermediaries based on the Olso7 wireless devices and a central device.

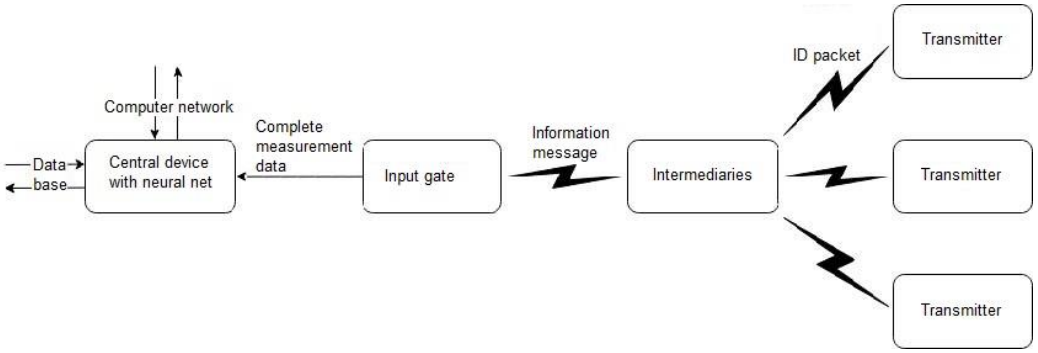


Fig. 2. Simplified block diagram of the system

The transmitter's task is to periodically send packets to nearby devices in the network of intermediaries. The packet contains a unique device ID and is processed by every device that receives it. In addition to the ID, key information is also the strength of the received signal. In PicOS it is normalized and adopted to values from 0 to 255 in the form of a data byte.

A device located in the intermediary network intercepts every nearby packet transmitted, processes the received packet while reading the strength of the reflected signal. The received information is accompanied by data about the receiver, i.e. its identifier, and then the packet is forwarded to the input gate. The task of the input gate is to receive packets from the entire network of receivers and transmitting them to the central device via the UART interface.

Software installed on the central device, shown in Figure 3 performs several functions as follows:

- Captures and processes packets by completing missing location data received by the input gate with packets containing a signal strength of 0.
- Communicates with the classifier server (2) sending forwarded packets through the input gate. In response, the classifier server returns a unique ID assigned to the zone specifying the location of the entity sending packets.
- Stores estimated transmitter positions in the PostgreSql database (1) for archival purposes.
- The graphical interface server downloads via the .NET server (3) locations of objects saved in the database (1), which allows the user preview of the location of the above-mentioned objects in real time.

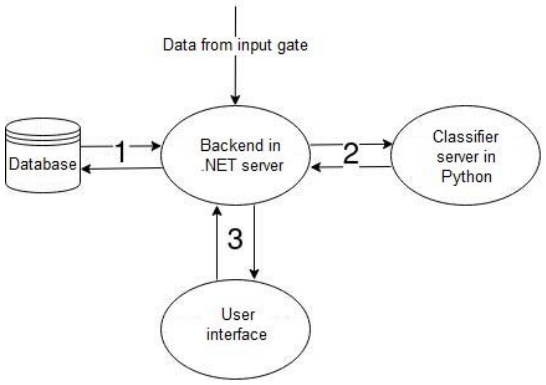


Fig. 3. Organization of software in the data processing unit

3.2. User interface

The user interface is a crucial element of this system because the end user will come into contact with it. To lower the complexity level as much as possible the interface cannot be too elaborate and should allow easy access to the most needed features while allowing more advanced users to perform more detailed activities. The requirements on user interface in this project include those concerning the tracking map, control panel, notification view, filtering and grouping of objects on the map, ease of configuration of individual devices and simple map navigation.

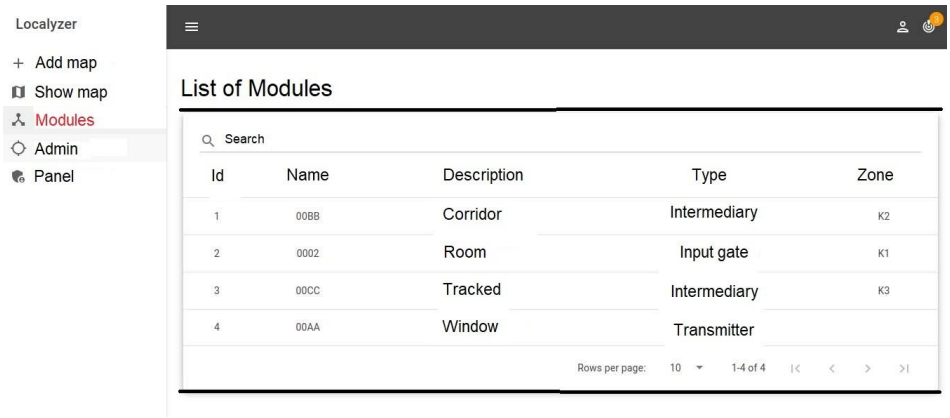


Fig. 4. Map view in the process of creating a building map divided into zones

To make it easier to navigate through the application, the user has the opportunity to choose main views from each level using the navigation bar on the left of the interface page (Fig. 4). The main functionalities include map view and display groups, events and modules. The user can hide the navigation panel at any time using a special button. To be able to display the location of objects, the user must add the appropriate facility map. The application uses for this purpose appropriately prepared SVG (Scalable Vector Graphics) files, created for example in Inkscape tool, based on which the application makes appropriate zones and displays the location (Fig. 5).

Required file elements map is to create zones and mark them with an Id containing the name of the zone and the Label with the zone number. Then, the application finds appropriate zones on the map and allows the user to interact with them. To create a new map, the MapCreator view is prepared, in which the user is able to upload a file with the map and assign appropriate modules to it. Due to the complicated handling of the SVG file, the view has been divided into two stages: file upload and parameter editing. To be able to move to the next stage it is necessary sending the appropriate graphic file.

Once it is uploaded, the application reads the file in text format and creates appropriate components that reproduce the elements of the SVG file, and then the user is presented with the map and view of shown in Fig. 5 list of modules. Zone names are taken based on the parameters specified in the elements and they clearly define a unique zone. One can interact with the map with the mouse and can also adjust the actual map view.

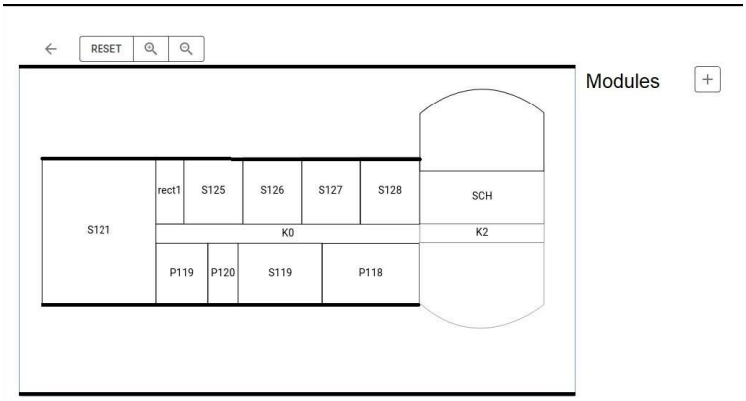


Fig. 5. A view of the modules list

4. CLASSIFICATION PROCESS

After the analysis of the advantages and limitations of the algorithms presented briefly in Sec. 1.2, a selection was made to use kNN as the preferred solution. This choice was dictated by taking into account several key factors that influence effectiveness and adaptation of the algorithm to specific needs. First of all, kNN is relatively simple to implement, which facilitates quick modifications as the project develops. This is important, especially in case of dynamic environments where model updates may be necessary for successful adaptation to changing conditions. This is also important, when dealing with sensitive data frequent changes or an evolving training data set. The flexibility of kNN translates into the ability of the algorithm to effectively adapt to data evolution. It should also be emphasized that kNN achieves satisfactory data accuracy outputs, which is a key aspect in the context of effective location of objects. At the same time, kNN achieves this task with a relatively small volume training data. This is important when data availability constraints are an issue.

4.1. Algorithm implementation

The module responsible for the algorithm due to the availability of the libraries used for data processing and machine learning was implemented in Python v3.8 using `numpy`, `scikit-learn`, and `tensorflow` libraries. Data transferred to the algorithm by the server backend in the query (see Fig. 3) are stored as a two-dimensional array in the `JSON` format. In case of data transfer error or incorrect format, an error message is returned. Otherwise readout of a two-dimensional array of data is passed to the loaded learning model machine for the purpose of predicting the location of a given module. Results in the form of one-dimensional array are returned to the backend.

```
async def predictws(ws, path):

    while True:
        try:
            msg  = await ws.recv()
            input_data = json.loads(msg)["Data"]
            if not input_data:
                print(json.dumps({'error': 'Input data is missing'}))
            if knn_classifier is None:
                print(json.dumps({'error': 'Model not loaded. Please train the model first.'}))
            predicted_class = knn_classifier.predict(input_data)
            result =  json.dumps({'PredictedClass': predicted_class.tolist()})
            await ws.send(result)
        except websockets.exceptions.ConnectionClosedOK:
            print("Connection closed")
            break
        except websockets.exceptions.ConnectionClosedError as e:
            print("Connection closed error", e)
            break
        except:
            print("Websocket error")
```

Fig. 6. A method providing the end node of the localization algorithm

This module provides an end node (Fig. 6) created using the `websockets` library which ensures more efficient real-time communication between services. The purpose of this method is to retrieve data from the query, load the model, and invoke method that determines the location based on the received data and returning the result to sender. In addition to estimating the location using an algorithm, this method also checks the correctness of the submitted data and whether the machine learning model exists and it was taught.

For the purposes of training the model, a separate procedure was created, whose tasks are: loading the prepared data, separating it into training and test data, training the model and finally saving it to disk (Fig. 7). This procedure is done with using the following functions: *load_data()*, *split_data()*, *train_knn_classifier()*, *evaluate_knn_classifier()*.

```
def load_data(file_path):
    data = np.loadtxt(file_path, delimiter=',')
    X, y = data[:, :-1], data[:, -1]
    return X, y

def split_data(X, y, test_size=0.2, random_state=42):
    X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=test_size, random_state=random_state)
    return X_train, X_test, y_train, y_test

def train_knn_classifier(X_train, y_train, n_neighbors=7):
    knn_classifier = KNeighborsClassifier(n_neighbors=n_neighbors, p=1, metric='manhattan')
    knn_classifier.fit(X_train, y_train)
    return knn_classifier

def evaluate_knn_classifier(knn_classifier, X_test, y_test):
    y_pred = knn_classifier.predict(X_test)
    accuracy = accuracy_score(y_test, y_pred)
    print(f'Accuracy: {accuracy:.2f}')

def load_and_train_knn():
    X, y = load_data(data_file_path)
    X_train, X_test, y_train, y_test = split_data(X, y)
    knn_classifier = train_knn_classifier(X_train, y_train)
    evaluate_knn_classifier(knn_classifier, X_test, y_test)
    return knn_classifier
```

Fig. 7. A method for training a machine learning model

In the first step, the *load_data()* function is responsible for loading the prepared data that constitute a set of information for the model training process. These data are then subjected to the process of splitting into training and test data by the *split_data()* function. This step is important to ensure that the model will be able to generalize effectively to new, never-before-seen data. Then, using the function *train_knn_classifier()*, the procedure starts the actual process of training the model.

Training and testing data are contained in one file in CSV format and it is assumed that data labels are included in the last column. It was also assumed that the data ratio 1,367 / 5,000 training to test ratio is 5:1, which translates into the most optimal accuracy of the trained model. The class of the trained model is `KNeighborsClassifier`, which comes with the `scikit-learn` library. This library allows detailed parameterization of the model with the following parameters:

- n_neighbors - k parameter specifying the number of neighbors
- weights - weight function used in predicting the result, defaults to the uniform value meaning that all points in each neighborhood have the same value weight
- algorithm - the algorithm used to calculate the result, by default the library itself decides which one is suitable
- p - power parameter for the Minkowski metric; when p = 1, this is equivalent to using Manhattan and Euclidean metrics for p = 2; for any other p, the metric used is Minkowski
- metric - metric used to calculate the distance between neighbors.

Finally, the *evaluate_knn_classifier()* function evaluates the performance of the model on the test set, providing significant feedback on its performance. As a result, after effective training and evaluation, the model is saved to disk, which ensures its subsequent availability and reuse in different contexts.

4.2. Data collection and training

To use the implemented classifier algorithm, it is necessary to collect data training sessions to train the model. In order to facilitate this step it was implemented in a program that gathers data from the network of modules and saves them to a file then processing them into the appropriate form. Training data were collected relying on defining the zone in the program and then taking measurements within a given zone. Once enough data have been collected in a zone, the user moves to the next zone and repeats the process.

Technically, the program opens the serial port immediately after starting program configuration, and then listens for data coming from a given port while saving them to a file. To enable user interaction and changing the zone in which the measurement is made, the program asynchronously waits for user commands passed through the console interface. The only property that the user can change is the Label that represents the name of the zone. After moving to a new name, the program passes it to the control object, which responds in real time by changing the value saved in the CSV file.

The test facility was a one-story building with 6 zones shown in Fig. 8, where each zone reflects one room. Once the locations of the intermediary modules and the input gate were determined, they have assembled training data to be used to train the classifier.

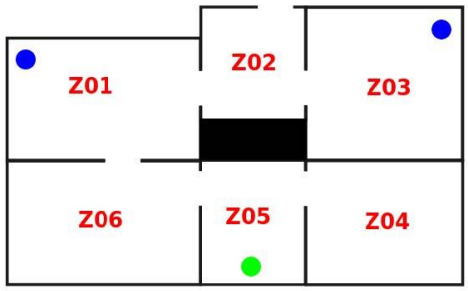


Fig. 8. Configuration of the tested object

Data collection was divided into two stages: collecting packets sent by the modules and processing them into an appropriate form that will be used to train the algorithm. A standard transmitter module was used to send packets, with which the person performing the measurements was constantly moving around the entire area of the zone. This way, for every zone approximately 70-100 measurements were made depending on its size. The result of what has been accomplished in measurements are data partially presented in Fig. 9.

Label	001	002	003
Z01	205	107	123
Z01	169	104	146
Z01	158	82	134
Z01	171	145	121
Z01	191	131	116
Z01	155		91
Z01	198	85	89
Z01	165	113	143
Z01	206	138	148
Z01	191	131	
Z01	190	89	142
Z01	201	88	116
Z01	185	108	111
Z01	200	107	148
Z01	158		113

Fig. 9. Sample of collected training data

As one can see, it was not always possible to collect a packet from all three modules, so missing measurements appear among the collected data. Moreover, during the data collection process, there was a problem of packets duplicating and getting lost. Due to this, the decision was made to remove duplicate packets and complete the missing packets based on the list of modules stored in the database along with assigned an RSSI value of 0. Missing data are due to factors such as interference from other wireless devices, walls that have scattered the signal, etc. To avoid such situations one can increase the number of intermediary modules or try to place them in other places, where the environment generates less interference.

5. OPERATIONAL TESTING AND EXPERIMENTS

The above-described system forms a network of devices whose task is to collect data enabling estimation of the location of a given object. Fig. 10 shows the sequence of the received data, all parameters necessary for determination were specified the location of the transmitter relative to the intermediaries that received the packet. During testing, the location of the transmitter is constantly changing, which can be seen in the following based on the RSSI parameter at the end of each line. At the moment of approaching the intermediary marked with the identifier 00CC, the indicator reading value the signal strength received by the above-mentioned module increased and at the same time the reading value of this parameter in the case of an intermediary with identifier 00DD changed. Additionally, one may notice that not all packets sent by device intermediaries have reached the input gate. A possible explanation for this situation is the fact that packets could arrive at the input gate and at the same time one of them may have been missed.

```
PicOS v5.4/PG220304A-WARSAW, (C) Olsonet Communications, 2002-2021
Leftover RAM: 9632 bytes
CC1100E: 1, 904.0MHz, 0/200kHz=904.0MHz
RECEIVED  (16): tagSeq:251 node:00CC tag:00AA RSS:166
RECEIVED  (16): tagSeq:251 node:00DD tag:00AA RSS:173
RECEIVED  (16): tagSeq:251 node:00CC tag:00AA RSS:166
RECEIVED  (16): tagSeq:251 node:00DD tag:00AA RSS:173
RECEIVED  (16): tagSeq:252 node:00DD tag:00AA RSS:206
RECEIVED  (16): tagSeq:252 node:00CC tag:00AA RSS:169
RECEIVED  (16): tagSeq:252 node:00DD tag:00AA RSS:206
RECEIVED  (16): tagSeq:252 node:00CC tag:00AA RSS:169
RECEIVED  (16): tagSeq:253 node:00DD tag:00AA RSS:210
RECEIVED  (16): tagSeq:253 node:00CC tag:00AA RSS:184
RECEIVED  (16): tagSeq:253 node:00DD tag:00AA RSS:210
RECEIVED  (16): tagSeq:254 node:00CC tag:00AA RSS:173
RECEIVED  (16): tagSeq:254 node:00DD tag:00AA RSS:201
RECEIVED  (16): tagSeq:255 node:00DD tag:00AA RSS:182
RECEIVED  (16): tagSeq:1 node:00DD tag:00AA RSS:172
RECEIVED  (16): tagSeq:2 node:00DD tag:00AA RSS:195
RECEIVED  (16): tagSeq:2 node:00CC tag:00AA RSS:192
RECEIVED  (16): tagSeq:3 node:00CC tag:00AA RSS:196
RECEIVED  (16): tagSeq:4 node:00CC tag:00AA RSS:201
RECEIVED  (16): tagSeq:4 node:00DD tag:00AA RSS:176
RECEIVED  (16): tagSeq:4 node:00CC tag:00AA RSS:201
RECEIVED  (16): tagSeq:4 node:00DD tag:00AA RSS:176
RECEIVED  (16): tagSeq:5 node:00CC tag:00AA RSS:207
RECEIVED  (16): tagSeq:5 node:00DD tag:00AA RSS:184
```

Fig. 10. Data sequences received through an input gate

For the purposes of checking correct operation two different environments were selected for the set, with a different number of people present, the level of signal interference and other characteristics of the obstacles to the transmitted signal. Due to the limited number of available MSP430 modules, testing communication between modules on a larger scale was not possible. The first experiment involved the object in a residential building with an area of approximately 80 m^2 shown in Fig. 8.

The modules were arranged in such a way as to evenly cover as much as possible of the building area. The first problem encountered turned out to be duplicated packets, sent approximately every 5-15 seconds depending on location. This problem is resolved at the central device level collecting measurement data.

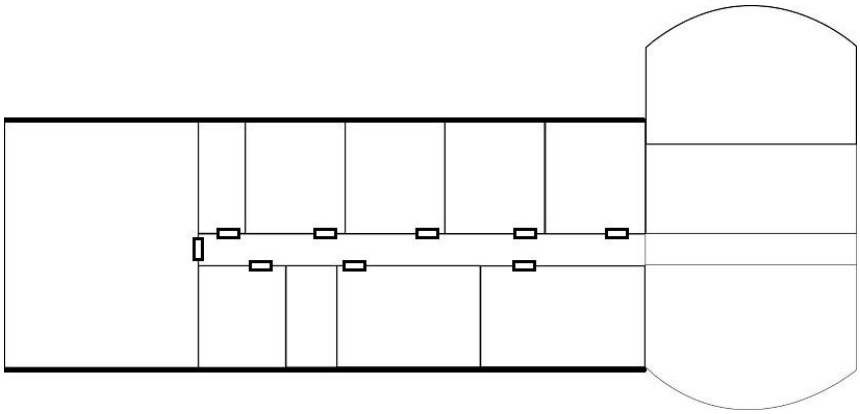


Fig. 11. Configuration of the second tested object

In the second facility shown in Fig. 11, the modules were tested while being spaced in one line evenly along the corridor and in the second configuration – one at the end of the corridor, and two near the stairs on opposite sides. The disadvantage of the first one is that there were significant problems with packet collection by the input gate at the time when the transmitter was also in line with the modules.

Then the problem of losing packets and their duplication deepened, which ultimately translates into the lower accuracy of final measurements. In the second module configuration, the problem of packet loss in the input gate receiving duplicate data was much smaller. The disdvantage such arrangement, however, is that it increases the number of obstacles that the signal must overcome, which may contribute to a significant loss of signal strength received by the input gate.

6. CONCLUSION

The aim of the project was to develop an effective system enabling precise determining the location of various objects inside buildings. In this context, the main goal was to create an intelligent solution that uses advanced classification and localization technologies. The application was implemented using a set of hardware modules with the help of which measurement data were collected in the form of received signal strength to estimate the location of objects.

Due to the complexity and problems encountered, filtering and grouping of objects on the map turned out more difficult than originally assumed. The learning algorithm was eventually created as a separate service with which the API server communicates using the WebSocket protocol, leading to reduced performance operation of the entire application. Despite the problems encountered, the main assumptions were met. The application user is able to configure the map and view the location of objects both historically and in real time.

To sum up, the project provides a solid basis for further development. Potential directions include optimization of classification algorithms, further improvement of the interface communication, as well as exploring new location technologies. In perspective, the system of intelligent classification of the location of objects can be used in various applications areas, from effective resource management to streamlining logistics processes.

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Usage of Mathematical Modeling in Bioprocess Engineering

Jožef RITONJA[a*], Robert BREZOVNIK [b]

[a] *University of Maribor, Faculty of Electrical Engineering and Computer Science, Koroška cesta 46, Maribor, Slovenia, jozef.ritonja@um.si*
[b] *University of Maribor, Faculty of Electrical Engineering and Computer Science, Koroška cesta 46, Maribor, Slovenia, robert.brezovnik@um.si*

Abstract

The paper presents the use of mathematical modeling and numerical optimization methods in bioprocess engineering. The fermentation process in batch bioreactors represents one of the most essential and useful bioprocesses. Systematic design of fermentation process control requires knowledge of the mathematical model of the fermentation process. The well-known and commonly used fundamental dynamic model of the fermentation process does not account for the impact of changing input variables (temperature, stirrer speed) on the course of fermentation. The paper derives an extended mathematical model that addresses the impact of temperature on the fermentation process. Parameter identification is carried out using particle swarm optimization. The presented structure of the new model and the procedure for identifying its parameters enable the determination of an accurate model of the fermentation process. The presented model was verified using model simulations and measurements of the real fermentation process.

Keywords: Bioprocess engineering, Fermentation process, Mathematical modeling, Numerical optimization

1. INTRODUCTION

Biotechnology is a field that combines engineering and science, holding immense significance and potential. In 2017, the global biotechnology market was valued at USD 414.50 billion and is projected to grow to USD 727.1 billion by 2025. Within this broad field, bioprocess engineering focuses on converting scientific discoveries into practical applications that benefit society [1]. While biopharmaceutical production is currently the most prominent application, bioprocess engineering also plays a vital role in traditional fermentation industries, producing ethanol (for beverages and fuel), lactic acid (for dairy products), carbon dioxide, hydrogen gas, butanediol (for pharmaceuticals and cosmetics), propanediol (for biopolymers), succinic acid (used in chemical, pharmaceutical, food, and agricultural industries), and aspartic acid (for polymer production) [2].

Industrial fermentation is a key biological process used across various biotechnology sectors: "white biotechnology" for industrial chemical production, "red biotechnology" for pharmaceuticals, "yellow biotechnology" for food production, and "gray biotechnology" for environmental applications [3].

In industrial fermentation, microorganisms (such as bacteria, yeasts, molds, or algae) or cells (animal or plant) are employed to create products beneficial to humans. These processes are carried out in bioreactors, which are central to bioprocess engineering. Bioreactors can be categorized by their construction and operation mode into three types:

* Corresponding author.

batch, fed-batch, and continuous [4]. Batch bioreactors operate in a closed system, preventing any exchange of substances or organisms during the process. This design simplicity translates to low production costs and easy maintenance, making batch bioreactors the most common and widely used type. Fed-batch bioreactors allow the addition of nutrients or organisms during the process, with all products remaining in the reactor until completion. Continuous bioreactors, or flow bioreactors, permit a steady inflow and outflow of substances or organisms, maintaining a continuous feed for the cells or microorganisms.

This study focuses on batch bioreactors. The fermentation process within a batch bioreactor is a complex nonlinear system with an unknown structure and time-varying parameters. Accurate mathematical models are essential for analyzing fermentation processes and designing control systems for batch bioreactors. Existing literature models treat the system as autonomous and fail to account for the impact of variables like temperature and stirring speed on the fermentation process. This paper introduces a mathematical model that incorporates these process variables.

The paper is structured into six sections. Section 2 discusses a fundamental mathematical model of the fermentation process in batch bioreactors and highlights its limitations. Section 3 proposes an improved model by introducing temperature-dependent parameters $\mu_{m9}(t)$ and $\alpha_9(t)$. The model derivation began with an in-depth theoretical analysis and systematic laboratory tests on a bioreactor, leading to the establishment of the model structure. This new structure, which includes the influence of process variables, differs from existing models. The subsequent parameter identification procedure utilizes particle swarm optimization. Section 4 describes this procedure in detail. The developed mathematical model was validated by comparing its simulations with experimental data from a laboratory bioreactor. Section 5 presents the experimental and simulation results using the advanced model. Section 6 provides a concluding remarks.

2. FUNDAMENTAL MATHEMATICAL MODEL

Fermentation is described as a process where an agent initiates the breakdown of an organic material into simpler components. In the field of bioprocess engineering, these agents are typically microorganisms, the initial material is termed the substrate, and the resulting material is called the product. During fermentation, microorganisms consume the substrate (essentially their food) and generate the product as they grow. This triad of microorganisms, substrates, and products is common to all fermentation processes [5].

Nonetheless, there exist numerous mathematical models with varying levels of complexity that depict the fermentation process within batch bioreactors. The majority of these models are grounded in the mass balances of the three principal components of fermentation. A fundamental and widely adopted mathematical model of the fermentation process consists of three nonlinear differential equations that describe the concentrations of the microorganisms, substrate, and product [4].

$$\dot{x}_1(t) = \frac{\mu_m\left(1-\frac{1}{P_i}x_3(t)\right)x_2(t)}{S_m+x_2(t)+\frac{1}{S_i}(x_2(t))^2}x_1(t) \tag{1}$$

$$\dot{x}_2(t) = -\frac{\mu_m\left(1-\frac{1}{P_i}x_3(t)\right)x_2(t)}{S_m+x_2(t)+\frac{1}{S_i}(x_2(t))^2}x_1(t) \tag{2}$$

$$\dot{x}_3(t) = \left(\alpha\ \frac{\mu_m\left(1-\frac{1}{P_i}x_3(t)\right)x_2(t)}{S_m+x_2(t)+\frac{1}{S_i}(x_2(t))^2}+\beta\right)x_1(t) \tag{3}$$

where the variables in the mathematical model represent the following biological quantities:
$x_1(t)$ - the concentration of the microorganisms (g/L),
$x_2(t)$ - the concentration of the substrate (g/L),
$x_3(t)$ - the concentration of the product (g/L)
and the parameters of the mathematical model are:
μ_m - the maximum microorganisms' growth rate (h^{-1}),
P_i - the product inhibition constant (g/L),
S_m - the substrate saturation constant (g/L),
S_i - the substrate inhibition constant (g/L),
α - the parameter that describes the relation between product yield and microorganism growth and

β - the parameter that describes the product yield that is independent of the microorganism growth (h^{-1}).

The mathematical model described by equations (1-3) is autonomous, meaning it lacks an input variable. This aligns with the practical operation of batch bioreactors, which do not have an input mechanism for controlling the fermentation process. At the beginning of fermentation, all three bioprocess components are introduced into the bioreactor. During fermentation, it is not feasible to add or remove any of these components. The fermentation dynamics are solely influenced by the initial quantity and quality of the substances and the type of batch bioreactor used. Thus, the transient behavior of the model is determined by the initial values of the model variables and the model parameters.

Throughout the fermentation process, the quantities of microorganisms and product increase, while the substrate quantity decreases. These quantities are measured and expressed as concentrations in the model.

In an autonomous fermentation process, where the fermentation depends only on the initial concentrations and the temperature remains constant, all parameters of the fundamental kinetic model are constant throughout the process. This fundamental kinetic model facilitates straightforward and efficient simulation and analysis of the time-dependent concentrations of microorganisms, substrate, and product given different initial concentrations. However, the main limitation of this model is its inability to account for the impact of temperature changes on the fermentation process, which is essential for control system design.

The current model cannot evaluate how temperature variations affect the concentrations of individual substances during fermentation, a necessary consideration for designing effective control systems. Therefore, it is crucial to develop a new mathematical model for the fermentation process in batch bioreactors that incorporates the effects of temperature changes.

3. EXTENSION OF THE FUNDAMENTAL MATHEMATICAL MODEL

Upon comparing experimental and simulation results, it becomes evident that temperature variations exert a similar influence on the observed fermentation product trajectories in experiments as alterations to the parameters μ_m and α in numerical simulations [6]. According to findings in [6], temperature changes notably affect parameters μ_m and α, whereas their impact on other parameters is minimal. The study reveals from [6] that the maximum growth rate of microorganisms, μ_m, affects fermentation speed but not the steady-state value of the fermentation product achieved at the process's conclusion. Conversely, parameter α influences the steady-state value of the fermentation product without significantly impacting transient phenomena [6].

This implies that in bioreactors experiencing variable temperatures, parameters μ_m and α cease to remain constant and vary in response to the bioreactor's temperature. Therefore, we introduced an additional differential equation into the fundamental mathematical model of the fermentation process to compute the bioreactor's temperature. This temperature is represented by a new variable $x_4(t)$. Instead of fixed parameters μ_m and α, we introduced temperature-dependent parameters $\mu_{m\vartheta}(t)$ and $\alpha_\vartheta(t)$. As established in [6], a static relationship exists between temperature and these model parameters. Given the narrow range of temperature fluctuation during fermentation (extremes can harm microorganisms), we opted for a linear dependence between temperature deviation and parameter deviation. Consequently, temperature-dependent parameters $\mu_{m\vartheta}(t)$ and $\alpha_\vartheta(t)$ are expressed using the following static functions:

$$\mu_{m\vartheta}(t) = \mu_m \left(1 + k_{\mu m}(x_4(t) - \vartheta_0)\right) \quad (4)$$

$$\alpha_\vartheta(t) = \alpha \left(1 + k_\alpha(x_4(t) - \vartheta_0)\right) \quad (5)$$

where the new parameters in the linear static equations are:

$x_4(t)$ - the temperature in the bioreactor (°C),

ϑ_0 - the temperature of the bioreactor's contents at the beginning of the fermentation process (°C), normally ϑ_0 is equal to the outside temperature,

$k_{\mu m}$ - the coefficient that outlined the effect of the temperature changing on the maximum microorganisms' growth rate μ_m $(°C)^{-1}$,

k_α - the coefficient that describes the impact of the tempera-ture changing on the parameter that describes the relation between product yield and microorganism growth $(°C)^{-1}$,

$\mu_{m\vartheta}(t)$ - the temperature-dependent maximum microorgani-sms' growth rate (h^{-1}), and

$\alpha_\vartheta(t)$ - the temperature-dependent parameter which expresses the connection between product yield and microorganism growth (h^{-1}).

The enhanced model incorporating temperature was achieved by extension the fundamental model with an extra differential equation to compute the bioreactor's temperature, and by substituting the constant parameters μ_{m} and α with temperature-dependent equivalents, detailed in equations (4, 5). The resulting mathematical model is formulated as follows:

$$\dot{x}_1(t) = \frac{\mu_{\mathrm{m}}\left(1+k_{\mu_m}(x_4(t)-\vartheta_0)\right)\left(1-\frac{1}{P_{\mathrm{i}}}x_3(t)\right)x_2(t)}{S_{\mathrm{m}}+x_2(t)+\frac{1}{S_{\mathrm{i}}}\left(x_2(t)\right)^2}x_1(t) \tag{6}$$

$$\dot{x}_2(t) = -\frac{\mu_{\mathrm{m}}\left(1+k_{\mu_m}(x_4(t)-\vartheta_0)\right)\left(1-\frac{1}{P_{\mathrm{i}}}x_3(t)\right)x_2(t)}{S_{\mathrm{m}}+x_2(t)+\frac{1}{S_{\mathrm{i}}}\left(x_2(t)\right)^2}x_1(t) \tag{7}$$

$$\dot{x}_3(t) = \left(\alpha\ \frac{\left(1+k_{\alpha}(x_4(t)-\vartheta_0)\right)\mu_{\mathrm{m}}\left(1+k_{\mu_m}(x_4(t)-\vartheta_0)\right)\left(1-\frac{1}{P_{\mathrm{i}}}x_3(t)\right)x_2(t)}{S_{\mathrm{m}}+x_2(t)+\frac{1}{S_{\mathrm{i}}}\left(x_2(t)\right)^2}+\beta\right)x_1(t) \tag{8}$$

$$\dot{x}_4(t) = \frac{1}{T_{\vartheta \mathrm{cs}}}\quad\left(u(t)-x_4(t)\right) \tag{9}$$

where additional to the symbols in (1-5):
u(t) - indicates the reference temperature of the bioreactor's temperature control system (°C), and
$T_{\vartheta cs}$ - is the time constant of the simple 1st order model of the controlled heating system (h).

The newly developed model takes into account the impact of temperature on both the transient and steady-state phases of the fermentation process, leading us to term it the temperature-considered model. This enhanced model (equations 6-9) marks a departure from the initial models (equations 1-3).

During the development and validation of the temperature-considered model, beyond exploring linear expressions (equations 4, 5), we also investigated various nonlinear analytical expressions to characterize how model parameters vary with bioreactor temperature. These functions were selected to ensure a strong fit between the model's predictions and experimental data [7]. Ultimately, linear functions were chosen due to their simplicity in implementation and their effectiveness in describing fermentation progress accurately.

The resulting temperature-considered model (equations 6-9) shares structural similarities with the basic model (equations 1-3), but functionally, it is fundamentally different. Unlike the autonomous nature of the basic model (1-3), which only simulates concentration responses based on initial values, the new model (6-9) consists of non-autonomous nonlinear differential equations. This allows it to predict concentration trends in the bioreactor under varying temperatures. As such, the model (6-9) is well-suited for designing fermentation control systems that account for bioreactor temperature changes—a capability lacking in the fundamental model (1-3).

4. IDENTIFICATION OF THE PARAMETERS OF THE EXTENDED MODEL

The parameters μ_{m}, P_{i}, S_{m}, S_{i}, α, β, $k_{\mu m}$, k_{α} and $T_{\vartheta cs}$ (as defined in equations 1-9) are influenced by both the composition and quantity of substances, as well as by external operating conditions. Under stable external conditions, these parameters typically remain relatively constant throughout the fermentation process [7].

To determine the parameters of mathematical models for fermentation processes in laboratory or industrial bioreactors, various optimization methods can be employed using measured bioreactor substance trajectories. In our study, we utilized the particle swarm algorithm (PSO) for parameter estimation.

Particle swarm optimization (PSO) is a population-based algorithm [8], originally introduced by Kennedy and Eberhart [9], that explores solution spaces by adjusting the positions of particles based on the quality of their current solutions. During the optimization, the swarm of particles varies throughout the selected area. The optimization algorithm calculates the objective function at each step and updates the particles' velocities accordingly, moving each particle toward the best-found location. PSO is a metaheuristic procedure capable of providing a sufficiently good solution to optimization problems even when assumptions about the problem are few, incomplete, imperfect, or non-existent. It can effectively search large solution spaces without relying on the gradient of the optimization problem, making it suitable for non-differentiable problems.

In our implementation, we employed the *particleswarm.m* function from MathWorks MATLAB/Optimization Toolbox, which is based on the algorithm described in [9] with modifications from [10, 11], and detailed in [12]. PSO

involves iteratively adjusting a swarm of particles, evaluating the objective function at each step to guide the search toward optimal parameter values.

Optimization was performed using the CO_2 concentration time course measurements. The objective function aimed to minimize the error between measured and model-predicted responses, typically quantified using the integral absolute error (IAE) metric [13].

For the temperature-considered model, identifying all nine parameters of the mathematical model was essential. PSO was utilized to determine these parameters concurrently, although we found better results by dividing the parameter identification into two phases. In the first phase, μ_m, P_i, S_m, S_i, α, and β were identified, while in the second phase, $k_{\mu m}$, k_{α}, and $T_{\vartheta cs}$ were calculated, following a systematic trial approach.

4.1. Calculation of the parameters μ_m, P_i, S_m, S_i, α, and β

In the initial phase of the optimization process, the parameters μ_m, P_i, S_m, S_i, α, and β were determined, constituting the fundamental aspects of the mathematical model under constant temperature conditions in the bioreactor. This model describes both the transient and steady-state behavior of the fermentation process based on the initial concentrations of substances in the bioreactor.

Initially, the initial concentrations of microorganisms, substrate, and fermentation product were measured for the fermentation process in the batch bioreactor under study, as detailed in Table 1.

Table 1. Initial Values of the Fermentation Process in the Analysed Bioreactor.

$x_1(0)$ = 2.6 mg/L
$x_2(0)$ = 9.0 mg/L
$x_3(0)$ = 0.1 mg/L
$x_4(0)$ = 22 °C

Subsequently, the fermentation process commenced, during which only the dissolved CO_2 concentration, representing the fermentation product, was monitored. This concentration is critical in the bioreactor. Throughout the fermentation, external conditions such as temperature and stirrer speed remained constant. The time courses of the dissolved CO_2 concentration were measured for a constant temperature of 22 °C, as well as for two different temperatures, as depicted in Figure 1.

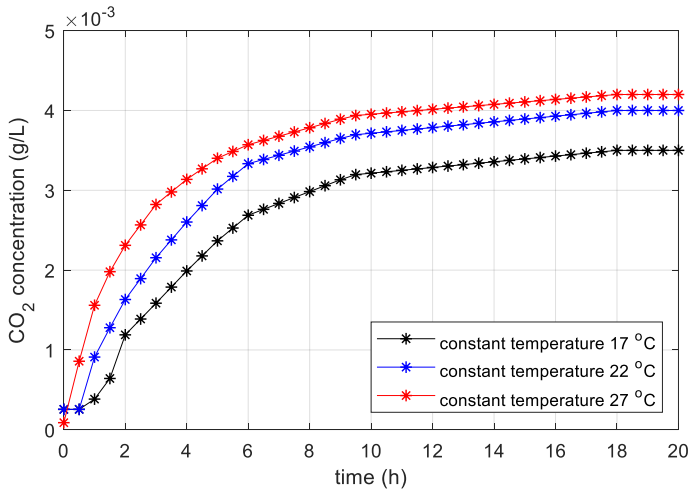

Fig. 1. Measured time courses of the CO_2 concentration during the fermentation processes with different bioreactor temperatures.

The PSO algorithm, utilizing the IAE objective function, was then employed to compute the parameters μ_m, P_i, S_m, S_i, α, and β for the foundational part of the model applicable to the constant bioreactor temperature. The IAE function quantified the integral of the absolute error between the measured dissolved CO_2 concentration (Figure 1) and the calculated state-space variable $x_3(t)$ from the nonlinear mathematical model (equations 1-3). Figure 2 illustrates the

progression of the objective function throughout the PSO process.

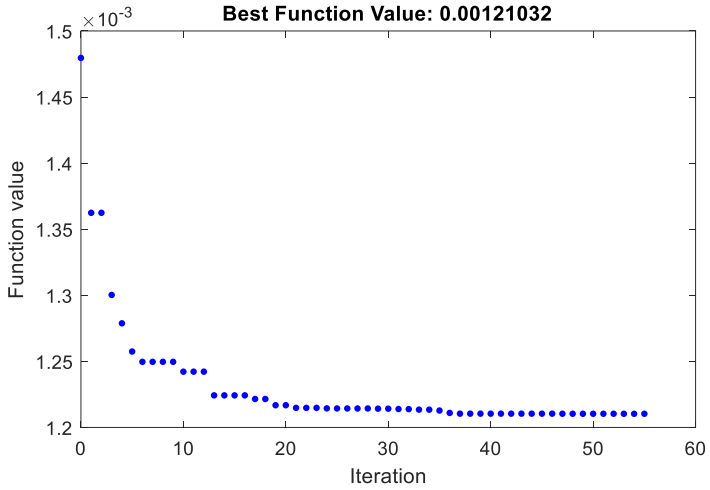

Fig. 2. The time course of the IAE objective function during the PSO with the parameters μ_m, P_i, S_m, S_i, α, and β.

As depicted in Figure 2, fewer than 60 iterations were necessary for the PSO algorithm to converge and determine the parameters μ_m, P_i, S_m, S_i, α, and β for the fundamental mathematical model. The identified parameters are summarized in Table 2.

Table 2. Parameters of the Basic Mathematical Model for the Fermentation Process in the Analysed Bioreactor

$\mu_m = 2.1\ h^{-1}$	$P_i = 0.75$ g/L
$S_m = 0.03$ g/L	$S_i = 1.0$ g/L
$\alpha = 0.38\ \frac{g/L}{g/L}$	$\beta = 0.002\ h^{-1}$
$\vartheta_0 = 22$ °C	

4.2. Calculation of the parameters $k_{\mu m}$, k_α, and $T_{\vartheta cs}$

In the subsequent phase of optimization, the parameters $k_{\mu m}$, k_α, and $T_{\vartheta cs}$ were determined. These parameters are integral to the extended portion of the mathematical model, which characterizes how varying temperatures influence the transient and steady-state dynamics of the fermentation process. Specifically, $k_{\mu m}$ and k_α quantify the effects of temperature variations on adjusting parameters $\mu_{m\vartheta}(t)$ and $\alpha_\vartheta(t)$, respectively. Meanwhile, $T_{\vartheta cs}$ specifies the temperature time constant of the bioreactor's heating system.

To identify these parameters, another fermentation experiment was conducted. This time, the reference temperature was step-changed from 22 °C to 27 °C at t = 3 hours. The evolution of dissolved CO_2 concentration during fermentation under variable temperatures is depicted in Figure 3. Once again, the PSO algorithm was employed, utilizing the IAE objective function to optimize the model parameters. The IAE objective function computed the integral of the absolute error between the measured dissolved CO_2 concentration (Figure 3) and the simulated variable x_3(t) from the nonlinear mathematical model (equations 4-9). The PSO algorithm adjusted the values of $k_{\mu m}$, k_α, and $T_{\vartheta cs}$ until reaching a minimum of the objective function. Throughout the optimization process, the previously identified parameters parameters μ_m, P_i, S_m, S_i, α, and β from the first stage (Table 2) were held constant.

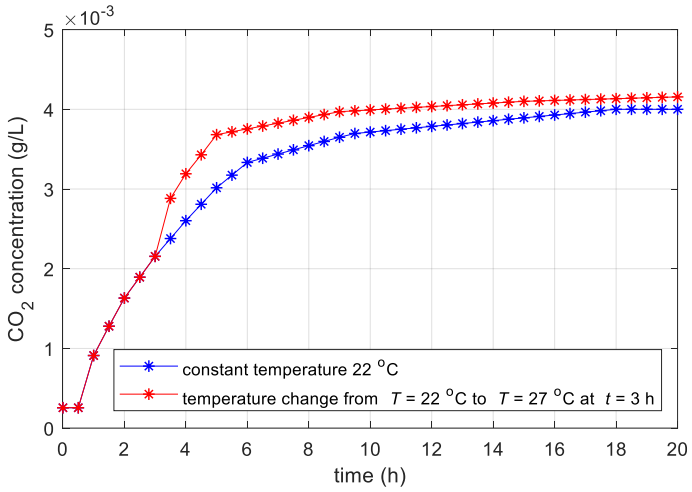

Fig. 3. Measured time courses of the CO_2 concentration during the fermentation processes with constant- and changeable bioreactor temperatures

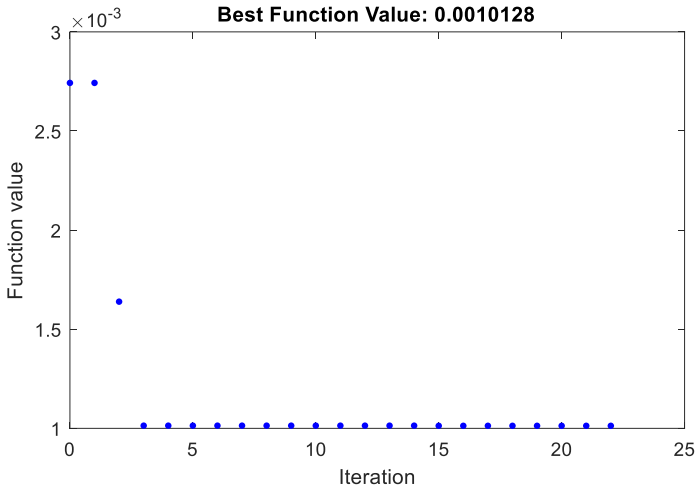

Fig. 4. The time course of the IAE objective function during the PSO with the parameters $k_{\mu m}$, $k_{\alpha,}$ and $T_{\vartheta cs}$.

Figure 4 illustrates that fewer than 25 iterations were required to identify the parameters parameters $k_{\mu m}$, $k_{\alpha,}$ and $T_{\vartheta cs}$. The computed values of these parameters are presented in Table 3.

Table 3. Parameters of the Supplemented Part of the Mathematical Model for the Fermentation Process in the Analysed Bioreactor.

$k_{\mu m} = 0.14$ (°C)$^{-1}$
$k_{\alpha} = 0.03$ (°C)$^{-1}$
$T_{\vartheta cs} = 0.1$ h
$\vartheta_0 = 22$ °C

5. RESULTS

5.1. Model simulation

The simulation results of the identified temperature-considered model of the fermentation in the laboratory bioreactor are shown in Figure 5. Presented are the time responses of the microorganisms, substrate, and product in the case of constant temperature (solid lines) T = 22 °C, and the same variables in the case of the bioreactor's reference temperature step change from 22 °C to 27 °C in t = 3 h (drawn with dashed lines). It is evident that temperature changes generate substantial variations in the dynamics of all quantities of the fermentation process. The time course of the actual temperature in the bioreactor follows the reference temperature step change. The delay in the actual temperature is small – it corresponds to the short time constant of the controlled heating system $T_{\vartheta cs}$ = 0.1 h.

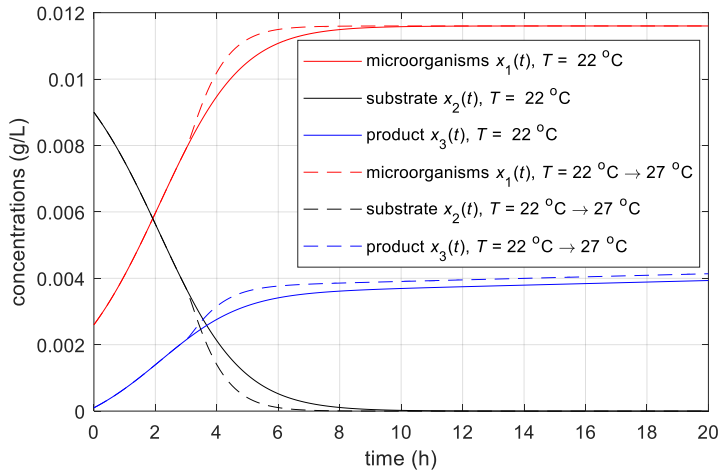

Fig. 5. Time courses of the concentrations of the microorganisms, substrate, and product during the fermentation processes with constant- and changeable bioreactor temperatures.

5.2. Model verification

The comparison between the measured CO_2 concentration response in the laboratory bioreactor and the simulated response from the identified temperature-considered model is illustrated in Figures 6 to 8.

Figure 6 displays the results of the fermentation process conducted at a constant bioreactor temperature of 22 °C. The simulated CO_2 concentration closely matches the experimental data across all phases of fermentation: the initial induction phase, subsequent exponential growth phase, and final stationary phase.

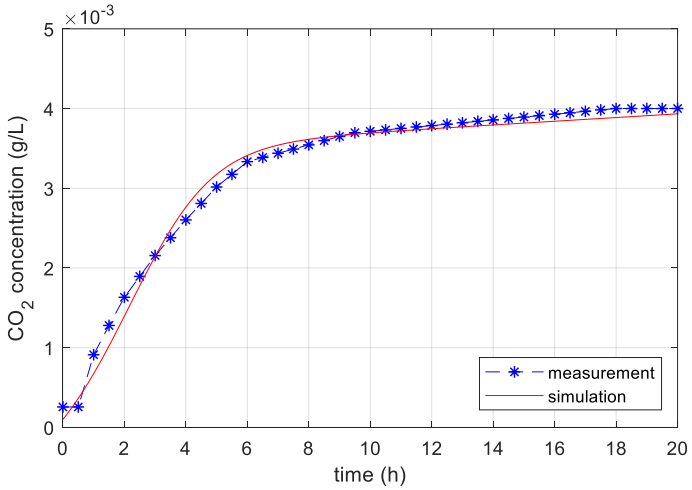

Fig. 6. Measured and simulated time courses of the CO_2 concentration during the fermentation process with constant bioreactor temperature 22 °C.

Figure 7 presents the outcomes of fermentation under variable bioreactor temperature conditions. A step increase in temperature from 22 °C to 27 °C at t = 3 h is evident in both experimental and simulation results. The impact of this temperature change is reflected in the altered slope of the concentration curve at the time of change, yet overall agreement between measured and simulated responses is observed.

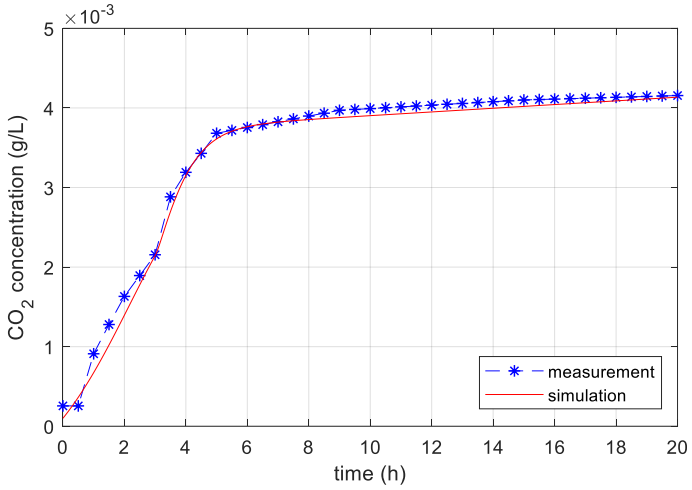

Fig. 7. Measured and simulated time courses of the CO_2 concentration during the fermentation process with variable bioreactor temperature (step change of temperature from 22 °C to 27 °C occurred at time t = 3 h).

Figure 8 depicts the results of another fermentation experiment where the temperature was stepped up from 22 °C to 27 °C at t = 6 h. Both experimental and simulated data are presented, showing consistent agreement. A slight discontinuity in the time course is noticeable around t = 6 h, which is less pronounced compared to the earlier temperature change at t = 3 h. Figures 7 and 8 affirm the empirical observation that the influence of temperature variations on CO_2 production is more pronounced during the initial stages of fermentation (high growth rate) and diminishes in the later stages (low growth rate).

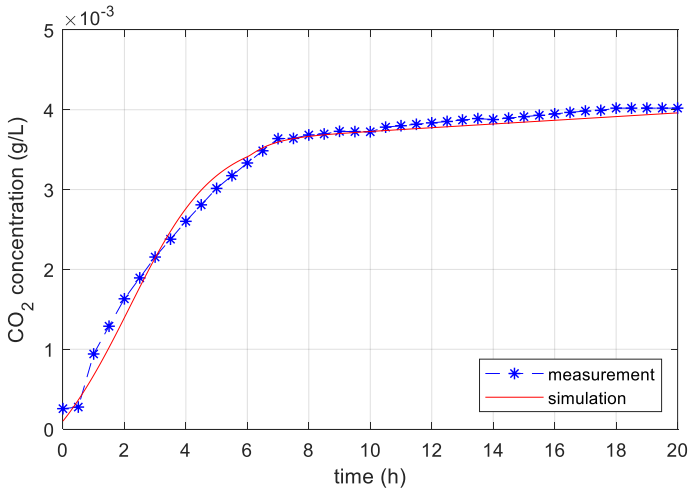

Fig. 8. Measured and simulated time courses of the CO_2 concentration during the fermentation process with changeable bioreactor temperature (step change of temperature from 22 °C to 27 °C occurred at time t = 6 h).

These results underscore the applicability of the developed model for studying fermentation processes and designing control strategies. The employed parameter optimization approach, while straightforward, may be time-intensive.

6. CONCLUSIONS

The primary contribution of this study lies in the development of an advanced dynamical model that incorporates the effects of temperature variations on both the transient dynamics and steady-state characteristics of the fermentation process. Key aspects of the newly introduced temperature-considered model include:

- This model represents a significant evolution from earlier models detailed in the authors' previous publications [6,7,13-16], offering a more streamlined structure.
- With a total of nine parameters, the model allows for customization to specific bioreactors through parameter identification. The Particle Swarm Optimization technique was employed for this purpose.
- The identification and validation of the model involved multiple fermentation experiments conducted on two distinct batch bioreactors. The findings from numerous experiments and simulations consistently support the conclusions presented in this study.

These features underscore the utility of the developed model for enhancing our understanding of fermentation processes and for facilitating the design of effective control strategies in bioreactor operations.

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Global Education, Teaching and Learning (IAC-GETL)

The Impact of Practical Pedagogical Training on the Development of Future Teachers' Skills: The Case of Primary Education Students at the Faculty of Education, University of Maribor

Polona JANČIČ HEGEDIŠ[a*], Amadeja LAVRENČIČ [b], Monika MITHANS [c]

[a] *University of Maribor, Faculty of Education, Koroška cesta 160, 2000 Maribor, Slovenia, polona.jancic1@um.si*
[b] *University of Maribor, Faculty of Education, Koroška cesta 160, 2000 Maribor, Slovenia, amadeja.lavrencic@student.um.si*
[c] *University of Maribor, Faculty of Education, Koroška cesta 160, 2000 Maribor, Slovenia, monika.mithans1@um.si*

Abstract

Practical pedagogical training plays an important role in the education of future teachers, who need to respond and adapt to the diverse needs of their pupils and use modern pedagogical approaches. We aimed to discover how students of classroom teaching at the Faculty of Education, University of Maribor, perceived the development of their work-related skills inside and outside the classroom during their practical pedagogical training. We conducted a survey of 238 students in the academic year 2022/23. The participants rated the development of skills relating to the classroom more highly than those relating to outside the classroom. Additionally, their skills development was rated as higher amongst those who were very satisfied with the implementation of the study programme and lower amongst those who were dissatisfied or very dissatisfied.

Keywords: practical pedagogical training, faculty, primary education, students, didactics

1. INTRODUCTION

Teachers are pivotal in today's society, serving as conveyors of knowledge, values, and skills to the youth. They are not just imparting academic content but also transmitting cultural values and essential life skills, acting as a bridge between generations and ensuring that important information and ethical standards are passed along. Yet conventional methods are increasingly being questioned. Teachers are now expected to develop novel effective teaching, learning, and assessment methods in formal and non-formal educational contexts [1], implement new curricula [2,3], and promote learning-centred participatory pedagogy and digitalisation [4]. Their professional tasks have, therefore, expanded considerably. As a result, there is a need to provide quality education and offer continual professional development to enable future educators to adopt new pedagogical approaches. Subsequently, programmes of study for the education of future teachers must adapt accordingly and respond to societal changes. Abid et al. [5] argued that a country's development is based on high-quality education; those who teach future teachers must therefore be able to develop their students' competence in all areas of the profession [6].

* Corresponding author.

Developing competence amongs future teachers at the Faculty of Education, University of Maribor

Primary education students have to acquire competence in a targeted way across a variety of subjects. This is achieved through practical pedagogical training [7,8]. It opens up the possibility of building on the theoretical knowledge the students have acquired in their classwork with experience in a real working environment [9]. I can have a decisive impact on the acquisition of general and specific competence [10], which encompases a complex combination of knowledge, skills, understanding, values, and attitudes orientated towards quality performance [11,12].

Practical pedagogical training is one of the key forms of active study [13], and identifying the link between it and theory is essential. The training constitutes a process of learning that combines thinking, observation, and practical action. Students receive information, establish lines of communication with their teaching environment, participate in the implementation and planning of activities, and learn about the importance of evaluating their work in preparation for their careers [14].

The principal objectives of practical pedagogical training are to gain a deeper understanding of the professional roles of practitioners, to learn more about oneself and one's suitability for the profession, and to develop the essential professional skills of planning, implementation, management, analysis, and evaluation of one's work [6,8,15]. Practical pedagogical training enables students to acquire related knowledge and skills and to integrate the practical and theoretical aspects of teaching [16]. Students are given the opportunity to test themselves in the teaching profession, experience some of the problems arising therefrom, become acquainted with the functioning of a primary school, discover whether they have chosen the right career path, and so on. [17,18]. Moreover, developing the students' competence is designed to increase their employability upon graduation [9].

At the University of Maribor Faculty of Education [19], practical pedagogical training is evenly distributed throughout the programme. Students are actively involved in educational work at primary schools, and the proportion is increasing from year to year. It enables them to constantly reflect on their theoretical knowledge and apply it in real situations.

Practical pedagogical training for future teachers as a factor in the development of competence

As was noted above, practical pedagogical training is of key importance in the students' education because it allows them to apply what they have learnt [13] and develops their professional competence [12]. The students are expected to acquire competence in the classroom; competence in their work outside the classroom and school; and competence relating to their professional development [20]. Students must be familiar with different approaches to maintaining a positive classroom climate and motivating pupils; they must also be able to manage the educational process and, based their knowledge of the curriculum, to design annual and ongoing plans. They must also select and prepare appropriate didactic material and adapt teaching forms and methods to the needs of the class; cultivate the ability to choose different ways of testing and assessing knowledge; formulate criteria for assessing knowledge; and gain insights into the legalities of classroom management [20]. To develop competence regarding work outside the classroom and the school environment, students have to acquire knowledge of the characteristics and ways of working of a school (including learning about the key features of the school's legislation and documentation); comprehend the functioning of the school counselling service and management (including their purpose, areas of work, and methods of working with other professionals and parents). Students should be trained to be actively involved in activities inside and outside the formal curriculum and understand their roles as class teachers. Several studies have affirmed the fundamental role practical training plays in modern teacher education programmes [12,21,22,23].

Prospective teachers themselves are made aware of the significance of practical pedagogical training. Valenčič Zuljan's [15] study of first-year of primary education studies at the Faculty of Education, University of Ljubljana, showed that students valued highly the impact of practical training on their professional development. Other researchers also found that classroom students rate practical training very highly because of the newly acquired knowledge and usefulness it offers [7,18]. Kiggundu and Nayimuli [17] highlighted the fact that students recognised the value of practical training and perceived it as a central component of their preparation for their careers. However, Čagran et al. [21] claimed that it is given insufficient attention.

2. RESEARCH

1.1 Research purpose

We sought to discover what students of the Primary Education programme at the Faculty of Education, University of Maribor, thought about the development of work-related competence inside and outside the classroom during their practical pedagogical training.

A descriptive and non-experimental method of empirical pedagogical research was used.

1.2 Research sample

The survey, which was conducted in the academic year 2022/23, was based on a non-randomised sample of 238 students at the Primary Education programme at the Faculty of Education, University of Maribor. The research sample varied according to students' satisfaction with the delivery of the study programme. On average, students were satisfied (Table 1).

Table 1 - Student Satisfaction With the Delivery of the Study Programme

		1	2	3	4	5	Total	M	SD
Satisfaction with the delivery of the study programme	f	4	25	44	137	28	238	3.7	0.88
	f%	1.7	10.5	18.5	57.6	11.8	100.0		

Note: 1 - very dissatisfied; 2 - dissatisfied; 3 - neither satisfied nor dissatisfied; 4 - satisfied; 5 - very satisfied; M - arithmetic mean; SD - standard deviation

1.3 Instrument

The questionnaire used to collect the data was adapted from Rus Kolar's [7] doctoral dissertation. The questionnaire contains several content strands. The questions were closed-ended, with only one requiring students to express their opinions. The relevant section for the present study concerned students' self-assessment of the development of their skills relating to work in and outside of the classroom during their practical pedagogical training. They gave their answers on a 5-point rating scale (1 = very dissatisfied, 2 = dissatisfied, 3 = neither satisfied nor dissatisfied, 4 = satisfied, and 5 = very satisfied).

The questionnaire also included questions relating to the duration of the training, the achievement of the students' objectives, the acquisition of new knowledge, the development of general didactic and pedagogical-psychological skills and abilities, the fulfilment of expectations, and suggestions for improving the training. (The latter are not discussed in the present study.)

2. 4 Data collection and processing procedures

The data for the survey were collected via a questionnaire on the website 1.ka, which was made available from May to June 2023. The link to the questionnaire, together with the invitation to participate, was sent to the providers of the pedagogical training at the Faculty of Education, University of Maribor, who then invited their students to fill it in. Incomplete questionnaires (where students filled in only demographic data) were excluded from further processing and analysis. The responses were processed and analysed (at the level of descriptive and inferential statistics) using IBM SPSS Statistics. To compare several independent samples, we used the non-parametric Kruskal-Wallis test.

3. RESULTS

Table 2 displays the students' ratings of the development of their skills-related work inside and outside the classroom on a 5-point scale (1 = *very little*, 5 = *very much*).

Students rated their ability to "communicate effectively with students in Slovenian" as being well-developed as a result of their training (M = 4.0; SD = 0.82). They also rated highly the development of their ability to master basic classroom management skills (M = 3.9; SD = 0.91); develop social skills in students (M = 3.8; SD = 0.94); speak successfully in public (M = 3.8; SD = 0.95); create an optimal and stimulating learning environment (M = 3.8; SD = 0.92); understand sport and exercise as the basis for a healthy lifestyle (M = 3.7; SD = 0.94); communicate effectively with teachers and other staff in the establishment (M = 3.6; SD = 1.06); engage in ongoing, substantive, and methodological preparation and preparing didactic aids in a timely, contextual, and methodical manner (M = 3.6; SD = 1.02); and formulate clear rules for discipline and behaviour in the classroom (M = 3.6; SD = 0.99). The lowest scores were for communicating in a foreign language for teaching activities (M = 2.3; SD = 1.14); communicating within and across disciplines, both nationally and internationally (M = 2.4; SD = 1.07); and managing educational organisations (M = 2.5; SD = 1.21).

Table 2 - Students' Self-Assessments of the Development of Work-Related Skills Inside and Outside the Classroom During Their Practical Teaching Training

Skill	*M*	*SD*
Effective communication with students in Slovenian	4.0	0.82
Mastering basic classroom management skills (working with individual pupils and the whole class, working in pairs and groups, and so on)	3.9	0.91
Developing students' social skills	3.8	0.94
Successful public speaking	3.8	0.95
Creating an optimal and stimulating learning environment	3.8	0.92
Understanding sport and exercise as the basis for a healthy lifestyle	3.7	0.94
Effective communication with teachers and other staff in the institution	3.6	1.06
Ongoing, substantive, and methodological preparation and preparation of didactic aids (textbooks, books, multimedia, and so on)	3.6	1.02
Establish clear rules for discipline and behaviour in the classroom	3.6	0.99
Adapting lessons to the individual characteristics of pupils in terms of their prior knowledge, interests, learning styles, and abilities	3.5	0.96
Appropriate use of strategies to deal with inappropriate behaviour and conflict	3.4	1.07
Confronting the challenges of innovative approaches to learning with confidence	3.3	1.00
Using ICT and developing students' information literacy	3.3	0.98
Finding new sources of knowledge (i.e., professional and scientific literature)	3.2	1.07
Mastering and using different ways of testing, assessing, and evaluating pupils' knowledge and achievements	3.2	1.11
Cross-curricular planning and implementation of team teaching	3.2	1.10
Mastering and applying research methods, procedures, and processes	3.1	1.01
Working with the work and social environment and organising teamwork	3.0	1.11
Effective communication with parents and others responsible for pupils	2.7	1.25
Planning and managing projects in education	2.7	1.19
Involvement in research and development activities at school, local, national, and international levels	2.7	1.16
Managing education and training organisations	2.5	1.21
Communication within and between disciplines, both domestically and internationally	2.4	1.07
Communicating in a foreign language for teaching activities	2.3	1.14

Note. *M*: arithmetic mean*; SD*: standard deviation.

We then applied the Kruskal-Wallis test to examine whether there were differences in students' self-assessments regarding their satisfaction with the delivery of the programme.

Statistically significant differences emerged for most of the items. No statistically significant differences were found in the statements "Effective communication with pupils in Slovenian" (χ^2 = 4.725; p = .317); "Developing students' social skills" (χ^2 = 5.396*; p* = .249); and "Finding new sources of knowledge (i.e., professional and scientific literature)" (χ^2 = 5.938*; p* = .204). In short, the students, regardless of their satisfaction with the programme, rated the

development of these skills similarly. For all other statements, the Kruskal–Wallis test revealed a statistically significant difference in satisfaction with the delivery of the programme. Students who were very satisfied with the delivery felt that they had developed more than their less satisfied counterparts. Students who were dissatisfied or very dissatisfied with the delivery rated the development of their work-related skills inside and outside the classroom lowest. The ability to prepare didactic aids was rated highest by students who were neither satisfied nor dissatisfied with the delivery;very dissatisfied students gave the lowest ratings.

4. DISCUSSION

Practical pedagogical training enables future teachers to acquire practical experience, skills, and knowledge that would be difficult or even impossible to acquire by theory alone. We sought to discover how students of Primary Education at the Faculty of Education, University of Maribor, perceived their work-related skills development inside and outside the classroom during their training. The results showed that students rated the development of their inside-class skills more highly than their outside-class skills; Rus Kolar [7] noted likewise. During their practical pedagogical training, students wanted to spend as much time as possible working directly with students and paying more attention to developing related associated skills. The limited duration of pedagogical teaching training often meant that they did not have enough time to develop additional ones.

The highest-rated competencies included the ability to communicate effectively with students in Slovenian (M = 4.0) and master basic classroom management skills (e.g., managing individual students and the whole class and working in pairs and groups; M = 3.9) - both of which are linked to the objectives of the training (e.g., planning, implementing, and evaluating lessons; [8]). Being able to deliver a successful public speech was also highly rated (M = 3.8). In practical pedagogical training, students are required to speak in front of students, student peers, and tutors, so they are likely to be able to hone this skill. It was encouraging to observe that students rated highly the capacity to develop students' social skills (M = 3.8) and create an optimal and supportive learning environment (M = 3.8); both aspects help build better interpersonal relationships and positively impact students' motivation and self-confidence (and, consequently, their academic performance).

Some of the skills that the students were expected to develop or acquire [24,25] were less highly evaluated. These primarily concerned the work and social environment and communication between stakeholders (at the collective, local, and broader international levels). The lowest scores were given to the support provided for communicating in a foreign language for teaching activities (M = 2.3) and within the profession and across disciplines, both locally and internationally (M = 2.4). Such competence is important in a globalised world where teachers are faced with a wide range of challenges and learners. Again, these findings confirmed those of Rus Kolar [7].

5. LIMITATIONS

The survey's limitations may be attributed to the sample and the data collection process. The findings cannot be generalised to the entire population of students at the Primary Education at the Faculty of Education, University of Maribor because we could not satisfy the random sampling condition. When generalising the findings it is also essential to keep in mind that they are based on students' subjective assessments, which do not necessarily reflect the reality of the situation. Students who showed willingness and were motivated to participate were included in the study.

6. CONCLUSION

Most of the work-related skills inside and outside the classroom were, according to the students, better developed during their training by those who were very satisfied with its delivery. This was less the case for students who were dissatisfied or very dissatisfied. The satisfied students were more motivated and involved in the delivery of the programme and the practical pedagogical training; they were also more highly motivated when working with their tutors, who provided them with additional support (e.g., assistance in solving problems) and feedback, and allowed them to participate more actively in the teaching process. Programme leaders, professors, and all those involved in the programme should therefore pay close attention to the quality of delivery, which is intrinsically linked to student-centred approaches [26] where students take a proactive role in their learning [27]. By focusing on these aspects, training programs can better equip future teachers with the comprehensive skill set required for the evolving demands of the education sector.

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Validating a Conceptual Model Describing Empathic Patterns in Complex Discourse

Michal LEVI-KEREN[a], Rinat Arviv ELYASHIV [b], Landler-Pardo G.[c] , Yehudith WEINBERGER [d*]

[a, b, c] *Kibbutzim College of Education and the Arts, 149 Namir rd., Tel – Aviv, Israel*
[d] *David Yellin Academic College of Education, Maagal Beit Hamidrash st., Jerusalem, Israel & Kibbutzim College of Education and the Arts, 149 Namir rd., Tel – Aviv, Israel. Yehudithw@dyellin.ac.il*

Abstract

Empathy is an essential competence for dealing with challenging situations in the educational field. Proper guidance and practice using simulations has great potential for developing empathy: establishing effective communication, constructing productive interactions, and building trust and reciprocity between all partners in educational settings. Therefore, it is important to incorporate such activities in the curriculum of teaching education programs. Based on the conceptual EPIC (**E**mpathic **P**atterns in **I**nterpersonal **C**ommunication) model - a practical tool was constructed to provide a pedagogical instrument to cultivate empathic skills among student teachers. Using the Delphi technique, the paper presents the validation process of the practical tool, following four steps: selecting experts, first round of a survey with content experts, second round of a survey with clinical experts, and analysis of the experts' responses.

Keywords: Empathy competences, Simulation Based Learning (SBL), validation, Delphi technique, student teachers.

1. THEORETICAL FRAMEWORK

Our study focuses on a set of communication skills relevant to empathic behaviour and the ways they can be improved, since empathy is considered a key component in promoting good relationships and fruitful interactions at home, in school, the community, and globally (Weinberger, 2017).

1.1 Empathy

Empathy is defined as the ability to see the world from the perspective of the other (Tolmacz, 2008; Rogers, 1975), including the talent to identify and understand the state and emotions of another person (Miller & Wallis, 2011). Empathic people are involved in a constant process of being sensitive, moment-by-moment, to the feelings, understandings and experiences of the other person (Weinberger & Bakshy, 2015).

In the humanistic worldview, the importance and necessity of empathy in fruitful interpersonal interaction focuses on developing and nurturing people (Aloni, 2013) with sincere concern for the development and well-being of each individual and the nature of society. These, accompanied by tolerance, patience, sensitivity, respect, acceptance, and

* Corresponding author.

openness to the state of the other are values, which may also be considered ethical expressions of teachers' empathy (McAllister & Irvine, 2002).

Duan and Hill (1996) argued that there is a 'diversity of the ways in which empathy is conceptualized' (p. 261). Empathy is a multi-dimensional concept that encompasses both affective and cognitive facets (Hall & Schwartz, 2018; Hawk et al., 2011; Tettegah & Anderson, 2007). The affective dimension of empathy stresses the emotional response of the individual when he or she identifies what the other person is experiencing, whereas the cognitive dimension emphasises his or her understanding of the other person's internal state, motivations and perspectives (Hoffman, 2000).

The term 'empathy' has been used by social scientists to identify a number of distinct but related phenomena. The broad range of phenomena described by the term has, in turn, created challenges in understanding and measuring the construct (Lishner et al., 2017). In order to analyse and organise the empirical research on empathy in teaching, Berkovich (2020) suggests grouping the studies according to four conceptualisations of empathy: empathy as a trait, empathy as a state, empathy as communication, and empathy as a relationship. In the present study, we address the approach of 'empathy as communication'. This approach suggests that empathy is a conversational process focused on a set of empathic practices that can be learned.

Empathy as communication can play a critical interpersonal and societal role in conflict situations, as they are complex and highly emotional. Conflicts of various kinds are inevitable, especially in schools that bring together diverse personalities, rules, and values, and differences between the various actors that make up the school: students, teachers, staff, and parents (Valente et al., 2020). Facing conflicts is a challenge for most teachers who at times act in a non-empathic manner - a phenomenon called 'empathic failure' (Zaki & Cikara, 2015). Since it is impossible to eliminate school conflicts, it is essential to cultivate empathic skills in the educational context. The joint construction of solutions to these situations can be achieved by a correct use of empathy, assertiveness, active listening, and feedback (Valente et al., 2020). Supporting this claim, recent research (Schumann & Dragotta, 2021) has shown that fostering empathy might be a powerful way to promote more constructive responses to conflict in interpersonal relationships.

Studies show that empathy can be enhanced and learned through proper guidance and practice (Costantini, 2019). Use of successful empathic patterns by professionals during complex encounters has great potential for establishing effective communication, constructing productive interactions, and building trust and reciprocity between all partners in educational settings (Cooper, 2010). Furthermore, there is evidence that interventions which have addressed these skills increased student teachers' academic performance and improved classroom behaviour, and consequently, bettered their chances of workplace success (Schwartz et al., 2020).

Although the importance of empathy and other soft skills is widely discussed, and the consensus is that efforts need to be concentrated on developing these skills (European Commission, 2013), they are not included in college curricula or in professional development programs (Nigh, 2021). One example of an effort to cultivate empathy in teacher education programs is the theoretical framework of the Complete Empathic Act (CEA) for teachers. The process described by this framework is defined by three main dimensions: empathic **awareness,** empathic **understanding** and empathic **behaviour (**Weinberger & Bakshy, 2015). This framework emphasises only the theoretical aspect of empathy. It does not offer a practical tool for teacher education purposes. The literature presents a few other attempts to incorporate empathic components in teacher education, some of which use simulations as a clinical learning method for promoting communication skills (Eluz et al., 2019).

1.2 Simulation as a model for experiential learning

Simulation Based Learning (SBL) is a methodology for experiential learning which is already a well-established practice in the fields of aviation, military, and medicine (Donehower Paul et al., 2020). In a recent meta-analysis of 145 empirical studies (Chernikova et al., 2020), it was concluded that simulations are among the most effective means to facilitate learning of complex skills (e.g., critical thinking, problem solving, communication, and collaboration) across several domains (e.g., medical and teacher education, management). Simulation has also emerged as an effective tool for the training and professional development of educators in various stages of their career: students, interns, new teachers and veteran teaching staff.

Simulations have many features that address the complexity of real-world situations (Davidsson & Verhagen, 2017). Video-taped simulations mimic a reality characterized by an emotionally charged atmosphere in which an issue essentially touches on values, personal and professional features, or a challenge to social status (Kartal et al., 2016).

Simulated encounters are usually followed by debriefing, during which the participants practice communication skills and social-emotional competencies (Kolenova & Halakova, 2019).

Studies focused on education have shown that beginning teachers who experienced simulation-based learning during their academic studies developed significant practical knowledge and acquired skills such as classroom management, ethical practice, lesson planning and implementation, and differentiated teaching for students with varying learning needs (Kaufman & Ireland, 2019). Learning through simulations gives participants a sense of efficacy in coping with complicated situations in a school context (Eluz et al., 2019) and a method by which to cultivate communication skills, such as empathy, profound listening, reflection, and assertiveness (Kasperski, & Crispel, 2019), and to develop cooperation and leadership skills (Diamond et al., 2011). Lateef et al. (2019) suggested that simulation-based learning also leads to personal development manifested in awareness of values, patterns of behaviour and thinking, empowerment, self-efficacy, sense of control, and the ability to make informed decisions about coping with challenges.

A recent study conducted by the authors (Weinberger et al., 2022) attempted to develop a conceptual model that could serve as practical tool for introducing empathic competences to student teachers during their training. The model is behaviour-based and relies on video-taped simulations designed to train students in how to empathically respond to complex situations in the education system. Watching these videotapes enabled the researchers to identify, conceptualise and discuss the diverse empathic patterns. These analyses, which aligned with the literature, enabled us to formulate an **E**mpathic **P**atterns in **I**nterpersonal **C**ommunication (EPIC) conceptual model. This model represents a holistic view of the various empathic patterns and the relationships between them, developed in order to simplify the complexity of the behavioural manifestations of empathy. The model includes two core patterns, seven categories and 23 sub-categories, each of which was derived from several examples of empathic gestures and empathic discourse.

The core patterns, including verbal and non-verbal communication, are intertwined. Verbal communication refers to four oral content categories addressing the cognitive and emotional elements of empathy: a) positioning the conversation; b) open heart strategies; c) managing reactions; and, d) setting limits. Each one of the four categories includes sub-categories, for a final total of 17 categories. The non-verbal pattern refers to three categories addressing the behavioural dimensions of empathic patterns: a) body language; b) tone of speech; and, c) manner of speech, and all together include six sub-categories. The EPIC model extends, deepens and complements the theoretical framework of the 'complete empathic act (CEA)' (Weinberger & Bakshy, 2015).

While past research has mainly focused, theoretically and empirically, on the importance of cultivating empathy skills in teacher training programs, there is a lack of attention being paid to the development a way to integrate such skills through use of a practical tool. Such a tool can serve as a pedagogical means for fostering empathic skills, as well as (and mainly) for managing complex situations in the educational arena. In the current study, we attempt to fill this gap by validating our findings regarding the initial conceptual model - the EPIC model. Hence, we aimed to gather further input from some relevant stakeholders: content experts in empathy and psychology and clinical experts in conducting videotaped simulation sessions in order to test the applicability of the model for practice.

2. METHOD

The method selected for this study is based on the Delphi technique. The technique involves a structured process of conceptualisation and synthesis of knowledge about a particular topic, while sharing opinions amongst experts until reaching a consensus (Renzi & Freitas, 2015; Silva & Sa, 2020). It allows experts to exchange ideas and express personal opinions regarding the design of outcomes, such as social scenarios, research instruments or a practical tool (Renzi & Freitas, 2015; Van der Linde et al, 2005). Table 1 summarizes the steps that were taken throughout the study.

Table 1: Study design

Step		**Description**
1	Producing a group of items based on the literature review	A literature review was conducted of the concept of empathy to identify empathy skills and construct a set of relevant items.
2	Designing the practical tool	The conceptual model was built in line with Step 1 above, and accordingly a practical tool was constructed. It was based on both theoretical knowledge and clinical experience (simulations).

		This tool consisted of seven dimensions, including 23 items of empathy competencies.
3	Selecting experts	Defining the expert selection criteria and contacting each professional. Four specialists in the field of psychology and empathy (content experts) as well as seven facilitators from a simulation centre (clinical experts) accepted our invitation.
4	First round of survey – content validation	A Google Form link of the practical tool was sent to the content experts.
5	Second round survey – clinical validation	Two focus groups were conducted with the clinical experts.
6	Analysis of the responses	The responses were analysed and modifications were made to the tool accordingly.

The first two steps were dedicated to producing and designing a practical tool based on the conceptual model. The next four steps describe the validation process, which is presented in the current paper. We applied this process according to the Delphi technique's principles.

2.1 Validation process of the EPIC practical tool

The two first stages relating to the construction of the practical tool are described in Weinberger, et al. (2022). This paper describes its validation process. The validation process comprised the next four stages: selecting experts, first survey round, second survey round, and analysis of the responses.

The selection of experts: Two groups of experts were selected for validation of the practical tool. The first group concentrated on the theoretical aspect of the EPIC practical tool, and the second group focused on the clinical aspect. Obtaining recommendations from two groups of experts represents a holistic and diverse approach to the issue examined – empathy skills, and makes the process less susceptible to bias or self-interest. The theoretical content group consisted of four senior specialists in the field of psychology and empathy. This group of experts conducts research related to the issue of soft skills and empathy, and lead SEL (Social-Emotional Learning) forums in order to integrate these topics in teacher education programs. The clinical experts group included seven facilitators. The members of this group, four women and three men, are experienced in conducting simulation sessions dealing with varied complex and challenging situations from the field of education. We turned to the experts via e-mail, inviting them to participate in the EPIC practical tool validation process. All of them accepted our invitation.

First survey round: This step refers to the content validation process. It concentrated on the theoretical aspects of the practical tool. We created a Google Form questionnaire adding the tool clauses and two main questions: 1. To what extent does each of the items in the practical tool represent an empathic pattern relevant to interpersonal communication discourse? 2. Do you have any comments? The questionnaire was sent to the specialists separately via e-mail, asking them to complete the form within two weeks. The experts' responses were collected and saved *anonymously*.

Second survey round: This step focused on the clinical aspect of the EPIC tool. We formulated two focus-group settings, which included three segments. In the first segment, the participants were introduced to the study's aim and the tool. In the second segment, a simulation scenario was viewed. This scenario presented a conflict situation between two preschool team members: a novice kindergarten teacher and his veteran teacher's assistant. Afterwards, the participants were asked to individually complete the online questionnaire – identifying empathic patterns and interpersonal communication skills; they then discussed their responses. In the third segment, a different simulation scenario was screened. This scenario presented a parent-teacher conference. Again, the participants were asked to individually complete the online questionnaire, after which they discussed their responses. The two focus group sessions were conducted via the Zoom platform; the duration of each was almost two hours. The sessions were recorded and transcribed. The participants' names were coded to maintain anonymity.

Analysis of the responses: The participants' responses were organised in two documents. One document summarized the responses of the content experts and the second document summarized the clinical experts' responses. Both documents were quantitatively analysed as well as qualitatively, using a content analysis approach. The study authors then separately read these documents, performed an initial analysis and organized the results.

3.RESULTS

3.1 Content validation

The four specialists were asked to rank the degree to which the 23 items represent empathic patterns on a three-level scale (1 = hardly represents, 2= partially represents, 3= highly represents). The descriptive statistics are presented in Table 2.

As shown, a high level of agreement between the content experts was found for most of the tool's items (14 out of 23, 61%). Most (12 items) reached the maximum score (M=3) while another two items were very close (M=2.75). Partial consensus was found for eight items (35%) and a low level of agreement (M=1.25) was found regarding only one item (4%). The experts explained that the item in question, 'assertive discourse', is associated with disengagement, detachment and in some cases, even with alienation. They stated that assertiveness might produce manipulative behaviour rather than empathic action. The experts' comments can be classified into two categories:

1. Items that require modification or clarification: For example, one of the experts indicated that the item, 'using opening remarks', exemplified small talk that might not be relevant to the dialog content or atmosphere. They suggested that this item should express the idea of generating a positive spirit at the beginning of the interchange. Similarly, the experts mentioned that the item, 'body movements', required clarification, while suggesting it be replaced with the phrase, 'body gestures'.
2. Items that reflect duality: For example, 'calm and quiet', as a tone of speech, and 'separation between personal and professional', are ambiguous and may be effective in one context and harmful in another. Likewise, they explained that the item 'using plural language' might obscure the individual perspective of participants in the dialog. Moreover, it was suggested that the item, 'suggesting alternatives', should embrace the idea of reciprocity and a bottom-up process while discussing solutions and possibilities.

The experts also suggested considering the addition of two items to the practical tool in order to strengthen its content validity: 'clarifying the needs of the discourse partners' and 'using trust-based expressions.

Table 2: Descriptive statistics of the EPIC practical tool

The categories	Empathic patterns	**Mean**	**SD**	**Min**	**Max**
High level of agreement	1. Listening attentively	3.00	.00	3	3
	2. Paraphrasing	3.00	.00	3	3
	3. Acknowledging the difficulties	3.00	.00	3	3
	4. Stepping into another's shoes	3.00	.00	3	3
	5. Encouraging dialog	3.00	.00	3	3
	6. Asking clarifying questions	3.00	.00	3	3
	7. Using examples	3.00	.00	3	3
	8. Facial expressions	3.00	.00	3	3
	9. Body movements	3.00	.00	3	3
	10. Content oriented	3.00	.00	3	3
	11. Manner of speech reflecting listening	3.00	.00	3	3
	12. Confident	3.00	.00	3	3
	13. Presenting the purpose of the dialog	2.75	.50	2	3
	14. Alleviating verbal conflict	2.75	.50	2	3
Partial level of agreement	15. Using opening remarks	2.50	.58	2	3
	16. Clear message	2.50	.58	2	3
	17. Separation between personal and professional	2.50	.58	2	3
	18. Absence of response	2.25	.50	2	3
	19. Using explanations	2.25	.96	1	3
	20. Using plural - expressing partnership	2.25	.50	2	3
	21. Calm and quiet	2.25	.50	2	3
	22. Suggesting alternatives	1.75	.96	1	3

Low level of agreement	23. Assertive discourse	1.25	.50	1	2

In summary, the content validation of the EPIC tool showed that most of the items were found to be highly representative of the concept of empathic behaviour. Disagreement was found for only one item. Adjustments were suggested by the experts.

3.2 Clinical validation

The aim of the clinical validation was to examine the practical aspect of the EPIC tool. In this regard, seven clinical experts used this tool for the purpose of analysing the simulation scenarios and then shared their impressions and opinions with their colleagues via focus groups. The clinical experts were asked to relate to whether they could recognize the empathic patterns of the practical tool in the conduct of the participants during the two simulations. Each pattern was dichotomously coded as 'did not appear in discourse' (0) or 'appeared' (1). Table 3 summarizes the seven experts' responses.

The results indicate that there is a high level of agreement among the clinical experts concerning the first simulation scenario depicting collaborative teamwork between a novice kindergarten teacher and a veteran teacher's assistant. The experts agreed that the new kindergarten teacher expressed empathic patterns throughout the conflictual discourse. They described him as authentic, honest and respectful, while smiling and being supportive. The experts indicated that during this simulation, the challenging barriers were removed, and a change towards consensus and accomplishment was achieved. For example, one of the experts said:

> *The kindergarten teacher was very empathic. He spoke in a respectful manner. He treated his assistant with respect. He was calm and pleasant. … I recognized empathic behaviour. He found the way to engage the assistant and gained her trust while building mutual respect and a sense of partnership*.

Table 3: Number of empathic patterns in EPIC tool recognized by the experts, according to each simulation scenario.

Core Patterns	**The categories**	**Empathic patterns**	**Simulation scenario**	
			1	**2**
Verbal Communication	Positioning the Conversation	Using opening remarks	7	0
		Presenting the purpose of the dialog	6	1
	Open Heart Strategies	Listening attentively	7	7
		Paraphrasing	5	3
		Acknowledging the difficulties	6	3
		Stepping into another's shoes	7	1
		Encouraging dialog	7	6
		Asking clarifying questions	7	7
		Using plural - expressing partnership	7	4
	Managing Reactions	Using explanations	7	5
		Using examples	7	6
		Alleviating verbal conflict	7	6
		Suggesting alternatives	7	3
		Absence of response	7	7
	Setting Limits	Clear message	7	3
		Assertive discourse	7	5
		Separation between personal and professional	7	6
Non-verbal Communication	Body Language	Facial expressions	7	4
		Body movements	6	4
	Tone of Speech	Content oriented	7	6
		Calm and quiet	7	5
		Manner of speech reflecting listening	7	5

	Manner of Speech	Confident	7	4

As for the second simulation scenario – a parent-teacher conference, Table 3 indicates that the clinical experts were generally in agreement regarding the ratings of the degree of the student teacher's empathy. They were less confident and less certain regarding the manifestations of the empathic patterns. On the one hand, they felt that the teacher in the simulation exhibited empathic patterns during the dialog with the parent (actor). He listened, asked questions, gathered information and tried to make progress and to provide appropriate answers to solve the problematic issues discussed. He seemed to be honest and respectful. However, his words and body language made the experts uncomfortable. At the same time, they felt that the teacher was not open hearted and did not step into the other side's shoes in order to really understand the parent's point of view. In the experts' opinion, the student teacher was more assertive and less empathic, and at the end of the dialog, progress was barely achieved. The experts, in part, said the following: '*He was a good listener; he asked a lot of questions. The questions were honest. I felt he really wanted to know the answers, but I did not feel he was open to accepting other opinions'*; and: '*He listened carefully to the father but did not enter his shoes at any point of the discussion. He seemed to be interested in the father's thoughts, but he was not open to understanding his point of view'*.

As we can see, the experts' opinions indicate that the EPIC practical tool is sensitive to the differences between the various circumstances, and empathic patterns and their application in educational encounters can be discerned. This fact provides support for the validity of the tool.

The clinical experts also referred to the structure of the EPIC tool. They mentioned that it succeeds in sharpening the concept of empathy, and even more specifically, the items exemplify main empathic patterns. The experts emphasised that the tool was easy to use and suited for use in academic workshops.

Nevertheless, they indicated that some of the items were not clear. One item was, 'using plural – expressing partnership'. They suggested omitting the first part of the item ('using plural') and using only the second part ('expressing partnership'). They also referred to the item, 'separation between personal and professional'. In this regard, the experts stated that the item should be rephrased since it implies distance and non-empathic behaviour. Another comment was made regarding the item, 'using opening remarks'. They believed that this item is relevant to interpersonal communication competency and not unique to empathy skills. Regarding the item, 'using explanations', the experts stated that arguments and explanations can be made without expressing empathy.

4. CONCLUSIONS

The Delphi technique was used to construct and validate a new model for the analysis of empathic patterns: the EPIC practical tool. The aim of the practical tool is to increase student teachers' awareness of empathic patterns and to provide them with an opportunity to practice empathic skills in a safe and controlled environment. In this paper, we focused on the validation process which followed four steps: selecting experts, first round of the survey with content experts, second round of the survey with clinical experts, and analysis of the experts' responses. Involving both content experts and clinical experts allows a holistic perspective and diverse opinions of the concept of empathy and empathic patterns.

Although the two expert groups worked separately, they reached consensus. The Delphi method brought up a variety of comments, ideas and recommendations that provided theoretical and practical recommendations for clarifying and sharpening the model as a practical tool. As a result, some modifications were made which aimed to increase the accuracy of the characteristics of empathy as a complex construct (Gibbons, 2011; Lishner et al., 2017). The modification procedure was conducted by the study's authors and was based on theoretical and methodological considerations. In line with the recommendations emerging from the validation process, the following changes were considered and/or made:

1. The item 'using opening remarks' was changed to 'using opening remarks that convey a positive spirit'
2. The item 'using plural - expressing partnership' was not changed to 'Using expressions indicating partnership' (we decided to omit 'using plural', as suggested).
3. The item 'separation between personal and professional' was changed to 'presenting professional considerations'.
4. The item 'body movements' was changed to 'body gestures'.
5. The item 'assertive discourse' was removed.

The updated EPIC model, as transferred to a practical tool, is presented in Table 4. It is important to note, that some of the patterns included in the practical tool are not unique to the concept of empathy but rather, represent interpersonal communication methods. Nonetheless, they are vital patterns in empathic dialog and should be included in the EPIC practical tool. Generally, the tool was found to be well-structured and easy to use during a simulation workshop.

Good quality of communication is an essential condition for establishing and maintaining a meaningful educational relationship (Altavilla et al., 2021). The importance of empathy as a communication skill has received considerable validation with the introduction of 'social and emotional learning' theory (Durlak et al., 2011). In addition, COVID-19's challenges, facing all education systems, has drawn attention to these social skills, which were in high demand in the workforce in 2020 (Cheng, 2020). Therefore, in the next step, we are planning to construct a pilot study to examine the application of the practical tool among student teachers. The goal of the pilot will be to increase student teachers' capability in using empathic patterns in the educational arena, while facing conflictual situations. The pilot will be based on the three dimensions of the CEA theoretical framework: awareness, understanding and behaviour (Weinberger & Bakshy, 2015). Thus, during the pilot, the students will be introduced to the concept of empathy and the practical tool, learn to identify empathy skills, and practice its implementation in a simulation setting.

Incorporating the practical tool in teacher education programs has the potential to help new teachers cope with challenging educational encounters, while training the mind, the eye and the spirit simultaneously (Janesick, 2015), and develop practices and competencies required to promote future teachers' educational goals (Osberg & Biesta, 2010).

Table 4: EPIC practical tool

Core Patterns	**The categories**	**Empathic patterns**	**Empathic Behaviour Apparent**	
			Yes (1)	**No (0)**
Verbal Communication	Positioning the Conversation	Using opening remarks that convey a positive spirit		
		Presenting the purpose of the dialog		
	Open Heart Strategies	Listening attentively		
		Paraphrasing		
		Acknowledging the difficulties		
		Stepping into another's shoes		
		Encouraging dialog		
		Asking clarifying questions		
		Using expressions indicating partnership		
	Managing Reactions	Using explanations		
		Using examples		
		Alleviating verbal conflict		
		Suggesting alternatives		
		Absence of response		
	Setting Limits	Clear message		
		Presenting professional considerations		
Non-verbal Communication	Body Language	Facial expressions		
		Body gestures		
	Tone of Speech	Content oriented		
		Calm and quiet		
	Manner of Speech	Manner of speech reflecting listening		
		Confident		

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Business Game in Learning / Teaching Process

Temur JAGODNISHVILI[a], Manana KAJAIA[b],
Tamar SHAISHMELASHVILI[c*]

[a] Georgian Technical University, Faculty of Engineering Economics, Media Technologies and Social Sciences, Head of the Department of Georgian Philology and Media Technologies. 77 Kostava St., Tbilisi, Georgia, t.jagodnishvili@gtu.ge

[b] Georgian Technical University, Faculty of Engineering Economics, Media Technologies and Social Sciences, Department of Georgian Philology and Media Technologies, 77 Kostava St., Tbilisi, Georgia, manana_qajaia@yahoo.com

[c] Georgian Technical University, Faculty of Engineering Economics, Media Technologies and Social Sciences, Department of Georgian Philology and Media Technologies, 77 Kostava St., Tbilisi, Georgia, tamartamriko830@gmail.com

Abstract

Knowing the state language is of great importance in the life of the country's citizens: relations with state institutions, discussions and debates in the parliament or in any other state institutions take place in the state language. It is a fact that currently the issue of learning/teaching the state language in densely populated regions is still a problem. In the leading countries of the West, the form of second language teaching is based on content (Content-based second language teaching), i.e. integrated teaching of subject content and language. For integrated teaching, we used the latest method - role play. The aim of the paper is to recognize the contextual semantics of the new word concept in the world of Georgian cultural and linguistic awareness offered in the form of crosswords with collocations and specific target phraseology and in this way to enrich the vocabulary. Business game belongs to the intellectual type of games. The solution of a specific task here is mainly carried out by the method of intellectual storming (brainstorming), the effectiveness of which is well known. By selecting the passed material, it is delivered in a puzzle form. In the first stage, the mini/micro world offered as a puzzle is recognized, the mini/micro world is invaded, and the search word-concept is grasped. In the next stage, there is a move from this micro world (situationality) to the macro world - getting to know the linguistic awareness of the language to be studied. So, the educational cognitive crossword developed and made as a result of the passed material is an effective technology for entering the world of the language to be studied.

Keywords: role play, crosswords, business game, vocabulary, integrated

1. INTRODUCTION

One and the same language, due to the translational education of the speakers of the language, can be the state language in one country, and the language of the national minority in another.

By giving an opportunity of language learning, the state offers knowledge and engagement to its citizens, which is an effective tool for regions densely populated by ethnic minorities. This helps to acquire the state language at an appropriate level and, at the same time, it is an expression of concern for the preservation and development of minority languages. A similar conceptual approach to the integrated teaching of subject content and language leads to the desired result. The state increases the students' motivation to learn the language and assures that bilingual education guarantees their career advancement, which will be a prerequisite for their active participation in various fields.

* Corresponding author.

At the center of teaching should be the student, his interests and needs, the function of the teacher is to cooperate with students and promote the active involvement of each student in the process of gaining knowledge. The teacher should plan the work in such a way that the student develops the ability to analyze, which is necessary for the further use of assimilated material.

For the successful outcome of an integrated lecture, great importance is attached to properly and tastefully selected activities, it is necessary to select attractive content material and also an entertaining form of work, when the teacher's goal is language development for the student, questions and tasks should be presented without intellectual burden. In this way, they will have the opportunity to learn from mistakes by studying new unknown material.

It is desirable for the lecturer to use such a teaching method that corresponds to the students' knowledge, textbooks should be selected very carefully; Students should be offered a variety of activities, exercises, proverbs, riddles, puzzles and more. Also, it is necessary to use a variety of visual materials.

We will focus our attention on one of the important methods - role play.

2. MAIN TEXT

Human nationality and citizenship are based on two main pillars - national consciousness and cultural consciousness, and language is the guide on the way to perceive the world.

"Linguistic-speech environment, together with purposefulness of speech, significantly determines the efficiency and effectiveness of language learning. National environment, i.e. situationality, is typologically of two types: formal and informal. Formal includes: auditorium, academic group, focus group, etc. The informal environment is the living environment: yard, street, community, etc.

An indicator of the role of the informal language environment is the game - a purposeful-thematic imitation of being, the construction of various situations through the game - imitation, in the process of which the language learner constructs a phrase together with the lexical unit of the learning-expressive situation and, accordingly, acquires the element of speech in the language to be learned" (1).

So, target game (business game) plays a certain role in learning a non-native language. This is why the science of education attaches great importance to the targeted type of game - business game.

Effective teaching methods are the starting point of student activity and enthusiasm. Business games play an important role in deepening curiosity and increasing cognitive interest. Through the game, students learn about the world and each other.

The educational effect is based on the mental development of the student and his personality formation. As an active participant, he gains independence and the ability to make decisions, the positive special emotional environment of the games promotes communication, establishing contacts, and creating an attractive environment.

We refer to the students of the Georgian language training program who learn the Georgian language within the framework of the 1+4 program at the Technical University of Georgia. They are the largest ethnic minorities living in Georgia - Armenians and Azerbaijanis, who need integration in the country's life, Georgian society and political reality. For this reason, first of all, the language barrier must be overcome. It is within the framework of the above-mentioned program that they learn the state language, which is their second language.

Obviously, the attractiveness of the content of each integrated lecture depends on the audio-video materials, visuals, etc. When explaining the lecture, it is necessary to use a variety of visual materials. For example, it is possible to collect necessary terms written on paper and cut out in the Georgian language (the language to be studied).

Used terms, new words and phrases should be simplified by paraphrasing. Students who lack self-confidence see every mistake as failure, they think that they are unable to learn. To avoid this the lecturer should use another approach to the students and convince them that they will gradually succeed in everything if they do their best and work hard.

In order to increase student engagement, it is necessary to design various motivating exercises, personal assignments, pair and group work strategies.In order to learn the language and develop practical speaking skills, it is important to listen to the radio, tape recordings, watch videos, read raw and unadapted texts (magazines, advertisements, etc.).

Listening promotes thinking, understanding and further analysis of the text. While listening, the student concentrates on the listening material, makes notes, remembers the main points and conveys what is perceived orally or in writing. For language learners, priority is given to interactive teaching.

While explaining a new material, it would be better to use a variety of visual materials. The new required terms written on paper can be given to the students, and they can also be instructed to complete the specified task using the dictionary.

When planning the lecture, the lecturer should properly assign the relevant material, he should not burden the students with secondary information. The main information should be underlined.

First of all, it is necessary to prepare easy-to-understand material for learning a new topic, and for the next lecture, the diversity of the language is gradually increasing in order to study the topic thoroughly. It would be better if the language learner could narrate in his own words what he understood while reading.

It is recommended that the lecturer use activities in which students "need to find missing information: these types of activities include role-play, situational question-and-answer exercises, problem solving" (2). At this time, group work and information exchange are very important. In this way, their speaking and thinking skills can be trained and their language level can be improved.

Along with the teaching of written and oral general course, in order to check the acquired knowledge and active vocabulary, it is advisable to use educational-business games. The mentioned integrated lessons are intended for assimilation of educational material, thematic material of subject programs. Depending on the specifics of the game situation, associative thinking, visual, emotional and information memorization skills are involved in the process. Among the organizational forms of game activity, the group form of the game is preferred, when opponents strive for the same goal in a competitive environment.

It should also be noted that “role play promotes the process of cross-cultural dialog while providing opportunities for oral communication” (3).

Among the intellectual types of business games, the world of Georgian cultural and linguistic awareness offered in the form of crosswords is very interesting, the solution of a specific task is mainly carried out here by the method of intellectual storming (brainstorming), the effectiveness of which is well known, and it is aimed at penetrating the Georgian linguistic world and mastering its peculiarities. This is the delivery of the conceptual and specific elements of the Georgian world in a puzzle form, which is united by the principle of crosswords. Each stage of the games is loaded with new interactive puzzles, fun tasks.

For example, while learning the text of the foundation of Tbilisi and its sights, it is desirable not only to use documentary sights (photos, audio and video material...), but also show them the spot. And then to conduct an integrated lesson with crosswords. Solving the crossword, after already studied material, gives an effective and desirable result.

The same method can be used while teaching them the text about the life and work of the great Georgian primitivist artist, Niko Pirosmanashvili. Before visiting the museum of Niko Pirosmanashvili in Tbilisi, it is recommended to watch the feature film "Pirosmani", as well as other documentaries and animated films, then the students can visit the existed Museum in Tbilisi, and the symbolic grave of Pirosmani on Mtatsminda. Finally, an integrated lesson with visible materials and crosswords will already bring the appropriate result (Fig.1).

Cooperative learning makes the learning process especially cheerful and develops students' higher-order thinking skills. As a result, it promotes the development of "creative and critical thinking; developing a sense of tolerance and empathy; development of communication skills; to imagine possible perspectives; self-reflection; self-realization" (3).

This is the way to get to know the world of Georgian cultural and linguistic awareness united by the principle of crosswords.

This is the presentation of conceptual and specific elements of our world in a puzzle form. The offer to guess the word with questions and description-characterization creates the situationality of the search word first of all, with targeted description-characterization it outlines the contours of the concept expressed by this word, in this way the face-icon of the search word and the mini (micro) world bordered by this face-icon are created, from where the movement towards the macro world begins in order to get to know and understand the linguistic awareness of the language to be studied.

So, a crossword is an effective technology for entering the world of the language to be studied, but it should also be taken into account that its creation requires a lot of intellectual effort from the author, especially when the crossword is uniquely (thematically-problematically) targeted and is not just a general exercise of wisdom. This is especially true for a crossword designed to facilitate the learning of a non-native language. Intrigue is added to savvy here. Intrigue (to intrigue) also aims to increase interest in the non-native language by focusing on the self-esteem of the language learner.

It should also be noted that in order to test the students’ knowledge, each crossword is accompanied by exercises, dictionary of foreign words and written tasks of the lexical-grammatical type, with attached answers, which, of course, provide even more opportunities to strengthen knowledge. It should also be taken into account that

its compilation requires a lot of intellectual effort from the author, especially when the crossword is exceptionally (thematically-problematic) targeted and not just a general exercise of wisdom.

Crossword puzzles prepared and offered in a non-native language provide educational value.

So, target game (business game) plays a certain role in the acquisition of a non-native language.

3. CONCLUSION

Penetration into the world of Georgian cultural and linguistic consciousness in the form of crosswords is carried out by the method of intellectual storming (brainstorming) and aims to master its peculiarities. The educational value of the paper is important - the proposed technology of studying Georgian, as a non-native language, based on crosswords is new and the first attempt, which, in the future, will naturally arouses to a variety of opinions, discussions, and new points of view.

In terms of achieving results in the work process, the demonstration method, i.e. visual representation of information appeared to be quite effective, while the analysis and explanatory method was advanced during group work, when the students themselves gave explanations to each other while searching for information.

Role play is based on cooperative learning method.

Students do work together, help each other, and during joint learning their mood improves, the desire for knowledge, the need for interpersonal relationships and the sense of responsibility increase.

If the student has well-developed language skills, analytical thinking skills, appropriate lexical-grammatical knowledge, and the ability to connect all of this, he/she will be able to overcome difficult material with joy, raise his motivation and solve the riddles of the linguistic world of crosswords easily.

This paper draws attention to the selection and presentation of linguistic material. It promotes the development of group work skills and practical teaching, improves teamwork skills, teaches analytical thinking and decision-making skills.

4. FIGURES

The crossword

Horizontally: 5. Niko Pirosmani depicted his beloved one on this painting “... Margarita"; 6. He dedicated this painting to the good person who helped the homeless; 9. The character of the musical “Pirosmani"; 10. Sleep medicine; 11. A refrain in a Georgian song; 12. TV presenter ... Grigolia; 14. How old was Nikala when he moved to Tbilisi; 16. Pirosman - “Childless millionaire and poor ... with children"; 17. Nikala - “A girl with a ..."; 18. Gray bird; 22. Cow and ...; 23. I was, you ...? 24. The poet brother of the painter Kirill Zdanevich, who played a big role in the promotion of Pirosmani; 27. Day of the week; 28. “Sorry" - in the native language of Actress Margarita; 29. Pirosmani said: “I was born for … and I must die for …"; 31. “I live in Pirosmani Street and every morning I meet... " (Lado Asatiani); 32. Niko Pirosmani's native village.

Vertically:1. What nationality was Pirosmani's love Margarita? 2. A kind of plant; 3. Nikala _ “Tamar ... "; 4. Georgian musical; 5. Alphabet or...; 7. Single digit number; 8. The first word of Tato’s poem “Merani"; 13. Shout - scares the devil; 14. Nikala - “… of the rich Kinto"; 15. One of the paintings from Nikala's animalistic series; 16. What nationality was Nikala's “Dustman”? 19. “The dog was barking and… was going"; 20. The grave or...; 21. Biblical Moses built; 25. From times immemorial - “From ... and from Baba" ; 26. This artist played the role of Pirosmani in the movie; 29. “The mountain will not meet the .., other wise man will see man again"; 30. Writer ... Yoseliani.

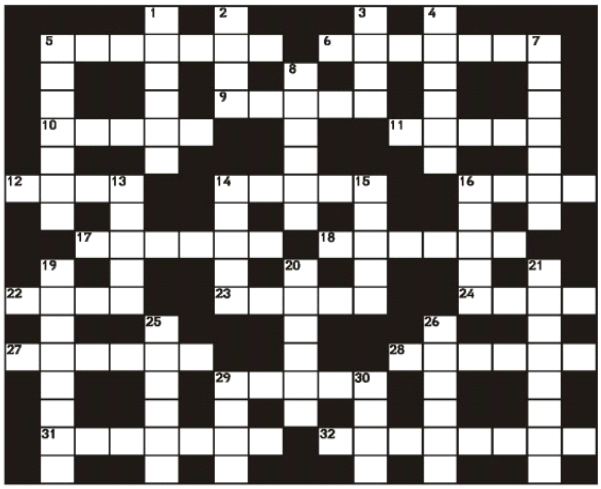

Figure 1

The crossword is accompanied by a dictionary of foreign words and a task to be completed, which contains questions and grammar material.

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Using ASR Technology to Assess EFL Learners' Pronunciation

Sanaa ZIANE [a*], Abdelbasset DOU [b]

[a] *Naama University, Faculty of English, Algeria, sz.sanaas95@gmail.com*
[b] *DSPM Laboratory, Mostaganem University, Algeria, abdelbasset.dou.etu@univ-mosta.dz*

Abstract

This research investigates the potential of Automatic Speech Recognition (ASR) technology in enhancing and evaluating the pronunciation of English as a Foreign Language (EFL) learners. Traditional pronunciation instruction often lacks the capacity to provide learners with immediate, individualized feedback on their strengths and weaknesses. This study aims to address this limitation by examining the effectiveness and perceived value of ASR applications for pronunciation assessment and practice among EFL learners. The research employed an experimental design of a mixed-method approach, incorporating both quantitative and qualitative data collection. Participants, comprising an experimental group of second-year EFL learners at Naama University, were engaged in speech-to-text pronunciation exercises utilizing the Speechnotes application. The study sought to ascertain both the learners' perceptions of using speech recognition software for oral communication improvement and the efficacy of Speechnotes in evaluating their pronunciation. Preliminary findings suggest that ASR tools, such as Speechnotes, serve as a valuable resource for EFL learners, facilitating pronunciation practice and offering immediate feedback on errors. Learners expressed their satisfaction with the experiment despite some limitations related to their self-confidence and technical issues while using the application. A major recommendation for EFL teachers is to apply ASR technologies in their assessment of students' pronunciation.

Keywords: automatic speech recognition, pronunciation, assessment, Speechnotes, EFL context.

1. INTRODUCTION

Using technology in education has been the topic of interest in several research studies. Technology has impacted classrooms, teachers and students at different levels. Foreign language classrooms are one of the major benefited parts of using evolving technologies. Recently, English as a foreign language (EFL) teacher have started to utilize several computer-based or mobile-based strategies of teaching and assessment. However, the speaking skill in EFL context still witnesses challenges and improvements.

In the Algerian EFL context, teachers are based on students' knowledge of transcription to assess their pronunciations in quizzes, tests and exams. As a student at Naama University, learners tend to show more accurate pronunciation than their transcription of the words. That is, they could score better if the exam was oral or acoustic. The assessment of EFL learners' speaking has also been affected by new technologies worldwide. Automatic Speech Recognition (ASR) is an Artificial Intelligence (AI) technology that transforms any human speech into text.

* Corresponding author.

The utilization of such a technology in Algerian EFL classes to assess learners' pronunciation represents a less tackled area.

This paper aims to experiment the effectiveness of using ASR technologies to asses EFL learners' pronunciation. Besides, it aims to explore whether EFL learners at Naama University use ASR tools to improve their pronunciation. The study checks how can EFL teachers of speaking and phonetics benefit from ASR tools to assess their learners' pronunciation. The case of this study is second-year EFL learners at Naama University.

2. AUTOMATIC SPEECH RECOGNITION

One Specialized automated technique for identifying and transcribing spoken language is Automatic Speech Recognition (ASR). The ability of a device to comprehend spoken words is referred to as speech recognition [1]. When used appropriately, ASR is a well-designed speech recognition system that can help teach pronunciation. The computer's capacity to recognize and analyze a student's speech and then write down the words uttered adds realism and interest to the learning process. Additionally, it enables the sharing of pronunciation feedback with the students [2]; [3].

Wang [4] claimed that ASR can be approached from two basic perspectives: the hybrid technique and the end-to-end deep learning approach. To forecast transcriptions, the hybrid technique integrates three models: a language model, an audio model, and a lexicon model. The hybrid technique is currently widely employed, despite plateaus in accuracy.

Levis and Suvorov [1] defined ASR as "an independent, machine-based process of decoding and transcribing oral speech" (p. 316). The process of constructing a word string from an acoustic signal can be used for human-computer interaction [5] or dictation (transcription of a single speaker's monologue) tools, such as Intelligent Personal Assistants (IPA) built into smart devices (smart speakers and smartphones) [6]. The development of this technology began in the late 1940s and early 1950s. But because of novel model approaches and algorithms, advances in noisy speech recognition, and the need to incorporate it into mobile devices, it has been continuously improved [7]; [8].

While this technology is not new, it has advanced significantly in the previous several years to resemble real human speech more closely [9]; [10]. Along with the advancements, text-to-speech applications have drawn interest from academics as a possible pedagogical tool. Particularly, they are thought to be supporting foreign language classrooms with potential use for many language learning purposes and domains [11].

The utilization of ASR tools to enhance the assessment of English learners' pronunciation has been the subject of several researchers. However, in the Algerian EFL context, such an application for such an objective has not been widely conducted.

3. METHODS

This study is experimental research. A quasi-experimental design is followed. Experimental design is a powerful research approach used to investigate cause-and-effect relationships between variables. It is a controlled scientific experiment where researchers manipulate one or more variables (the independent variables) to observe their impact on other variables (the dependent variables). The core purpose is to test a hypothesis predicting that changes in the independent variable will directly lead to changes in the dependent variable. By carefully controlling and manipulating variables, researchers aim to establish clear causal links and draw reliable conclusions about the relationships between different phenomena. [12]

The first population is students of second-year LMD students who are currently studying EFL at the department of English, Naama University. The total number of participating students is thirty (30). They are divided into two main groups: fifteen students are in the experimental group and fifteen others are in the control group.

The experiment goes through three main steps: pre-test, intervention, and post-test. However, this section provides a detailed procedure of the experiment.

3.1. Pre-Test

In the initial phase of the research, the selection process for participants will be conducted meticulously to ensure the formation of two groups with similar proficiency levels. Utilizing a randomized or matched approach, participants at the same level (license 2) will be identified from the department of English, Naama University. This

step aims to minimize any potential biases in group assignment and ensure comparability between the control and experimental groups.

Following participant selection, the pre-test phase will commence, wherein a comprehensive assessment of pronunciation will be administered to all participants. This pre-test will consist of ten words, ten sentences, and one paragraph (see Appendix A), carefully designed to gauge various aspects of pronunciation proficiency among the learners. The recordings of participants' pronunciation attempts will be captured using the Speechnotes application, a consistent and reliable tool chosen for its ease of use and compatibility with the research objectives. Subsequently, the transcriptions of these recordings will be through assessment analysis and scoring based on a predetermined rubric for ASR pronunciation assessment.

3.2. Tests Rubrics

There are three main criteria considered in the assessment of participants' pronunciation: accuracy, fluency, and connected speech. They can be reflected on by the inaccuracies made by the text generated by the speech-to-text application (Speechnotes).

Accuracy (1 point): for correct pronunciation of individual sounds and words, appropriateness of stress and intonation patterns and precision in articulation.

Fluency (1 point): for smoothness and ease of speech flow, absence of hesitations, pauses, or interruptions, and natural rhythm and pacing.

Connected Speech (1 point): for the ability to link words together smoothly, coherence and fluidity in sentence and paragraph delivery, and clear transitions between words and phrases.

Soering is made as follows:

• 3 points: Excellent - Pronunciation demonstrates high accuracy, fluency, and respecting connected speech aspects.
• 2 points: Good - Pronunciation is to a good extent accurate and fluent with minor lapses in connected speech.
• 1 point: Poor - Pronunciation shows noticeable errors in accuracy, fluency, connected speech, impacting overall communication.
• 0 point: Pronunciation significantly hinders understanding due to frequent errors in accuracy, fluency, and connected speech.

3.3. Assigning Participants

Upon completion of the pre-test phase, the recruitment process for participants in both the control and experimental groups will be initiated. Participants will be informed of the study's objectives and requirements, and those willing to participate will be enrolled accordingly. Special attention will be paid to ensuring a balanced distribution of participants across the control and experimental groups to maintain homogeneity and enable meaningful comparisons.

3.4. Training

With participants recruited, the research will progress to the experimental intervention phase, where the focus will shift towards implementing a targeted training program aimed at improving pronunciation skills. The experimental group will undergo a series of six structured training sessions, each designed to leverage ASR technology and associated activities to enhance pronunciation proficiency.

These sessions will incorporate a variety of pedagogical strategies, including pronunciation drills, interactive exercises, and personalized feedback mechanisms facilitated by the speech-to-text activities on Speechnotes application. Throughout this intervention phase, close monitoring and documentation of participants' progress and engagement will be maintained to inform subsequent analysis and evaluation.

3.5. Post-Test

Following the completion of the experimental intervention, the research will transition to the post-test phase, wherein the effectiveness of the ASR-based training program will be assessed through a comprehensive evaluation of participants' pronunciation performance. Similar to the pre-test, participants from both the control and experimental groups will be tasked with pronouncing the same set of ten words, ten sentences, and one paragraph

(see Appendix A). The recordings of these post-test attempts will once again be captured using the Speechnotes application and transcribed for subsequent analysis.

3.6. Experiment Evaluation

By comparing the pre-test and post-test scores between the control and experimental groups, any discernible improvements in pronunciation attributable to the ASR-based training intervention will be evaluated. Statistical analysis will be employed to ascertain the significance of any observed differences and draw meaningful conclusions regarding the efficacy of utilizing Speechnotes as an ASR application for EFL pronunciation assessment and training.

4. RESULTS

Based on accuracy, fluency and connected speech quality, and based on the rubric presented in the previous chapter, the table below demonstrates the total scores of transcribed recordings of the control group participants. The highest total score was by ConS01 (5 out of 9). The lowest score was given to ConS11 (2.5)

Table 1. Pre-test Scores of Control Group

Students	Accuracy	Fluency	Connected Speech	Total
ConS01	1.5	1.5	2	5
ConS02	1	1	1.5	3.5
ConS03	2	1	1	4
ConS04	1	2	1	4
ConS05	1.5	1	1	3.5
ConS06	1	1.5	1	3.5
ConS07	1	1	1	3
ConS08	1.5	1.5	1	4
ConS09	1	1.5	1.5	4
ConS10	2	1.5	0	3.5
ConS11	1	1	0.5	2.5
ConS12	1.5	2	1	4.5
ConS13	1	1	1	3
ConS14	1.5	1	0.5	3
ConS15	2	1.5	0.5	4
Mean	1.366	1.333	0.966	3.666

The Control Group's pre-test scores show variability in accuracy, fluency, and connected speech proficiency. The mean scores are 1.366 for accuracy, 1.333 for fluency, and 0.966 for connected speech. Students generally perform better in accuracy and fluency, but struggle with connected speech, suggesting potential improvement areas.

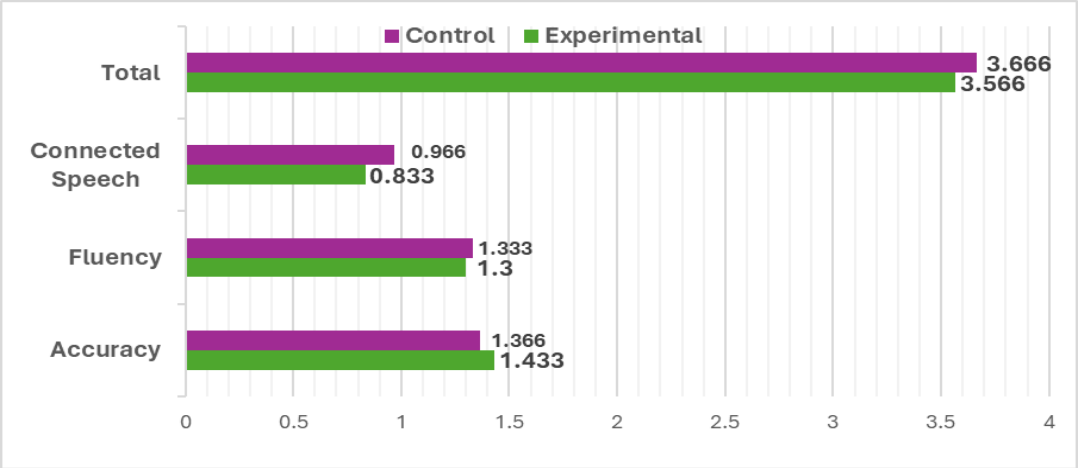
The table below shows the total results of assessing the experimental group pronunciations. After transcribing their recordings via Speechnotes, it appears that the highest score is 5 rewarded to ExpS10. Also, the lowest score 2.5 was given to ExpS1 and ExpS15.

Table 2. Pre-test Scores of Experimental Group

Students	Accuracy	Fluency	Connected Speech	Total
ExpS01	1	1	0.5	2.5
ExpS02	1	1.5	1	3.5
ExpS03	2	1.5	1	4.5

ExpS04	1	1	0.5	2.5
ExpS05	2	1.5	1	4.5
ExpS06	2	1	1	4
ExpS07	1	1.5	1.5	4
ExpS08	1.5	1	1	3.5
ExpS09	1.5	1	0.5	3
ExpS10	2	2	1	5
ExpS11	1.5	1.5	0.5	3.5
ExpS12	1.5	1	1	3.5
ExpS13	1.5	1	0.5	3
ExpS14	1	2	1	4
ExpS15	1	1	0.5	2.5
Mean	1.433	1.3	0.833	3.566

The Experimental Group's pre-test scores show varying performance levels in Accuracy, Fluency, and Connected Speech. The means of



accuracy, fluency and connected speech are 1.433, 1.3, and 0.833 respectively. Mispronunciations were the most significant, while unexpected breaks disrupted the flow. Despite these challenges, some parts were delivered correctly, indicating strengths despite weaknesses. Indeed, some parts were correctly delivered, suggesting that the speech had segments where the delivery was more effective, despite its flaws.

The bar chart below compares pre-test scores of control and experimental groups in three categories: Accuracy, Fluency, and Connected Speech. The Control group has a slightly higher total average score (3.666), while the experimental group outperforms in Accuracy. Both groups have similar challenges in Fluency, indicating potential areas for improvement.

Fig. 1. Comparison of Experimental and Control Groups' Pre-Tests

The intervention phase was directed by teachers of phonetics. The researcher kept on assessing the experimental group's pronunciation through Speechnotes transcripts of sets of words and sentences. After six sessions of training them, they were required to take the post-test along with the control group who did not receive assessment trainings.

Students in both groups recorded the same sets of words and sentences with one paragraph in the pre-test (see Appendix A) using Speechnotes. The table below shows post-test scores of the control group in three categories: accuracy, fluency, and connected speech. Total individual scores ranged from 2.5 to 5. The average scores were 1.333 in accuracy, 1.4 in fluency, and 1.1 in connected speech.

Table 3. Post-test Scores of Control Group

Students	Accuracy	Fluency	Connected Speech	Total
ConS01	2	1.5	1.5	5
ConS02	0.5	1.5	1	3
ConS03	1.5	1.5	1	4
ConS04	1	1.5	1.5	4
ConS05	2	1.5	1	4.5
ConS06	2	1	1.5	4.5
ConS07	0.5	1	1	2.5
ConS08	1	1	0.5	2.5
ConS09	1.5	2	1.5	5
ConS10	1.5	2	1	4.5
ConS11	1	1.5	1	3.5
ConS12	1	1.5	1	3.5
ConS13	2	1.5	1	4.5
ConS14	1	1	1	3
ConS15	1.5	1	1	3.5
Mean	1.333	1.4	1.1	3.833

However, post-test scores of the experimental group ranged from 4.5 to 7 in total. The average scores were 2.133 in accuracy, 1.833 in fluency, and 1.433 in connected speech.

Table 4. Post-test Scores of Experimental Group

Students	Accuracy	Fluency	Connected Speech	Total
ExpS01	2	1.5	1	4.5
ExpS02	2	2.5	1.5	6
ExpS03	2.5	2	1	5.5
ExpS04	2	2	1.5	5.5
ExpS05	2	1.5	1.5	5
ExpS06	2.5	2	2	6.5
ExpS07	2.5	2.5	2	7
ExpS08	2	1.5	1	4.5

ExpS09	2.5	2	1.5	6
ExpS10	2	1.5	1.5	5
ExpS11	1.5	2	1	4.5
ExpS12	2	1.5	1	4.5
ExpS13	2	1.5	1.5	5
ExpS14	2	2	1.5	5.5
ExpS15	2.5	1.5	2	6
Mean	2.133	1.833	1.433	5.4

The bar chart below compares criteria-based post-test scores of control and experimental groups. The experimental group showed higher scores at three levels: fluency (1.833), accuracy (2.133) and connected speech (1.433). Total average scores of the experimental group and control group are 5.4 and 3.833.

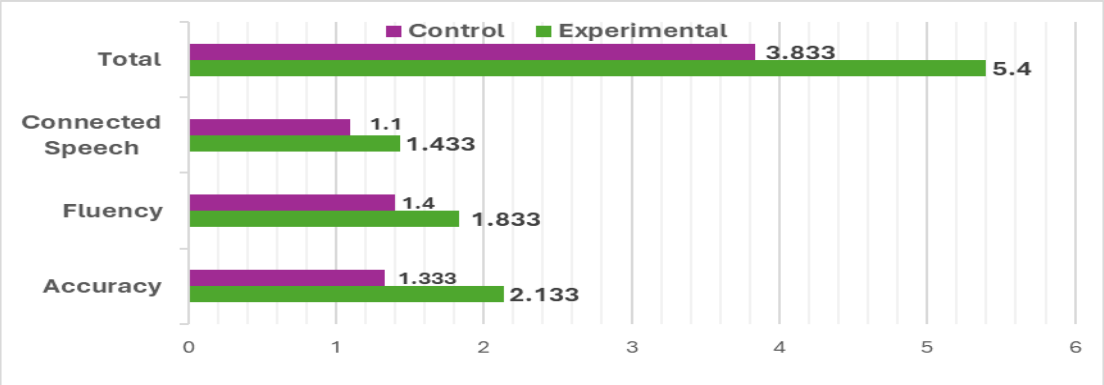


Fig. 2. Comparison of Experimental and Control Groups' Post-Tests

The t-tests are a method for evaluating experiment's results through comparing scores of two samples based on two tests. The t-tests are made to find the t-value and p-value. The first is the result of comparing two means and the second is the value of significance attributed to the progress made by the last test (post-test). The table below shows the overall means of pre-test and post-test of both experimental and control groups and the results of t-tests.

The control group improved slightly from 3.666 to 3.833 with a -0.166 difference. The t-value demonstrates a low value of -0.6102. the significance is 0.27 which is higher than $p < 0.05$. The interpretation of this can be summarized in claiming that there is no significant progress of the control group from the pre- to the post-test.

Table 5. t-tests Results

	Test Phase	**Mean**	***t*-value**	**Sig.**
Control Group	Pre-test	3.666		
	Post-test	3.833	**-0.6102**	.27332
	Diff.	*-0.166*		
Experimental Group	Pre-test	3.566		
	Post-test	5.4	**-6.437**	.00001
	Diff.	*-1.834*		

$p < .05$

By contrast, the experimental group improved obviously from 3.566 to 5.4 with a -1.834 difference. The t-value demonstrates a high value of -6.437. To confirm that the null hypothesis (no-impact) is refuted, a significance of 0.00001 is found in the scores of the experimental group. This significance is lower than $p < 0.05$. The interpretation of this can be summarized in claiming that there is a significant progress of the experimental group from the pre- to the post-test.

5. DISCUSSION

This study explored the impact of ASR technology on EFL learners' pronunciation. The experimental design targeted second-year EFL students at Naama University. Speechnotes application was used in the testing and training sessions. The findings suggest that integrating ASR-based training sessions significantly improved pronunciation skills in the experimental group, demonstrating the potential of this technology for enhancing EFL pronunciation learning.

Pre-test results revealed a varied level of pronunciation proficiency in both experimental and control groups, with challenges particularly observed in connected speech. This suggests a common starting point for both groups, highlighting the need for focused pronunciation instruction. However, post-test results showed a marked improvement in the experimental group's accuracy, fluency, and connected speech compared to the control group. The experimental group exhibited significantly higher scores, indicating the positive influence of ASR-based training sessions.

T-test analysis further confirmed the significant improvement in the experimental group's pronunciation, with a significant p-value lower than 0.05. The experimental group revealed a positive perception of ASR technology through the questionnaire. Students reported a high level of comfort using ASR to assess their pronunciation, believed it could significantly improve pronunciation, and found the activities helpful in identifying and correcting errors. However, a lack of confidence in independent practice was observed, suggesting the need for additional support and guidance for autonomous use. Overall, the participants expressed high satisfaction with the training sessions and perceived them as meeting or exceeding expectations.

The findings indicate that integrating ASR technology into EFL pronunciation instruction can be highly beneficial, leading to significant improvements in accuracy, fluency, and connected speech. However, challenges such as the need for guidance, confidence-building strategies, and addressing potential overreliance on technology should be considered. Future research could focus on developing personalized learning pathways, incorporating strategies to increase confidence in independent practice, and exploring the long-term effects of ASR-based training.

6. CONCLUSION

The present study aimed to investigate the potential impact of using ASR application on the enhancement of the pronunciation of second-year EFL learners at Naama University. Through assessing their speech-to-text practices, an experimental design was launched. Two groups of the same level participated in this study. Further, a questionnaire was designed for the experimental group in order to evaluate their experience. Interviews were also conducted with three EFL teachers. The study found that integrating ASR technology into EFL pronunciation instruction significantly improved learners' accuracy, fluency, and connected speech. Experimental group participants showed marked improvement compared to the control group, with t-tests confirming a significant impact of ASR-based training. This suggests that the first hypothesis of the study is validated.

The study's limitations include the relatively small sample size and the short duration of the intervention. It is recommended for further research to extend the sample size and the period of intervention. Future research is also required to utilize AI tools for assessment to enhance the scoring and assessment phase. To confirm the findings and explore the long-term impact of ASR technology, researchers are also recommended to conduct true experiments in this field. Despite these limitations, the study provides valuable insights into the potential of ASR technology for improving EFL pronunciation. By carefully addressing the challenges and incorporating best practices, educators can leverage this technology to enhance pronunciation learning and create more effective and engaging learning experiences for EFL learners.

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Appendix A. Speech-to-text Tests

Dear L2 students,

You are kindly requested to record the following lists of words and sentences and the paragraph on Speechnotes Application for the assessment of your pronunciation.

Part 1: Words

1. Required	2. Turret
3. Trade	4. Recorders
5. Black wear	6. Racism
7. Thirst	8. Commands
9. Contact	10. Person

Part 2: Sentences

1. She was lost in the dark of night.
2. He knew it was over the rainbow.
3. It's raining hard.
4. I made a mistake.
5. I waited for a while.
6. I'm going to the concert tonight.
7. The last day of March had been rainy.
8. It's the best cappuccino I've ever had.
9. It's the best pie he's ever eaten.
10. He arrived in this immense city through the old entrance.

Part 3: Paragraph

Environmental conservation plays a pivotal role in sustaining the delicate balance of our planet's ecosystems. As human activities continue to impact the environment, from deforestation to pollution, the need for conservation becomes increasingly urgent. By preserving biodiversity, safeguarding natural habitats, and adopting sustainable practices, we can mitigate the adverse effects of climate change and ensure a healthier planet for future generations. Each individual's commitment to reducing their ecological footprint contributes to the collective effort of environmental conservation, highlighting the shared responsibility we all have in protecting the Earth.

Using 3D Printer in STEM Education

Michal NACHSHON[a*], Amira ROM [b]

[a] *Development and Research in STEM Education, Oranim, College of Education, Israel. michal_n@oranim.ac.il*
[b] *Education & Psychology department, the Open University of Israel. amiraro1012@gmail.com*

Abstract

The integration of STEM subjects into a curriculum can be approached in various ways. Teachers engage students with stimulating activities that promote thinking skills at different cognitive levels. Additionally, incorporating scientific experiences and collaborative processes in the classroom, along with advanced technologies like 3D printers, enhances motivation and adds significance to the subjects being taught. Introducing advanced applied scientific experiments not only promotes digital literacy and creative thinking but also fosters thinking processes and independent learning, allowing students to progress at their own pace until they reach their goals. Our research examined the integration of modern technology, specifically 3D printers, in STEM education among college students who were in-training teachers. We used a qualitative paradigm as the primary research method. The findings indicated that these students recognized only benefits from the experience. They enjoyed using the printer and perceived the environment as one that developed the teachers-in-training abilities and skills. The connection to STEM was evident in the identification of knowledge areas required for problem-solving and in the application of operating the printer and related skills. Interestingly, however, the teachers-in-training placed the highest importance on technical aspects, while pedagogical issues received less attention.

Keywords: STEM-education, 3D printer, in-training teachers

1. INTRODUCTION

STEM (science, technology, engineering, and mathematics) learning is a process through which students integrate and blend knowledge, tools and skills, theories, concepts, data, perspectives, and practices from two or more disciplines. The goal of STEM learning is to produce outcomes, to explain phenomena, to solve problems in ways that were not possible using a single discipline. The educational way of thinking at the basis of STEM learning integration comprises an integral part of the forward thinking and development of the Western world. It serves as a springboard for the growth and socio-economic leadership of each citizen, for building students' readiness for a changing world through equity, for nurturing creativity and excellence, and for developing the future generation. This approach is compatible with all students from a variety of education levels (Pramesti et al, 2022) and allows educators to teach while integrating problem-emerging skills to equip the students (Xue, 2022). Many studies have shown that a learning process in STEM can improve cognitive skills (Weyer and Dell'Erba, 2022).The knowledge and skills acquired while learning the knowledge areas of STEM education accelerate education for thinking and are based on acquaintance with interdisciplinary phenomena and ideas, on the natural connectedness of the four knowledge areas and experience in planning solutions to complex, interrelated problems, using up-to-date technology and tools and suiting them to the modern workforce. The basis for learning is a passion for knowledge, and curiosity and respect for science and engineering, through the creation of a collaborative process led by educators, in formal and informal frameworks. And

* Corresponding author.

indeed, STEM education equips students with the necessary capabilities required for future changes. One way to do this is through the engineering design process, activities that reflect problems in the real world and their link to conceptual learning (King & English, 2016).

The five guiding principles of STEM education focus on integration, establishing relevance, focusing on 21st century skills with the goal of enabling students to be relevant as a modern workforce, project planning, and being careful to offer students a variety of classes and activities. STEM, according to this approach, is not a curricular component; rather, it is a tool for understanding and implementing instructions, applying knowledge, working as a team, listening to and offering criticism to one's peers and understanding the relevance of the acquired knowledge. Not every learning experience will include these components, but it is important that teachers have a deep understanding of the connections that can be made between them and are helped to establish a community of active learners focusing on doing. Pramesti et al. (2022) also noted the main teaching goals of the STEM approach focusing on preparing students for problem solving in an innovative and creative way, integrating critical thinking – cooperatively – through interpersonal communication with the goal of promoting acquisition of new information and knowledge enhancement.

Following the implementation and evaluation of an innovative curriculum for teaching sound, waves, and communication systems, Awad and Barak (2018) wrote about the effect of the integration of lab and project experience in STEM learning on students' level of interest, achievements, and motivation, and on their attitudes toward science and technology. Beyond that, as early as 1983, Gardner's theory of multiple intelligences stated that it is important to allow each student to express their abilities in ways that suit them. Nachshon and Rom (2018) also emphasized the importance of diversity in teaching methods for the advancement of students, advocating for providing students with different ways to express their abilities in the best possible way.

Introducing advanced applied scientific experiments constitutes a significant part of STEM education. It promotes digital literacy together with creative thinking during the process of grappling with an open assignment that includes several answers and fosters thinking processes and independent learning, done at students' personal pace who continually learn from their mistakes and correct them until reaching their goal. The integration of STEM subjects in a curriculum is done in several different ways. The teachers engage students using stimuli while fostering thinking skills. They enable students to find on their own, ways to solve problems by identifying the interconnected scientific knowledge areas where answers may be found. Moreover, the integration of scientific experience and collaborative processes in class, as well as the integration of advanced technologies, like 3D printer, intensify the motivation and impart significance to the subjects being taught (Reinking & Martin, 2019).

For the integration of 3D printing technology in teaching and learning within an elementary school in an interdisciplinary integration with a STEM approach, a pedagogical knowledge framework and technical support is required to guide teachers in their training processes and also for students in the implementation process in the classroom. Abu Khurma et al.(2023) also emphasize the positive perceptions of students and teachers regarding the interdisciplinary integration of 3D printing technology in teaching and learning but with the receipt of appropriate pedagogical training and technical aspects of 3D printing.

That's why we address the training of the students, we want to examine the teachers' training. And from this standpoint arises the research question: How do teachers studying toward a graduate degree in science education perceive the integration of a 3D printer in STEM education?

2. METHODOLOGY

The research examines the integration of cutting-edge technology, using the example of a 3D printer, in STEM studies among teachers studying toward a graduate degree in science education.

In this study, a qualitative paradigm was used as the primary research basis. Qualitative research paradigms stress the subjective experience, in order to expose and examine the unique context by developing a deep observation ability of phenomena from the personal perspective of individuals participating in the research (Patton, 2002). In this way, an understanding of the phenomena from the perspective of the participants develops, with the researchers' goal to hear how they understand the world in which they live.

The focus of this type of study is to understand phenomena, as they appear in the real world and through the eyes of those who experience them (Shakedi, 2012). In a qualitative research study, there is no single "correct" reality; rather, there is a collection of realities commensurate with the number of study participants.

The research was conducted among 28 graduate teacher-students - in-service teachers, training to be elementary school teachers, in the aim of integrating the design and 3D printing processes in the three-year program for teachers. At the end of the experiential section, the attitudes of the teacher-students toward integration of advanced technology, represented by the 3D printer, in STEM education were examined. They were required to note benefits and weaknesses

in relation to the link between their experience with the printer and the rationale of STEM education, to note the added value of gaining experience with the 3D printer technology, and to note the degree of enjoyment from the experience.

In the second stage, the teacher-students were asked to try to integrate the 3D printer into their science lessons in elementary schools, preferably in the upper grades. After the experience, they had to write down what challenges they encountered.

3. FINDINGS

The teacher-students were asked to relate to the benefits and drawbacks of integrating advanced technology following their experience using the 3D printer in STEM teaching. Their responses provided 99 statements. We can see in figure 1 that all the statements related to benefits only: enjoyment of the actual experience (39 statements), to a connection with STEM (38 statements) and to the added value in its use (22 statements).

The statements can be divided into three main themes: developing abilities and skills (50% of the statements), the importance of interdisciplinary integration (35% of the statements), and future applicability and demonstration (15% of the statements).

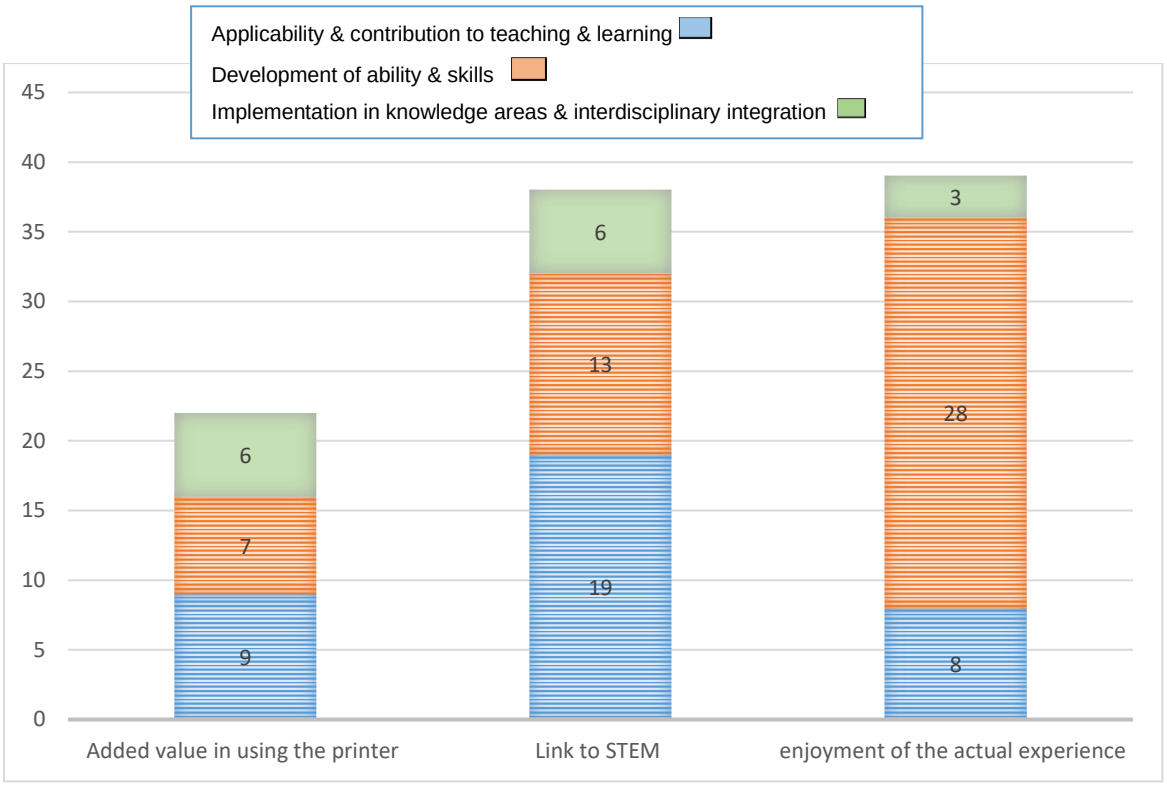

Figure 1: Distribution of the statements of the in-training teachers regarding integration of advanced technology through use of a 3D printer in STEM education (99 statements)

It appears that the in-training teachers not only experienced the process but also generated worthy products (see Figure 2), which were designed and printed with the aim of being used as a teaching aid for the topics being taught.

Figure 2 illustrates the 3D printer products that were used as teaching aids in teaching various topics:

1: A model comparing the planets in the solar system in terms of their size, location, and distance from the sun.
2-3: The characteristics of insects (winged insect and an insect with 6 legs) that include the structure of their body divided into three (head, chest and stomach), a pair of eyes, and antennas.
4: A model to demonstrate the relationship between surface area and volume.
5: A cross-section of lungs that enables demonstration of how their structure matches their function.
6: The echo chamber of a musical instrument, an ocarina, an ancient musical instrument, similar to a flute. It is round, with a hole on its side for blowing into, on its upper part; on its lower part, it has several holes for air to

escape and create musical notes.

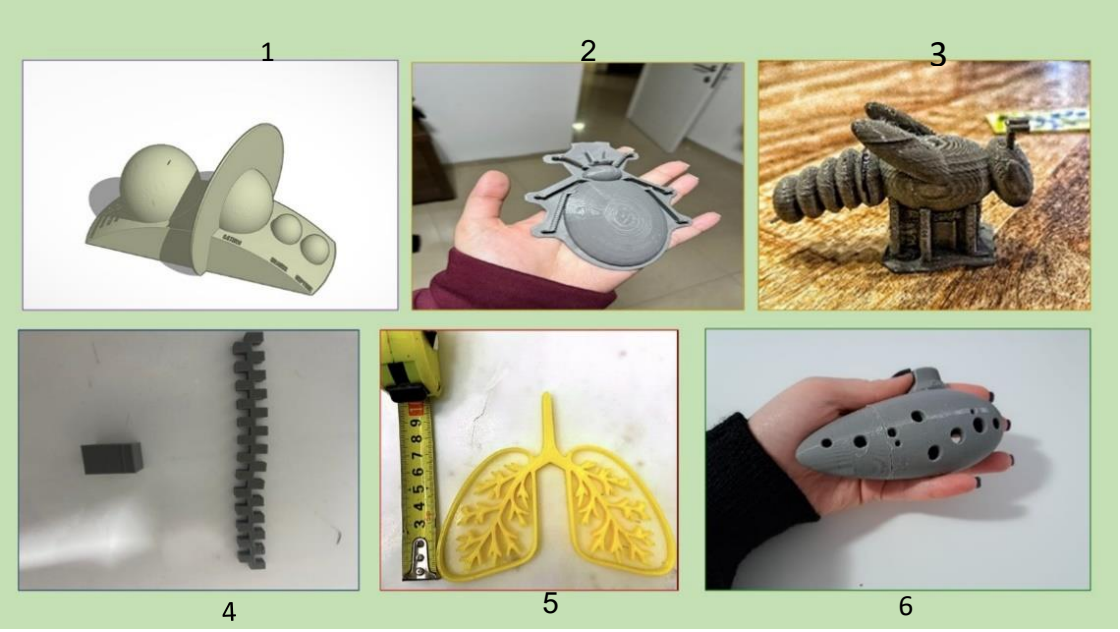

Figure 2: Teaching aids produced using the 3D printer

At the end of the presentation of products, a discussion was held about the limitations of the model in terms of its size, lack of mobility and that it was fixed to the base, its color, and the emergence of marks during its printing.

As we said before, in the second stage, the teacher-students were asked to try to integrate the 3D printer into their science lessons in their schools, preferably in the upper grades, and they had to write down what challenges they encountered. We collected all the answers and sorted them according to the criteria that arose from them. In table 1 we can see their answers.

It is interesting to note, as shown in Table 1, that the respondents placed the highest importance on criteria related to technical aspects, particularly logistics [61 (73.5%) of responses]. Pedagogical issues received less attention [22 (26.5%) of responses], with some mention of the need for teacher training.

Table 1: The teachers' answers to the challenges faced by integrating a 3D printer into STEM studies (83 answers)

The criteria	The answers	Answer type	Number of responses
Technical Complexity	3D printers require some level of technical expertise to set up and operate. Teachers need training to effectively use the equipment, troubleshoot issues, and maintain the printers.	Technical	17
Cost	3D printers and their associated materials can be too expensive for schools. Only one 3D printer available to schools, affecting the frequency and scale of 3D printing projects.	Technical	16
Maintenance and Repairs	Personnel problem: 3D printer needs regular maintenance, such as cleaning and calibrating, to ensure it function properly. Teachers may need support from technical staff or external resources for more complex repairs.	Technical	12
Safety Concerns	3D printers often use hot materials and moving parts, which can pose safety risks, especially with younger students. Teachers need to implement safety protocols and closely supervise students during 3D printing activities.	Technical	9
Time Constraints	Preparing 3D models, setting up the printer, and waiting for the printing process to complete can be time-consuming. This impact the integration of 3D printing into the regular curriculum, where time is already limited.	Pedagogical / Technical	9
Limited Curriculum Integration	Integrating 3D printing into the existing curriculum can be challenging. Teachers may struggle to find relevant and age-appropriate projects that align with educational standards.	Pedagogical	7
Software Challenges	Designing 3D models requires specialized software, which may be complex for elementary school students. Teachers may need to invest time in learning and teaching these software tools or find user-friendly alternatives.	Technical	4
Resource Availability	Access to a variety of materials for 3D printing, may be limited. This could impact the diversity of projects and materials that students can work with.	Technical	3
Limited Professional Development	Teachers may lack sufficient training and professional development opportunities related to 3D printing. Continuous learning is crucial for staying updated on new technologies and teaching methods.	Pedagogical	3
Curriculum Alignment	Aligning 3D printing activities with educational goals and standards can be challenging. Teachers may need support in creating projects that not only engage students but also contribute to their overall learning objectives.	Pedagogical	3

4. CONCLUSIONS

The research examined the integration of modern technology, represented by a 3D printer, in STEM studies among in-training teachers. The research showed that these teacher-students identified only benefits from the experience. They enjoyed the actual experience of using the printer and, identified the environment as developing students' abilities and skills. The link to STEM was expressed primarily in the application of operating the printer and developing abilities and skills.

In agreement with the approach of Reinking and Martin (2019), we found that using the 3D printer in STEM classes can lead to a unique learning experience involving advanced technology that combines active participation by the student, heightens creativity and innovativeness, improves analytical skills, problem solving over the long term, and critical thinking. The experience can also foster students' imagination up to the point of actual application in reality and boost design thinking. These skills can help people cope with global problems later on in life.

The study found that integrating a 3D printer in STEM studies is very important. The connection is natural and contributes to students' using skills and acquiring tools that will help them integrate in the 21st century technological society – alongside greatly enjoying themselves, feeling that they are realizing their potential in handling a problem having many solutions and coping with challenges.

3D printers should be made part of elementary as well as high school curricula. Every school should have such a printer and the necessary materials so that students are exposed to this field. Experiencing using a 3D printer in school ensures that students will be responsible for the results of the assignment that requires them to use their imagination while getting the opportunity to experiment with resources to reach results that may be successful or a failure. This experience can transform the process into something realistic and relevant to the digital space while also requiring involvement and the possibility of developing an educated, learning, and progressive community.

Introducing 3D printers in elementary schools can be an exciting and innovative addition to the learning environment. However, there are several challenges and difficulties that teachers may encounter during the implementation process. The lack of emphasis on pedagogical aspects by teachers, as part of the challenges in teaching through the integration of a 3D printer, indicates an absence of meaningful understanding in utilizing unique teaching methods tailored for integrating this printer.

These research findings confirm those of the study by Abu Khurma, Ali and Swe Khine (2023) who emphasized the positive perceptions of students and teachers regarding the interdisciplinary integration of 3D printing technology in teaching and learning. However, even there it appears that teachers are more likely to implement 3D printing in their classrooms when they receive appropriate pedagogical training and technical aspects of 3D printing.

Despite these challenges, with proper training, support, and planning, many of these difficulties can be overcome. Successful integration of 3D printing in elementary schools requires a collaborative effort involving teachers, administrators, technical support staff, and potentially external experts.

A central conclusion is that in order to implement the use of a 3D printer in STEM studies, it is necessary to act on two levels: on the first level - to overcome the logistical problems even if a larger budget has to be injected. Because it is our duty to train the young students for advanced skills, the 21st century skills.

And on the second level - to take care of advanced teachers' training. The professional development of teachers in STEM education should not stop at this point. They must experience and learn how to promote their students to 21st century skills.

Although the experimenters in this study were actual teachers who underwent additional training in STEM education, most of our conclusions highlight the integration of the 3D printer in STEM teaching as a significant tool that promotes student engagement and allows them to express their abilities in diverse ways. As Gardner (1983) suggested in his theory of multiple intelligences, each student must be allowed to express his or her abilities in ways that suit them. Integrating the 3D printer into teaching supports this goal.

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The Relationship between Teacher Self-Efficacy and Subjective Well-Being

Nikoleta IZDENCZYOVA [a*]

[a] *University of Presov, Faculty of Education, Department of Pre-school and Elementary Pedagogy and Psychology, 17. November 15, Presov, Slovakia, nikoleta.izdenczyova@unipo.sk*

Abstract

Previous studies demonstrate the importance of teacher self-efficacy and its association with a wide range of teaching and learning outcomes. These outcomes include teachers´ classroom behaviour, effort and goal-setting, their openness to new ideas, resilience, enthusiasm for teaching and longevity in their chosen career. The aim of this paper was to investigate the relationship between teacher self-efficacy and subjective well-being in students studying in the field of education and primary teachers. Two hundred and sixty-nine respondents participated in the research (159 bachelor students and 110 primary teachers). The research instrument used to measure teacher self-efficacy Slovak adaptation of The Ohio State Teacher Efficacy Scale (OSTES) and for subjective well-being were used The Emotional Habitual Subjective Well-Being Scale (SEHP) and The Overall Life Satisfaction (CZS). The Mann-Whitney test found no significant difference between the two groups of students on each of the variables measured. The results show a significant association between teacher self-efficacy and subjective well-being, while the strongest relationship was found between teacher self-efficacy and the cognitive component of subjective well-being.

Keywords: teacher self-efficacy, subjective well-being, student of pedagogy, primary teacher

1. INTRODUCTION

1.1. Teacher self-efficacy

The term self-efficacy its author A. Bandura (1997) defines as a person's belief in his/her abilities to overcome obstacles, stay motivated, achieve goals and perform well in meeting them. Teacher self-efficacy can be understood as a subjective assessment of the potentiality to carry out pedagogical activities, to achieve the desired outcomes of pupils' engagement and learning, even when pupils are unmotivated and difficult to work with (Tschannen-Moran, & Woolfolk Hoy, 2001; Poulou, 2007; Mojavezi, & Tamiz, 2012). This is a perspective very different from both theoretical models of teacher competence and objectively assessed teacher characteristics. This is because it is the teacher's subjective view of himself/herself. This theory emphasizes the role of beliefs about one's own abilities, which determines the subjective evaluation of what the individual believes he or she can still do and what he or she cannot do anymore.

* Corresponding author.

Previous research on self-efficacy has supported the thesis that a person's judgment of his or her self-efficacy in a particular activity is a good predictor of performance in that activity (Bandura 1997; Savia, 2008; Cheng, & Chiou, 2010). Research confirms the impact of teacher self-efficacy not only on the performance of the teacher himself or herself but also on the performance of his or her students, as teachers with high self-efficacy are more open to new ideas and new teaching methods; show higher levels of planning and organization, are more constructive in dealing with their students' mistakes, and are more persistent in the face of difficulties (Tschannen-Moran, Hoy, & Hoy, 1998; Mojavezi, & Tamiz, 2012; Künsting et al, 2016; Shahzad, & Naureen, 2017). Teacher self-efficacy also demonstrates a positive association with factors underlying teachers' psychological well-being, including personal accomplishments, job satisfaction, and commitment to stay in the profession (Wang, Hall, & Rahimi, 2015; van Rooij, Fokens-Bruinsma, & Goedhart, 2019). Conversely, negative associations have been found between teacher self-efficacy and factors of psychological burnout and perceived stress (Schwarzer, & Hallum, 2008; Zee et al., 2016; Skaalvik, & Skaalvik, 2017; Ghasemzadeh, Nemati, & Fathi, 2019).

According to Bandura (1997), the most important sources of self-efficacy are previous mastery experiences with similar types of tasks (serving as an indicator of capability); verbal persuasion (e.g., social support from colleagues and the school administration); vicarious experiences (e. g., modelling and observation of techniques, observing other teachers mastering similar challenges); and emotional arousal (associated with the perceived capability that influence the process and outcomes of the task attempted, e.g., teacher noticing his or her heartbeat when facing a challenge). The four sources undergo a form of cognitive processing that determines how the source of information will be weighted and influence the desired teaching task.

Given that Bandura (1997) describes mastery and vicarious experience as the main sources of self-efficacy, it can be assumed that self-efficacy will increase with years of teaching experience. Experience may be a key ingredient in teacher's sense of efficacy. This assumption was confirmed in the research of Tsui (1995), who found that years of teaching experience in the classroom environment is a predominant factor in shaping feelings of teacher efficacy. Similarly, however, Coladarci, & Breton's (1997) study found a weak but significant positive correlation between age and personal teaching effectiveness. Four years earlier, a study by Hoy and Woolfolk (1993), yielded a weak correlation between teachers' personal self-efficacy and years of teaching experience. In contrast, a study by Tschannen-Moran & Woolfolk-Hoy (2002), yielded no significant differences in teacher self-efficacy by age or gender. However, the same study revealed significant differences between experienced and novice teachers.

1.2. Subjective well-being

Definitions of subjective well-being emphasize either the emotional aspect, the cognitive aspect, or use a combination of both. According to Diener (1984), the emotional component of subjective well-being can be divided into two partial components, namely positive and negative affect. The cognitive-evaluative component includes global life satisfaction and satisfaction with various specific areas of life. The circular model of affective reactions has been used to elucidate the nature of the emotional component (Watson, Clark, & Tellegen, 1988, In Džuka, 2004). This model also serves as a starting point in measuring the emotional component. The circular model can be reduced to two mutually independent dimensions - positive and negative affect. When measured, positive affect is represented by positive adjectives and negative affect is represented by negative adjectives. In the case of measuring the emotional component of subjective well-being, it is about how often (not how intensely) persons experience particular affective reactions. To measure the cognitive component, both an assessment of a person's satisfaction with his or her life globally and an assessment of a person's satisfaction with specific areas of life are used.

Scholars in the field of subjective well-being claim that the employees' evaluations of their lives are essential phenomena and should be considered as an aspect of a good life. They also had indicated that subjective well-being is beneficial for demonstrating citizenship behaviour, work performance, and resilience (Diener et al., 2018). There is some evidence on the relationship of teachers' subjective well-being to student outcomes (Caprara et al., 2006; Duckworth et al., 2009; Hwang et al., 2017).

Over the past few decades, there has been a shift in research on subjective well-being away from trying to identify the needs whose satisfaction will result in a sense of happiness. Instead, researchers have sought to identify comparative factors that influence whether or not resources will affect subjective well-being. In other words, whereas past researchers have attempted to identify external, situational, or bottom-up factors that consistently influence happiness (e.g., health, financial income, age, gender), more recent research has focused more on top-down processes in an individual's personality (personality factors, adaptation, coping, locus of control, resilience). Bottom-up and top-

down models of subjective well-being are seen as contradictory by, e.g., Feist et al. (1995). Diener et al. (1999) already 25 years ago recommended placing more emphasis on the interaction of internal factors (e.g., personality traits) and external life circumstances in research on subjective well-being. Whereas, according to bottom-up theories, objective life circumstances may be the primary predictors of an individual's level of subjective well-being, from a top-down perspective, our subjective interpretations of life events have the primary influence on our subjective well-being. Experiences are not objectively good or bad, but are subjectively interpreted. Thus, we can include self-efficacy among the top-down factors.

1.3. Relationship of teacher self-efficacy and subjective well-being

According to Bandura (1997), high levels of occupational self-efficacy are related to stress reduction, higher self-esteem, physical health, and life well-being. Conversely, low levels of occupational self-efficacy are related to more symptoms of anxiety and depression, as well as lower levels of subjective well-being (Bandura et al. 2003).

A number of studies have investigated the relationship between occupational self-efficacy and subjective well-being. These studies have shown that higher levels of occupational self-efficacy are positively associated with greater subjective well-being among educators and other professionals. For example, a study by Bandura, & Locke (2003) found that teachers with high levels of occupational self-efficacy reported higher levels of job and overall life satisfaction. Similarly, a study by Scholz et al. (2002) found that occupational self-efficacy was positively related to work-related stress, with individuals with higher levels of self-efficacy experiencing lower stress levels and greater overall well-being. Other studies have explored the potential negative impact of low occupational self-efficacy on subjective well-being. For example, a study by Betoret (2006) found that low self-efficacy among teachers was associated with increased levels of burnout and reduced job satisfaction.

Some studies have also examined the role of self-efficacy in enhancing or undermining well-being specifically in educators. It was found that teachers with higher levels of self-efficacy had greater job satisfaction than teachers with lower levels of self-efficacy (Caprara et al., 2003). Similarly, Tschannen-Moran, & Hoy (2007) found that self-efficacy beliefs were a significant predictor of teachers' job satisfaction and that teachers with high levels of self-efficacy were more likely to persist in their careers and experience greater overall well-being. A significant correlation between self-efficacy and subjective well-being has also been found in other studies (Caprara, & Steca, 2005; Yu et al., 2005; Cui, 2016). When teachers possess high self-efficacy in performing required tasks, they experience favourable outcomes including satisfaction (Zee et al., 2016) and well-being (Huang et al., 2019; Perera et al., 2019; Moè, & Katz, 2020).

However, not all studies found a significant relationship between occupational self-efficacy and subjective well-being. For example, a study by Bakker et al. (2004) found that self-efficacy beliefs did not significantly predict work engagement or burnout in health care workers. Despite some mixed findings, most research supports the notion that professional self-efficacy is an essential predictor of subjective well-being in educators and other professionals. Self-efficacy beliefs can influence an individual's motivation, resilience, and ability to cope with work-related stressors, which in turn affects their overall well-being and job satisfaction. However, self-efficacy beliefs are not static and can be influenced by a variety of factors, including workplace conditions and relationships.

2. METHOD

2.1. Research design and instruments

The aim of this paper is to determine the relationship between teacher self-efficacy and the subjective well-being of future and practicing teachers. Due to the disproportionate representation of men and women in pedagogical fields of study and among primary teachers, no gender differences were detected. Based on the information presented in the theoretical part, the following hypotheses were tested:

H1: Primary teachers will have significantly higher teacher self-efficacy than bachelor students of pre-school and elementary pedagogy.

H2: Respondents with a higher score in teacher self-efficacy will experience greater subjective well-being (they will have a higher score in positive affect, a lower score in negative affect and a higher score in satisfaction with life).

The data collection was conducted in January and February 2024 in print form among students of pre-school and elementary pedagogy and among primary teachers. Three main research instruments were administered:

Slovak version of The Ohio State Teacher Efficacy Scale (OSTES), and to measure respondents' subjective well-being we used two instruments: the Emotional Habitual Subjective Well-Being Scale (SEHP) and the Overall Life Satisfaction Scale (CZS).

Slovak adaptation of The Ohio State Teacher Efficacy Scale (OSTES)

The Ohio State Teacher Efficacy Scale (OSTES) (Tschannen-Moran, & Woolfolk Hoy, 2001), the instrument to measure teacher self-efficacy was translated into Slovak version by Gavora (2011). Good reliability of the instrument was found - Cronbach's alpha coefficient was 0.94. The instrument consists of 24 items. The questions focus on what the teacher (or preservice teacher) is able to do in a given situation. For example, „What are you able to do to help students better understand the curriculum?“, or „How much can you do to get children to follow classroom rules?“ Respondents select an answer on a 9-point scale, ranging from 1 = „nothing at all“ to 9 = „very much“. The higher the score on the questionnaire, the better the respondent's teacher self-efficacy.

The Emotional Habitual Subjective Well-being Scale (SEHP) (Džuka, & Dalbert, 2002)

The Emotional Habitual Subjective Well-Being Scale (Džuka and Dalbert, 2002), capturing the emotional components of subjective well-being, consists of two subscales. It contains a total of 10 items representing positive and negative emotions and bodily sensations. The scale measuring positive experiencing consists of 4 items (enjoyment, physical freshness, joy, happiness) and the scale measuring negative experiencing consists of 6 items (anger, guilt, shame, fear, pain, sadness). Respondents indicate the frequency of occurrence of a given emotion or bodily sensation on a 6-point scale with the response format: „almost always“ (6), „very often“ (5), „often“ (4), „sometimes“ (3), „rarely“ (2), „almost never“ (1). For example, item 1 is: "How often do you experience anger?" For positive experiencing, the reliability is expressed by a Cronbach's coefficient of 0.84, for negative experiencing 0.82.

The Overall Life Satisfaction Scale (CZS) (Dalbert, 1992)

The Overall Life Satisfaction Scale (CZS) is one of the two scales of the original Allgemeines Befinden (Dalbert, 1992) and captures the cognitive component of subjective well-being. It consists of 7 items and the person's task is to judge to what extent the item fits him or her. The degree of agreement is expressed by the person by selecting the appropriate number on the numerical scale, where the number 6 means “fits completely”, 5 means „fits to a great extent”, 4 means „fits somewhat“, 3 means „does not fit rather well”, 2 means „fits to a great extent”, and 1 means „does not fit completely”. For example, item 1 reads „My life could hardly be happier than it is.” The Cronbach's coefficient for this scale is 0.80.

The collected data were analyzed using SPSS 25.0 software. Among statistical methods, Mann-Whitney U-test and Spearman's correlation coefficient were used to find out the relationships among the variables. Due to the size of the research population and its composition, the gender of the respondent was not taken into account in the analyses and only students were compared with primary teachers.

2.2. Research sample

The research sample consisted of primary teachers and 1st year Bachelor's degree students studying in the Early Childhood and Elementary Education programme. Teachers were from 11 primary schools in Košice and Prešov districts (eastern part of Slovakia). A total of 110 teachers participated in the study, 7 of them were male and 103 were female. The average age of the teachers was 43.84 years, with the youngest participant being 26 years old and the oldest 63 years old. The average length of teaching experience of the respondents was 17.19 years, ranging from 1 year to 43 years of experience. A total of 159 students participated in the study. The mean age of the students was 20.2 years (range 19.08 - 23.3). There were 4 males and 155 females among the students.

2.3. Ethic statement

The aims and objectives of the research were explained to the students and teachers. Written informed consent was obtained from all participants involved in the study.

3. FINDINGS

There was no significant difference in the final score in teacher self-efficacy, nor in the components of subjective well-being between students of pedagogy and primary teachers. The assumed difference in teacher self-efficacy between students and teachers based on the research of some authors was not confirmed.

Among the components of subjective well-being, respondents scored lowest on *negative affect* (a subscale of the emotional component of subjective well-being). In this subscale, a maximum score of 6 was possible, a mean score of 2.70 was measured for students, and a mean score of 2.44 was measured for teachers. Only 11 teachers and 14 students experienced negative emotions more often than occasionally (their mean scores were higher than the scale mean of 3.5).

In the *positive affect*, (a subscale of the emotional component of the subjective well-being), respondents could achieve a maximum score of 6. The mean score for students was 4,01 and for teachers was 3.74. 21 students and 18 teachers achieved a mean score higher than the scale mean (3.5) - that is, they experienced positive emotions more often than occasionally.

Both groups of respondents scored highest on the cognitive component of subjective well-being – *overall life satisfaction*. Here, a maximum score of 6 was possible. The mean score was 4.65 for students and 4.71 for teachers. For no teachers and only for 5 students, the mean score in this component was below the scale mean of 3.5. These students were rather dissatisfied with their lives.

Table 1. Difference in the values of the variables: teacher self-efficacy and components of subjective well-being between students of pedagogy and primary teachers

	Students (N = 159)		Teachers (N = 110)		
	AM	SD	AM	SD	Mann-Whitney test
Teacher self-efficacy	7,54	0,90	7,41	0,79	ns
Positive affect	4,01	0,73	3,74	0,97	ns
Negative affect	2,70	0,69	2,44	0,61	ns
Life satisfaction	4,65	0,73	4,71	0,63	ns

(Abbreviations: AM – arithmetic mean, SD – standard deviation, ns – nonsignificant)

Subsequently, we investigated the association between the teacher self-efficacy score and the components of subjective well-being through Spearman's correlation coefficient. We included all participants in the analyses because of similar results in mean scores between students and primary teachers. The strongest association emerged between teacher self-efficacy scores and life satisfaction (cognitive component of subjective well-being). Regarding the emotional component of subjective well-being, its *positive affect* component correlated positively with teacher self-efficacy (but only at the $p \leq 0.05$ level), whereas *negative affect* correlated negatively with teacher self-efficacy. These results confirm that high teacher self-efficacy corresponds with higher subjective well-being scores.

Table 2. Correlations between variables: teacher self-efficacy and components of subjective well-being obtained across the entire research sample (N = 269)

Components of subjective well-being	Teacher self-efficacy
Positive affect	0,244*
Negative affect	-0,371**
Life satisfaction	0,384**

(Abbreviations: * $p \leq 0,05$, ** $p \leq 0,01$)

4. DISCISSION

The teaching profession places high demands on teachers. In recent years, there has been a growing scholarly interest in teacher self-efficacy. This has been attributed to an increased focus on promoting teacher efficacy and satisfaction and reducing teacher burnout. Researchers and policy makers have turned their attention to teacher self-efficacy as a determinant of teacher effectiveness (Klassen, &Tze, 2014), that may explain why some teachers disengage from, become dissatisfied with, and leave the profession (Granziera, & Perera, 2019).

The aim of this paper was to investigate the relationship between teacher self-efficacy and components of subjective well-being in students of pedagogy (prospective teachers) and primary teachers.

Based on the mean scores in teacher self-efficacy (Table 1), we can conclude that both students and primary teachers consider themselves to be relatively highly occupational self-efficient. Similar mean scores have been found in similarly focused studies (e.g., Gavora, 2011; Cansoy et al., 2020).

There was no significant difference in any of the measured variables between students of pedagogy and primary teachers, on the basis of which we consider the first hypothesis to be unconfirmed. The assumed difference in teacher self-efficacy between students and teachers based on the research of some authors was not confirmed. The results are not consistent with the findings of Coladarci, & Breton (1997). In contrast, a study by Tschannen-Moran & Woolfolk-Hoy (2002), yielded no significant differences in teacher self-efficacy by age. However, the same study revealed significant differences between experienced and novice teachers. Imants, &De Brabander (1996) concluded in their research that teacher self-efficacy is influenced by several factors. These include not only age or years of experience, but also position in the school hierarchy and gender. These and possibly other variables may mediate the relationship between age/years of experience and teacher self-efficacy.

According to the presented results, teacher self-efficacy is statistically significantly related to both emotional and cognitive components of subjective well-being.

We included all participants in the analyses because of similar results in mean scores between students and primary teachers. We found a positive correlation between self-efficacy and the cognitive component of subjective well-being (life satisfaction). Regarding the emotional component of subjective well-being, positive affect correlated positively with teacher self-efficacy, whereas negative affect correlated negatively with teacher self-efficacy. Based on these findings, we consider the second hypothesis to be confirmed.

The strongest association emerged between teacher self-efficacy scores and cognitive component of subjective well-being (life satisfaction). The correlation coefficient of 0.384 can be interpreted as a medium correlation between these two variables. Other research studies have found closer relationships between self-efficacy and psychological well-being, although other measurement tools have been used. For example, Siddiqui (2015) found a correlation between self-efficacy and psychological well-being in his research of 0.60 for male respondents and 0.55 for female respondents; Cansoy et al. (2020) found a correlation of 0.73.

Our findings regarding the emotional component of subjective well-being are in accordance with Zee's et al. (2016) assertion that when teachers feel efficient, they experience less negative emotions (stress, emotional exhaustion, depersonalization, burnout) and more positive emotions (high personal accomplishment, commitment and job satisfaction). When positive emotions increase, teachers' psychological functionality increases.

We can summarize that it has been confirmed that the more students of pedagogy and primary teachers see themselves as professionally efficient, the higher is their subjective well-being. This is in line with other research findings that have indicated that general self-efficacy strongly predicted psychological well-being (e.g., Gibbons, 2010; Siddiqui, 2015; Klainin-Yobas et al., 2016;). In the literature, it was found that teacher self-efficacy was related to psychological well-being (Bentea, 2017; Jeon et al., 2018; McInerney et al., 2015; Lipińska-Grobelny, & Narska, 2021). As can be seen from these evidences, general self-efficacy or teacher self-efficacy seems to be a determining structure in psychological well-being. According to Cansoi et al. (2020), teachers' self-efficacy beliefs can be related to psychological well-being, and self-efficacy can be an important predictor of psychological well-being.

The limitations of the study are the small number of respondents in the sample and the lack of representation of the statements of students from other universities, so the results cannot be considered representative. In the following research, data collection will be carried out at several pedagogical faculties in Slovakia, and we recommend viewing the results of the presented research as preliminary and pilot. Other variables such as personality, motivation, emotional intelligence and resilience will also be explored in the next larger research. Based on our research, we cannot assume the causality of the relationship between teacher self-efficacy and subjective well-being. It is not clear whether a high level of teacher self-efficacy is the cause of high subjective well-being, or whether high subjective well-being causes higher self-efficacy. Research in this area needs to be expanded with other contexts that will help create a more complex model with new, even non-linear relationships.

We plan the inclusion of additional data collection methods such as teacher self-observation and self-reflection as part of action research or interview with teachers. These qualitative methods can offer rich insights into teachers' subjective experiences, complementing the quantitative findings obtained through self-report questionnaires. This study relied heavily on correlation analysis to report the results. While correlation analysis provides valuable insights into the relationships between variables, it does not, as noted, determine causality or the direction of effects. To deepen our understanding of the causal relationships between teacher self-efficacy and subjective well-being, we

acknowledge the need for further research employing longitudinal designs. Longitudinal studies can help investigate the temporal dynamics and directionality of these relationships.

5. CONCLUSIONS

This study presents an insight into the teacher self-efficacy and its relationship to subjective well-being in students of pedagogy and primary teachers. A key result is the confirmation of a positive relationship between the level of teacher self-efficacy and both the emotional and cognitive components of subjective well-being. These pilot research results will need to be validated with a larger research population. The research inspires to include other variables such as motivation to the teaching profession, emotional intelligence, resilience, personality traits, etc. in further investigation. This would help to clarify the broader context needed to understand the relationship between teacher self-efficacy, subjective well-being and other variables. This will allow teacher preparation programmes in universities to focus more specifically on raising the level of self-efficacy of future teachers.

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Decomposing the Effects of Science Intrinsic and Utility Values on the Relationship between Students' Self-efficacy and STEM Occupational Expectations: An Application of the KHB Decomposition Method

Tamilka BONJEER[a*], Hana VONKOVA[b]

[a] *Charles University, Faculty of Education, Department of Education, Magdaleny Rettigove 4, Prague, Czech Republic, ftamilka@yahoo.com*
[b] *Charles University, Faculty of Education, Department of Education, Magdaleny Rettigove 4, Prague, Czech Republic, hana.vonkova@pedf.cuni.cz*

Abstract

Studies increasingly highlight that the effects of students' self-efficacy beliefs on achievement-related choices diminish when it is analysed alongside other motivational beliefs, particularly subjective task values. This indicates that these other motivational beliefs confound or mediate the effects of self-efficacy. The Karlson-Holm-Breen (KHB) decomposition method analyses the mediating effects of variables, especially when the outcome variable is categorical or ordinal. However, this has rarely been done with self-efficacy. In this study, we address this gap by examining the mediating effects of science intrinsic and utility values on the relationship between science self-efficacy and students' STEM occupational expectations using the KHB method. We used data (n = 24,665) from six countries in the 2015 Programme for International Student Assessment. Our initial analysis revealed that self-efficacy had significant effects on expectations, but these effects diminished as we incrementally added intrinsic and utility values. In separate models, intrinsic value mediated its effects by about 57%; utility value mediated it by 76%; and intrinsic and utility values jointly mediated it by 97%. The study recommends that for interventions aimed at improving students' educational outcomes through their self-efficacy beliefs to have the greatest impact, they should also consider intrinsic and utility values.

Keywords: STEM, intrinsic, utility, self-efficacy, KHB.

1. INTRODUCTION

Self-efficacy—"the belief in one's capabilities to organise and execute the courses of action required to produce given levels of attainment" (Bandura, 2000, p. 16)—plays an important role in determining developmental and achievement-related outcomes in children (Bong & Skaalvik, 2003). According to Bandura et al. (2001), students' academic and self-regulatory efficacy perceptions in particular influence their judgments regarding the kinds of occupational tasks they are efficacious at. Consequently, children's occupational self-efficacy influences the careers they want to engage in or avoid in their adult lives. Several studies have also shown that students' self-efficacy beliefs in a given academic domain influence their achievements within it (Grigg et al., 2018; Pajares, 2004; Street et al., 2022), their motivation (Skaalvik et al., 2015), as well as their aspirations and expectations (Aschbacher et al., 2014; Kang, 2023; Woods et al., 2023). Owing to these important contributions to achievement and developmental outcomes, there have been much research as well as the development of interventions aimed at improving students' self-efficacy beliefs (Bonne & Johnston, 2016; Czocher et al., 2020; Zakariya, 2022).

* Corresponding author.

Recently, researchers have begun to highlight that self-efficacy beliefs tend to have less predictive power on achievement-related outcomes when analysed with other motivational beliefs, particularly subjective task values. Wu et al. (2020, p. 159) summed up this observation about self-efficacy in particular in the following terms: "Previous empirical studies also have found that when considered together, subjective task values demonstrate a stronger correlation to motivational achievement behaviours than self-efficacy". Subjective task values are the importance or values that individuals attach to different aspects of a task or available options, and they may take the form of intrinsic, attainment, cost, and utility values (Eccles, 2005). Task values are aspects of the expectancy-value theory by Eccles and colleagues. They have been demonstrated to hold significant explanatory power over achievement-related behaviours (particularly gender differences), including students' educational attainments, aspirations, and expectations, among others (Chow et al., 2012; Eccles & Wang, 2016; Lazarides et al., 2021; Lazarides & Lauermann, 2019). Despite the observation that self-efficacy demonstrates stronger relationships with achievement-related outcomes when analysed without task values but loses its predictive powers when analysed simultaneously with them, there is a lack of research on how task values suppress the relationships between self-efficacy and achievement-related outcomes. This current study seeks to address this limitation by examining how the relationships between students' science self-efficacy beliefs and their occupational expectations in science, technology, engineering, and mathematics (STEM), are mediated by two task values: science intrinsic and instrumental (utility) values. We apply a unique approach to achieve this. Specifically, we use the KHB decomposition method (Karlson et al., 2012)—Karlson, Holm, and Breen (KHB). Usually, in logit or probit models, the changes in the effects of variables in different models (e.g., when self-efficacy is analysed with and without intrinsic and utility values) cannot automatically be attributed to the addition of the other (confounding) variables (Breen et al., 2021) (in this case, intrinsic and instrumental values). The KHB approach overcomes this limitation by separating the effects of independent variables on categorical outcome variables into direct and indirect effects (Karlson et al., 2012), to understand the confounding effects of a variable on other variables. To the best of our knowledge, no study has specifically attempted to disentangle the confounding effects of task values on a categorical achievement-related outcome variable such as students' occupational expectations through the KHB. We thus make important contributions to the literature by applying the KHB approach to understanding the extent to which intrinsic and utility values confound the relationships between students' STEM occupational expectations and their science self-efficacy beliefs.

1.1. Self-efficacy and task values as predictors of students' expectations and aspirations

The expectancy-value theory (EVT) contributes significantly to understanding the formation and sources of students' educational and occupational expectations. Its fundamental tenets are that students' expectations of success (expectancies) and the values they attach to different activities, such as school subjects (math, science, languages, etc.) and occupations, influence their choices and persistence in those activities (Eccles, 2005; Wigfield & Cambria, 2010). Differences in students' achievement-related outcomes, such as expectations and aspirations, are therefore explained as resulting from differences in expectations for success and task values between them. The EVT posits four types of task values: intrinsic, cost, attainment, and utility. According to Wigfield and Cambria (2010), intrinsic value (interest) concerns the enjoyment that one derives from engaging in an activity. Attainment value is the importance that one attaches to doing well on a task. In addition, utility value concerns how a person considers a task to be useful in achieving their future goals. Finally, cost concerns the effort that the individual perceives they need to exert to accomplish a task. The other major aspect of the EVT is expectations for success (expectancies), which is empirically similar to self-efficacy and academic self-concepts (Wigfield & Eccles, 2000). In this study, we thus use the literature on self-efficacy, expectancies, and academic self-concepts as substitutes.

Students' beliefs in their abilities in a given academic domain significantly influence their approaches to tasks within it. For example, students with high academic ability beliefs in a given subject usually do well in that subject, take more related courses, and even look forward to taking more related courses (Marsh & Yeung, 1997). In terms of post-secondary course selection plans, students with high ability beliefs in an academic domain are more likely to want to further their studies in that same or related domain (Saß & Kampa, 2019). Generally, perceived self-efficacy in science and math is associated with increased interest in STEM aspirations, expectations, and attainments (Kahraman, 2022; Kwon et al., 2019; Sahin et al., 2017; Sakellariou & Fang, 2021; Wu et al., 2020). However, the positive impacts of ability beliefs, including self-efficacy on students' approaches to tasks or course selection behaviours differ from context to context. For example, in Finland, Kang (2023) found that compared to girls, the self-efficacy beliefs of boys in science had a stronger influence on STEM aspirations. However, Woods et al. (2023) found in the United States that the effects of efficacy beliefs on STEM aspirations were stronger for girls than for

boys. On the contrary, Aschbacher et al. (2014) also found in the United States that the effects of efficacy beliefs on students' intentions to pursue STEM did not differ by gender.

Task values in math and science also have significant impacts on students' choice-related behaviours, including STEM educational and occupational expectations. Science and math intrinsic and utility values increase the likelihood that a student will anticipate pursuing a STEM programme or career. This has been found to hold across several contexts (Dickhäuser & Stiensmeier-Pelster, 2003; Kahraman, 2022; Lv et al., 2022; Vinni-Laakso et al., 2019). Of the four types of subjective task values, utility value, in particular, appears to exert the greatest influence on students' persistence and study intentions in STEM (Kahraman, 2022). The association between students' science task value and their likelihood of majoring in STEM is supported by intervention studies (Harackiewicz et al., 2014). However, just like ability beliefs, students with higher task values in academic subjects other than math and science (for example, languages) tend to show more interest in non-STEM rather than STEM study fields (Lauermann et al., 2015; Widlund et al., 2019). Thus, as students' motivational beliefs (task values, self-concepts, ability beliefs, etc.) in math and science decrease, their study intentions and interest in STEM decrease.

1.2. The mediating roles of task values: a theoretical and empirical justification

According to Pajares (2004), self-efficacy affects human performance both directly and indirectly through other determinants. Thus, there are grounds to expect the influence of self-efficacy on students' STEM educational and occupational expectations, as well as other achievement-related behaviours, to be affected by other motivational variables in statistical models. The results of different studies appear to support this, as when analysed together with EVT constructs, particularly task values, the coefficients of self-efficacy generally diminish or tend to be the smallest. The suppressing or confounding effects of other motivational variables are summed up in the following from a recent study:

> Regression analyses indicated that when controlling for years in college and major GPA, academic self-efficacy contributed unique variance to choice, effort, persistence, and continuation...However, when the four task value variables were added to the model, self-efficacy did not contribute unique variance to any of the four achievement behaviours. (Wu et al., 2020, p. 159).

Other related studies support this. For example, Guo et al. (2017, p. 88) found that when students' science (biology, chemistry, physics, and earth science) utility and intrinsic values are one standard deviation below the mean, the relationship between self-concept of ability and aspirations becomes insignificant ($M = -0.02$, $SE = 0.02$, $p = 0.211$; $M = -0.01$, $SE = 0.01$, $p = 0.346$, for self-concept of ability's interactions with intrinsic and utility values, respectively). However, at one standard deviation above the mean, it becomes a significant determinant of aspirations ($M = 0.22$, $SE = 0.02$, $p < 0.001$; $M = 0.17$, $SE = 0.02$, $p < 0.001$, for self-concept of ability's interactions with intrinsic and utility values, respectively). This resulted in them concluding that self-concept of ability is a significant determinant of students' aspirations only at higher levels of intrinsic and utility values. In other words, the relationship between self-concept of ability and aspirations can be confounded when it is analysed with intrinsic and utility values.

1.3. The present study

Subjective task values are potential confounders or mediators in the relationship between ability-related beliefs and students' achievement-related outcomes. To the best of our knowledge, studies quantifying the extent of these confounding effects of task values are rare. In the present study, we contribute to the literature by examining the relationships between students' self-efficacy and task values (intrinsic and utility) in science and their STEM occupational expectations, focusing on how task values confound the relationships between self-efficacy and expectations. We use the KHB decomposition method to achieve these objectives. The KHB decomposition approach quantifies the extent of the confounding effects of variables in probit and logit models. Based on the literature, we hypothesise that:

- When analysed simultaneously with intrinsic and utility values in science, students' self-efficacy would be weakly related to their STEM occupational expectations. These weak relationships should be due to the confounding effects of intrinsic and utility values.

- We also expect the KHB decomposition to reveal large confounding effects, as we believe that moving from being statistically significantly related to STEM expectations to being unrelated to them requires mediating variables to exhibit stronger confounding or mediating effects.

2. METHODS

2.1. Participants and data

We used data from the Programme for International Student Assessment (PISA) to achieve the goals of the study. The data is available for public use, and we accessed it from the Organisation for Economic Co-operation and Development (OECD, n.d.). The PISA is a survey of the skills of 15-year-old children in the domains of science, math, and reading in OECD member countries, including other partner countries. The survey also measures the attitudes and values of children on a range of issues pertinent to their development. The surveys have been conducted every three years since 2000 (OECD, 2010).

In this study, we used (combined) data from six countries (three OECD and three non-OECD countries). The total sample analysed was 24665. The countries and their respective samples that made up the total sample are as follows: Croatia (3371), Hungary (2732), Japan (3354), Qatar (8511), Sweden (3110), and Tunisia (3587). Our main goal was to get a large and diverse sample to test our hypothesis. As a result, we randomly selected and combined data from the six countries with varying levels of economic development as well as political and cultural orientations. This way, we believe any resulting findings would not be attributed to any factor inherent to any one particular country.

2.2. Variables

Dependent variable: student STEM occupational expectations (STEM vs. non-STEM). The 2015 PISA survey included a question measuring the occupational expectations of students. This was an open-ended question, allowing students to write down the jobs they expect to have by adulthood. The question was as follows: "*What kind of job do you expect to have when you are about 30 years old*?" In PISA, the responses of students to this question were coded based on the classification of occupations by the International Labour Organisation (ILO). The ILO assigns codes to occupations based on their skill requirements or the level of education required to perform them. In this study, we limited our analysis to STEM and non-STEM occupations that require higher educational training (professionals, technicians, and associate professionals). The ILO groups STEM occupations into three major groups (science and engineering, health, and information and communications technology). We combined the data for these three groups and labelled them as STEM occupations. All other occupations that also require higher educational training were combined and labelled non-STEM. Thus, our outcome variable, students' occupational expectations, was categorical (STEM = 1; non-STEM = 0). There is no generally agreed-upon conceptualisation of what STEM and non-STEM are. However, our conceptualisation is common in STEM education research (Ahmed & Mudrey, 2019; Wang et al., 2015).

Independent variables:

Science self-efficacy. This was a variable we derived from the PISA science self-efficacy scale (it is labelled SCIEEFF in the PISA technical framework). The SCIEEFF is based on eight Likert items with four response categories each (1 = I could do this easily; 4 = I couldn't do this easily). This was reversed-coded and used in the analysis. The main question was, *"How easy do you think it would be for you to perform the following tasks on your own*?" A sample of the eight items under this main question is "*Recognise the science question that underlies a newspaper report on a health issue*".

Intrinsic value (enjoyment of science). This was derived from the PISA enjoyment of science scale, which PISA labelled JOYSCIE. The JOYSCIE is based on five positively scored Likert items with four response categories. The main question was as follows: *How much do you disagree or agree with the statements about yourself below*? The responses ranged from 1 (*strongly disagree*) to 4 (*strongly agree*). A sample of the five items is "*I generally have fun when I am learning <broad science> topics*".

Utility value (*instrumental motivation for science*). We used students' instrumental motivation as a proxy for their utility value for science. This was derived from the PISA INSTSCIE scale. This consisted of five Likert items with four response categories each (1 = *strongly agree*; 4 = *strongly disagree*). It was reverse-coded and used in the analysis. A sample of the five items is "*Making an effort in my <school science> subject(s) is worth it because this will help me in the work I want to do later on*".

Gender and students' achievements in science. We included gender and achievements as control variables. As it would be shown later, our initial analysis revealed that math, science, and reading achievements had negligible and statistically insignificant relationships with students' occupational expectations. As a result, we found the inclusion of all of them in the models to be redundant. We, however, decided to retain only science since all the motivational variables, as well as the outcome variable, were science-related

2.3. Analysis (the KHB decomposition method)

The main analysis was logistic regression based on the KHB decomposition approach. With this approach, two main regression models are estimated, enabling a comparison of the coefficients between different models. The key estimation procedures are as follows (Breen et al., 2021; Karlson et al., 2012):

- First, a full regression model is estimated (model 1). This model includes all the variables (controls, mediators/confounders, and the independent variable of interest—in this case, science self-efficacy).
- A second model is also estimated (model 2). This includes the independent variable of interest (science self-efficacy) and a residualised version of the confounders. The confounders are residualised with respect to the variable of interest (this means that in the second model, the confounders are not correlated with the variable of interest). By comparing the coefficients of the two models, one can then determine the extent to which the confounders (science utility and intrinsic values) confounded the relationship between the variable of interest (science self-efficacy) and students' STEM occupational expectations.

Usually, the results returned through this process would include those from model 1 (called the full model), model 2 (the reduced model), the differences in the coefficients between models 1 and 2, and the percentage of the confounding effects. It essentially decomposes the effects of the variable of interest into direct and indirect effects. We first separately examined the confounding effects of science intrinsic and utility values (two models, one for each of intrinsic and utility values). After this, we examined the joint confounding effects of intrinsic and utility values by including them in the same model. This was to allow us to understand both their unique and joint effects. KHB is a widely used approach (Du & Wong, 2019; Li et al., 2023; Smith et al., 2019), but to the best of our knowledge, it has rarely been applied to investigate the confounding effects of subjective task values on self-efficacy.

There were a few missing responses for derived variables, and we replaced them with their means as is commonly done. All derived variables were also standardised to have a mean of 0 and a standard deviation of 1. This was to allow for easy interpretation of the resulting coefficients from the regression models. The student achievement variable (science) is composed of ten plausible values; as a result, all analyses were performed ten times (each time with a different plausible value) and averaged to obtain the final results.

3. RESULTS

3.1. Descriptive statistics

The descriptive statistics for the study variables are in Table 1 below. The results show that girls constituted about 55% of the total sample analysed. It should be noted that the total sample of 24665 represents students with tertiary education-level STEM and non-STEM-related occupational expectations from the six countries from which it was drawn; it does not represent the total number of 15-year-olds who took part in PISA 2015 in the six countries. The results also show that more than half of the students (54%) expect to have STEM careers by the time they reach the age of 30. Overall, more girls than boys expect STEM careers; however, the difference is marginal (0.51%). Also, more girls than boys have expectations for non-STEM-related occupations, and the difference is large (about 61%).

Table 1. Descriptive statistics for variables (n = 24665).

Variable	N (percentage); mean (sd)
Gender (boys)	11060 (44.84%)
Students with STEM expectations	13363 (54.18%)
STEM expectations by gender (boys)	6613 (49.49%)
Students with non-STEM expectations by gender (boys)	4447 (39.35%)
Science self-efficacy (mean [sd])	0.020 (1.023)

Science intrinsic value (mean [sd])	0.052 (1.067)
Science intrinsic value (mean [sd])	0.011 (1.085)

The results of correlation analysis (Table 2) show that STEM expectations are positively correlated with all variables examined. Gender (being a boy) is also positively correlated with all but science utility value. Science utility value is also not related to achievement in science. Finally, science self-efficacy and intrinsic value are positively correlated with all the variables.

Table 2. Correlations between variables.

Variable	1	2	3	4	5	6
1. STEM expectations	1					
2. Science achievement.	0.039***	1				
3. Science intrinsic value	0.203***	0.112***	1			
4. Science utility value	0.273***	-0.002	0.414***	1		
5. Science self-efficacy	0.106***	0.122***	0.32***	0.281***	1	
6. Gender (boy)	0.102***	0.076***	0.032***	-0.007	0.049***	1

*Note: *** p≤0.001*

3.2. Logistic regression analysis

The results for logistic regression analysis without the decomposition are in Table 3 below (Model 1 to Model 4). This analysis was performed using the multiple imputation of missing data package in R—*mitools*— (Lumley, 2022). This analysis was necessary as it allowed us to observe how the relationships between self-efficacy and STEM expectations change as new variables are introduced. We used *mitools* for Models 1-4 because it was efficient, as it allowed us to estimate each model once rather than ten times because of the science plausible values that were included—it can analyse models with plausible values in one step. However, the KHB decomposition method was implemented using the *khb* package in R (Orsholits, 2021), and the results are presented in Table 4. The KHB analyses were conducted ten times, each involving a distinct plausible value for science. The results of the KHB method in Table 4 are therefore the averages of ten distinct analyses.

The first (Model 1) in Table 3 included students' science self-efficacy, gender, and achievement in science. The results show that both student science self-efficacy and gender (being male) were statistically associated with STEM occupational expectations. More specifically, a standard deviation increase in self-efficacy increases the odds of STEM expectations by about 1.22 (22%)—this is arrived at by exponentiating the estimated coefficient. Being a boy relative to a girl also increases the odds of STEM expectations by about 1.48 (48%). Science achievements, however, have negligible effects on students' expectations.

Table 3. Logistic regression coefficients for predictor variables of students' STEM occupational expectations.

Variable	Model 1 β (Std. Error)	Model 2 β (Std. Error)	Model 3 β (Std. Error)	Model 4 β (Std. Error)
Science self-efficacy	0.199***	0.088***	0.052***	0.006(0.014)
	(0.013)	(0.014)	(0.014)	
Science intrinsic value		0.366***		0.212***
		(0.013)		(0.014)
Science utility value			0.538***	0.469***
			(0.014)	(0.014)
Controls				
Gender (boy)	0.391***	0.394***	0.439***	0.434***
	(0.026	(0.027)	(0.027)	(0.027)
Science achievement.	0.0004**	0.000	0.001***	0.0005***
	(0.000)	(0.000)	(0.000)	(0.000)
Constant	-0.196	-0.088	-0.338	-0.259

Note: ** p≤0.01; *** p≤0.001

In Model 2, we added science intrinsic value to the variables in Model 1. The results show that science intrinsic value is associated with higher odds of STEM expectations (odds ratio = 1.40). The coefficients for gender and achievements in science remained almost unchanged. However, the coefficient for science self-efficacy decreased significantly. In Model 3, we added science utility value to the variables in Model 1. The results show that a standard deviation increase in science utility value increases the odds of STEM expectations by about 71% (odds ratio = 1.71). While the coefficient for gender improved marginally in Model 3, that of science self-efficacy dropped significantly. In Model 4, we analysed all variables simultaneously. The results show that science self-efficacy became unrelated to STEM expectations. However, science intrinsic and utility values, as well as gender, remained significant determinants of students' STEM expectations.

It could be seen that the addition of science utility and intrinsic values resulted in self-efficacy losing its predictive power on STEM expectations from Model 2 through to Model 4. We used the KHB decomposition method to determine the extent to which their additions confounded the relationship self-efficacy has with STEM expectations. The results of this are in Table 4 below. The results show that when science intrinsic value was added to Model 2, the resulting reduction in the coefficient for self-efficacy was about 0.118. This indicates that the value of self-efficacy on STEM expectations that is mediated by intrinsic value (indirect effect) is 0.118. The confounding percentage shows that science intrinsic value accounted for about 57.47% of the reduction in the coefficient for self-efficacy. The reduction in the coefficient of self-efficacy in Model 3 (0.163) was attributed to science utility value. This value also represents the part of the effect of self-efficacy on STEM expectations that is explained through science utility value. The confounding ratio is about 76%. Finally, when all variables were considered (Model 4), intrinsic and utility values jointly reduced the coefficient for self-efficacy by about 0.211. Together, they mediated the relationship between self-efficacy and students' STEM occupational expectations by about 97%.

Table 4. KHB decomposition results for the mediation of science intrinsic and utility values on the relationship between science self-efficacy and students' STEM occupational expectations.

Mediating variables		β (Std. Error)
Science intrinsic value (Model 2)	Reduced model	0.206*** (0.013)
	Full model	0.088** (0.014)
	Difference	0.118*** (0.005)
	Confounding %	**57.47**
Science utility value (Model 3)	Reduced model	0.215*** (0.013)
	Full model	0.052*** (0.014)
	Difference	0.163*** (0.005)
	Confounding %	**75.99**
Science utility & intrinsic values (Model 4)	Reduced model	0.217*** (0.014)
	Full model	0.006 (0.014)
	Difference	0.211*** (0.007)
	Confounding %	**97.23**

Note: Reduced model—model excluding a mediating variable(s); full model—model including a mediating(s) variable; difference—difference between the full and the reduced model; ** $p \leq 0.01$; *** $p \leq 0.001$.

4. DISCUSSION

Motivational beliefs, particularly those from the expectancy-value theory of achievement motivation tradition, are increasingly pointed out as suppressing the predictive powers of self-efficacy beliefs when they are all included in the same statistical models. In this study, we used the KHB decomposition analytical method to decompose the individual and joint effects of two motivational beliefs—science intrinsic and utility values—on students' science self-efficacy beliefs and STEM occupational expectations. The results of our analysis supported the body of research that shows that self-efficacy becomes weakly related to achievement-related outcomes and choices.

We first examined how students' self-efficacy beliefs are related to their STEM occupational expectations, holding constant two covariates that are considered critical determinants of students' STEM educational and occupational expectations—gender and students' achievements in science. We found students' science self-efficacy beliefs to have statistically significant and positive effects on their STEM expectations, consistent with previous studies (Guo et al., 2017; Wu et al., 2020). This means that when students perceive themselves as capable of performing scientific tasks and solving science problems in school, they are more likely to consider science-related careers. It could be that when

students perceive themselves as efficacious in science in school, it makes them believe that they have the abilities and skills needed for science-related careers; as a result, they tend to view STEM careers as viable future career options. Being a boy relative to a girl was also found to increase the likelihood that a student would expect a STEM occupation. This is also consistent with previous studies (Jansen et al., 2021, 2021b; Perez-Felkner et al., 2017). We found this despite the fact that in the sample of students analysed, the total number of girls with STEM expectations was marginally higher than that of boys. For achievements in science, the effects on STEM expectations was found to be very negligible. The influence of achievements in science on the occupational paths that students consider appears to be marginal generally (Du & Wong, 2019). It is possible that this accounted for what we observed in this study.

We also found students' science intrinsic and utility values to be positively related to their STEM occupational expectations. We found this in models where each motivational belief was examined without the other and in a model where they were jointly examined. The results for these two motivational beliefs are also consistent with other previous studies (Dickhäuser & Stiensmeier-Pelster, 2003; Kahraman, 2022; Vinni-Laakso et al., 2019). It means that when students find science tasks enjoyable and interesting to do (intrinsic value), it increases the probability that they will want to pursue STEM careers in the future. For utility value, of the variables studied, we found it to have the greatest influence on students' expectations. The positive relationship that utility value has with expectations may be expected given that by definition, utility value is future-oriented—it consists of the individual's considerations of how an activity or task (e.g., doing well in science) is useful and would contribute to them realising an outcome that is future-related (e.g., being an engineer, teacher, etc.), which is expectations in this study.

We found the statistical significance of the relationship between self-efficacy and STEM expectations to diminish as we incrementally added science intrinsic and utility values. It became unrelated to STEM expectations when we analysed all variables together. This supported the hypothesis we posited from the start: that self-efficacy would lose its statistical significance when analysed simultaneously with science intrinsic and utility values. It is also consistent with previous studies Guo et al., 2017; Wu et al., 2020). Through the KHB decomposition method, we were able to determine the extent to which science intrinsic and utility values accounted for the loss in the predictive power of students' science self-efficacy beliefs on their STEM occupations, consistent with our hypothesis. The joint mediating impact of intrinsic and utility values was found to be greater than that observed for any one of them; it was, however, less than the sum of their effects from the models where they were analysed separately. This suggested that the joint mediation effect of intrinsic and utility values is not a sum of their individual effects. This underscores the complexities that underlie the motivational beliefs that shape the educational and occupational paths that students consider.

5. CONCLUSIONS

The study examined the influence of students' science self-efficacy beliefs and intrinsic and utility values on their STEM occupational expectations while controlling for their gender and achievements in science. The study specifically focused on the mediating role of intrinsic and utility values in the relationship between self-efficacy and expectations. Through the KHB decomposition method, the study determined that when analysed simultaneously, intrinsic and utility values significantly confound the effects of self-efficacy on STEM expectations. This suggests that the influence of students' self-efficacy beliefs on their expectations is largely mediated through the intrinsic and utility values that they attach to science. This has implications for interventions aimed at improving students' educational outcomes through their self-efficacy beliefs. Among others, it suggests that for interventions to have the greatest impact, they should consider not only self-efficacy but also intrinsic and utility values. We recommend further studies using the KHB decomposition method to examine the mediating role of other motivational beliefs, such as science cost and attainment values, as knowledge from such studies could contribute to how motivation interventions should be conceived or designed.

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Edupreneurship and its Importance in Education

Fethi KAYALAR[a*]

[a] *Erzincan B. Y. University), Faculty of Education,Turkey, fkayalar@erzincan.edu.tr*

Abstract

The phenomenon of poverty and unemployment requires educational institutions to take part in producing an entrepreneurial young generation, where they have the entrepreneurial skills if they graduate from school or are unable to work in their respective fields of education. It is hoped that entrepreneurship education will be able to become an added value in education by creating a pattern of thinking to be independent and have a competitive spirit. For this reason, it is necessary to build edupreneurship in order to foster an entrepreneurial spirit. Thus, the concept of entrepreneurship was born to help educational institutions create a young generation who have entrepreneurial skills so that they can reduce the level of poverty and unemployment. Then the concept of entrepreneurship is expressed in the science of entrepreneurship, namely creative and innovative businesses that give rise to various ideas which can be in the form of technopreneurs in the technology sector, cyberpreneurs in the cyber sector, agropreneurs in the agricultural sector, santripreneurs in religious schools, then the teaching sector, teacherpreneur and the education sector, namely edupreneur. In the study, the importance of edupreneurship was argued under the light of literature.

Keywords: Edupreneurship, Entrepreneurship, Teacherpreneurship, Educational Management

1. INTRODUCTION

Education has always been at the most important place in the process of social change. However, as the ages changed, the roles also changed. Basic education, which was the duty of the family in the agricultural society, turned to the state with the industrial society. Secondary and higher education has always been the responsibility of the state. A new process is taking place in the information age. The leading role in education passes to education entrepreneurs. Innovative approaches of education entrepreneurs come to the fore in both basic and higher education. It is necessary to distinguish education entrepreneurship from traditional private school investment. This new understanding of education goes beyond the concerns of "Let's provide the same education with better quality", "Let's reach a lower number of students per teacher" or "Let's provide education in a better decorated school building".

Education entrepreneurs have taken their place in the sector as a modern investor that "develops, innovates and increases competition". Researching global examples, integrating technology, science and art into education and developing models that include an individual understanding are the new dynamics of the sector. These dynamics emerged as we entered the Industry 4.0 era, forced by the circumstances.

Edupreneurship is a combination of the words education and entrepreneurship. Edupreneurship wants to place entrepreneurial concepts and attitudes in the world of education. Education, which is often understood as a process of self-maturation, is combined with entrepreneurship, which in French means adventurer, risk taker and entrepreneur. Entrepreneurs are more than just entrepreneurs because there must be added value and something different. Etymologically, referring to the two meanings above, edupreneurship can be interpreted as entrepreneurship education, namely a learning process that focuses on entrepreneurial activities both in theory and practice. The

* Corresponding author.

confirmation of theory and practice here is none other than because entrepreneurship is not a myth, but a reality or construct (building) that can be studied through intense learning, training, simulation and internship processes. So, in the meaning of the word entrepreneurship here there are three important things that we can know, namely creativity innovation (renewal of creative power), opportunity creation (opportunity to be creative), and calculated risk talking (calculation of risks taken). If entrepreneurship is understood in these three ways, then it can be said that every human being is born as an entrepreneur with the potential to be a creative innovator, a reliable opportunity creator, and a brave risk taker.

Meanwhile, according to the Ministry of National Education, entrepreneurship is an attitude, spirit and ability to create something new that is very valuable and useful, both for oneself and for others. Entrepreneurship is a mental attitude and spirit that is always active and creative, empowered, creates, works, is modest, and tries to increase income from its business activities. Entrepreneurship is defined as a person who is skilled at exploiting opportunities in developing his business with the aim of improving his life. This entrepreneurial spirit does not only have to be possessed by entrepreneurs, but it really needs to be possessed by any profession and role in various different functions, whether it is the profession of teacher or lecturer, pupil or university student, doctor, soldier, police, and so on.

The triggers for developing edupreneurship potential in each individual are not the same. Riant Nugroho mentioned three typical entrepreneurs, including becoming an entrepreneur because he was forced to, becoming an entrepreneur because of opportunity, and becoming an entrepreneur because of choice.

First, individuals learn to live independently, for example by raising livestock, becoming traders, or running certain businesses because they are forced to do so due to limitations, poverty, dropping out of school or the death of their parents. There are also people who choose to become entrepreneurs because they were laid off from the company where they worked. Second, someone builds a business because of the power that supports it. An example is someone who runs a business because he begins to see opportunities and possibilities, such as government political policies and facilities. Third, someone has set a vision of becoming successful and rich by building a business and business network because they are reluctant to become an employee. A person tries to realize the dream of wealth, prosperity and financial freedom without being tied to working hours with maximum income. They generally take formal education in the fields of management, business and finance or take part in various motivational training, courses and business management training.

2. WHAT IS EDUPRENEURSHIP

Edupreneurship is explained to be a unique part of entrepreneurship in the field of education. Entrepreneurship is a creative or innovative business by seeing or creating opportunities and realizing them into something that has added value (economic, social, etc.). Entrepreneurship in the social sector is called sociopreneurship, in the educational sector it is called edupreneurship. Edupreneurship is an integration model between schools, teachers and students. Entrepreneurship in this model aims to create a school that is a leader, able to provide stimulation for other schools. (Pelipa & Marganingsih, 2019) Edupreneurship is an approach through learning scenarios that can bring students' entrepreneurial ideas to life. Edupreneurship is entrepreneurship education. Entrepreneurship education is an effort to educate someone so that they can produce a product, both goods and services,that has sales value and is beneficial both for themselves and for others. So this entrepreneurship education has quite broad benefits, because it can make a good contribution to personal and social life. It is important to carry out entrepreneurship education because through entrepreneurship education, it will form a person who has independence, that is, he can stand alone without depending on other people, and is able to make his own decisions. An entrepreneur is a person who is independent and hardworking (Sumiyati, 2017).

Edupreneurship is a training program on how to introduce entrepreneurship concepts which is equipped with various examples of applications through the educational process. It is to use a variety of business strategies, depending on the nature of the product and the market segment they have chosen to serve. Edupreneurship is also education that produces students who are creatively innovative, reliable opportunity creators, and brave enough to take on life's challenges. (Sutrisno, 2017) Edupreneurship places mental concepts and entrepreneurial attitudes in the world of education. Education is often understood as a process of self-maturation which is then combined with entrepreneurship, which in French means adventurer, risk taker and entrepreneur. Entrepreneurs are more than entrepreneurs because there must be added value and something different. Entrepreneurs must be able to turn junk into gold through innovation and creativity in exploiting opportunities. Edupreneurship is a solution effort to eradicate educational unemployment and combines education and entrepreneurship which have so far been viewed in different studies. However, these studies still focus on the general and vocational fields of education in the countries (Assingkily & Rohman, 2019).

Edupreneurship is part of the implementation of entrepreneurship in the education sector, which is an activity that emphasizes creative or innovative efforts carried out by schools to obtain school achievements and increase income. Implementation of edupreneurship through a teaching factory means students carry out learning activities that are almost the same as those carried out in the world of business and industry. The concept of learning in real situations is to bridge the competency gap between the knowledge provided by schools and industry needs. The aim of this learning is to develop the character and work ethic (responsibility, discipline, honesty, cooperation, leadership, etc.) needed by the world of business and industry as well as improving the quality of learning outcomes that equip students with the ability to produce goods and/or services. And implementing edupreneurship through a business center, namely carrying out business practices by taking goods from schools and selling them to the community. Students are given the freedom to analyze the market, set prices, how to sell goods and make sales results reports (Kuat, 2017).

Entrepreneurship learning is implemented in various forms of production and business-based learning methods, including: Teaching Factory, Teaching Industry, Hotel Training, Incubator Unit, Business Center at school. Production and business-based learning methods are designed in order to improve the quality of entrepreneurial learning through learning by doing (Mulyatiningsih et al., 2014). Edupreneurship is the formation of the mental and entrepreneurial spirit of both pupils and students in an effort to achieve success in the field of education. Edupreneurship does not aim to make students become entrepreneurs, but rather at forming the character of edupreneurs in the field of education.

3. THE RISE OF EDUPRENEURSHIP

The phenomenon of poverty and unemployment requires educational institutions to take part in producing a young generation of entrepreneurs, where they have entrepreneurial provisions if they graduate from school or are unable to work in their respective fields of education. It is hoped that entrepreneurship education will be able to become an added value in education by creating a pattern of thinking to be independent and have a competitive spirit. For this reason, it is necessary to build edupreneurship in order to foster an entrepreneurial spirit. Thus, the concept of entrepreneurship was born to help educational institutions create a young generation who have entrepreneurial skills so that they can reduce the level of poverty and unemployment. Then the concept of entrepreneurship is expressed in the science of entrepreneurship, namely creative and innovative businesses that give rise to various ideas which can be in the form of technopreneurs in the technology sector, cyberpreneurs in the cyber sector, agropreneurs in the agricultural sector, santripreneurs in Islamic boarding schools, then the teaching sector, teacherpreneur and the education sector, namely edupreneur. Epistemologically, edupreneur comes from entrepreneur. So edupreneurship is part of entrepreneurship. Edupreneurship is schools that always carry out systematic meaningful innovation, transformational change without regard to existing resources, current capacity or national pressure in order to create new and superior educational opportunities. Edupreneurship more generally is all creative and innovative school efforts that are oriented towards excellence. Edupreneurship is a combination of the meanings of education and entrepreneurship which are a unity whose meaning cannot be separated. The two become one unit, a process carried out to reflect the concept of entrepreneurship education by educating someone to be able to do and produce something of marketable value. Then it can be used by individuals or groups as entrepreneurship education. Edupreneurship is part of the learning process that focuses on entrepreneurial activities both in theory and practice with confirmation of theory and practice. In edupreneurship it is none other than because entrepreneurship is not a myth but is realistic or a construct that can be learned through intense learning processes, exercises, simulations and internships (Ibda & Nasrulloh, 2018). The concept of edupreneurship in the literature (Mulyatiningsih et al., 2014) emphasizes creative or innovative efforts carried out by schools to obtain school achievements and increase income. A school's performance may not directly result in financial benefits but a high-achieving school has more opportunities for rewards, aid, and better student input. With this achievement capital, the school will gradually progress until it becomes a superior school. In this context, excellence does not have a direct financial impact but pioneers a more successful future. After becoming a superior school, opportunities and chances to earn additional income will become easier to obtain. The concept of edupreneurship allows educational institutions in many countries to transform into edupreneurs (Education Entrepreneurs or Educational Entrepreneurs), referring to the principles of companies that "develop innovative products and services to fill opportunities that have not been touched by government-run schools" (Lips, 2000).

Edupreneurship is a breakthrough change in the field of education to not only produce graduates in large quantities every period, but to produce graduates who are qualified, qualified and have high competitiveness to make positive and beneficial contributions to many people (Assingkily & Rohman, 2019)

4. CONCLUSION

In the new world order, the competitiveness of educational institutions is largely determined by their "learning speed". Learning speed, which expresses the time to process and use information, increases the quality of educational program applications of educational institutions. It is important to determine future education plans and roadmap from an innovative, foresighted and visionary perspective. Talking about the future is as valuable as thinking about the future. In our century, the concepts of "discovering innovations" and "attributing meaning to innovations" come to the fore. Instead of the generations that were considered with periods of approximately 20 years in the 20th century, there are now intermediate generations. Accessing information in the world is easier every day than the previous day. Nowadays, when we have access to information very quickly, we need to consider how to use information more effectively. We can express it as "the power of knowledge" because it includes educational research conducted by the OECD Organization for Economic Development and Cooperation, which is accepted as an international evaluation criterion.

The United Nations 2030 development goals include quality education, responsible production and consumption. We have been supporting the "European Green Deal" since its first day, which enables countries to develop new strategies to decarbonize energy systems all over the world. We support the “Paris Climate Agreement”, which represents the global fight against climate change and aims to leave a world with a more stable, healthier planet, more just societies and more vibrant economies. After 20 years, there will be a return to alternative natural resources instead of the resources we have started to consume today. We will not be able to use water and electricity as much as we want like today. In the future, models powered by fossil resources will come to the fore and human labor will decrease. We aim for our students to be "producers, not consumers". We are raising students who will write the software for machines and robots that will replace the human workforce in the future, as a generation that can "meet their own needs and be self-sufficient."

When we consider education as "quantity", it must be measurable, targets must be determined correctly and every piece of data that is realized must be evaluated. On the other hand, when we consider it in terms of "quality", education must achieve its purpose, have a widespread impact and benefit societies. That's why we consider education together with the concept of teaching. It is necessary to carry out measurement and evaluation processes in all details of education and training studies, from theory to practice, from A to Z. At this point, "skill" comes to the fore. In the process where education is supported by teaching, skills that can also be expressed as mastery or ability to conclude in areas of predisposition are the key to success. We believe that it is very valuable for our students to achieve success by supporting them at every level of knowledge and transforming their studies into skills as a target behavior.

We will expand our education abroad studies with the International Education Office so that our students can instantly follow global studies around the world and represent our country in the best way with our qualified studies. Our goal is to receive "respected education awards abroad". For this reason, we handle our education and training activities on a global scale and pay attention to applicable and sustainable criteria. We will have international projects, curriculum studies, and student exchange programs collaborations with different educational institutions from abroad. Thus, our students; It will be included in the global learning network with many International Education Offices to be established in different cities such as New York, London and Toronto.

Work that makes a difference in the education sector, as in other sectors, is only possible with "entrepreneurship". In entrepreneurship, where economic opportunities are transformed into new values, experiencing projects that are believed to be successful in the future through simulation studies comes to the fore. We create the definition of "sustainable education entrepreneurship" in our country with our professional experiences, professional field research, risk analyses, academic staff, research and development studies (R&D), intellectual perspectives, strong collaborations, vision projects and the national and international achievements we have achieved. With the experience we have gained over many years in education, we believe that investments in education are very valuable for the future of our countries

When looking at the relationship between education and socio-economic development; the education element increases the qualifications of the workforce and improves the social, cultural and institutional structure, thus increasing the "national income" and therefore the "level of development". Countries' expenditures on education are directly proportional to their development levels. Education investments have ever-increasing returns. As investments in education increase, national income also increases. As one moves from lower education level to higher level, individuals earn more income.

Contemporary societies have to raise "individuals with qualifications compatible with the requirements of the age" in order to establish a sustainable economic structure and to increase and maintain their welfare levels. Education systems should provide "employable skills" as well as raising individuals who are good and compatible with their own society. These skills must meet the requirements of the age. Therefore, 21st century skills should be seen as a necessity

rather than a choice. It is expected that high-skill jobs will increase from 36 percent in 2000 to 44 percent in 2025, and 90 percent of jobs will require qualifications. In the new century, a complex, competitive, constantly changing, knowledge-based, technology-driven economy will dominate social life.

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