18. september 2025 | 18 September 2025
Maribor, Slovenia

INFORMACIJSKA DRUŽBA

INFORMATION SOCIETY

Digitalna vključenost v informacijski družbi

Digital Inclusion in Information Society

Uredniki | Editors:
Boštjan Šumak, Maja Pušnik, Saša Grašič

Zbornik 28. mednarodne multikonference
Zvezek H

Proceedings of the 28th International Multiconference
Volume H

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PREDGOVOR MULTIKONFERENCI INFORMACIJSKA DRUŽBA 2025

28. mednarodna multikonferenca *Informacijska družba* se odvija v času izjemne rasti umetne inteligence, njenih aplikacij in vplivov na človeštvo. Vsako leto vstopamo v novo dobo, v kateri generativna umetna inteligenca ter drugi inovativni pristopi oblikujejo poti k superinteligenci in singularnosti, ki bosta krojili prihodnost človeške civilizacije. Naša konferenca je tako hkrati tradicionalna znanstvena in akademsko odprta, pa tudi inkubator novih, pogumnih idej in pogledov.

Letošnja konferenca poleg umetne inteligence vključuje tudi razprave o perečih temah današnjega časa: ohranjanje okolja, demografski izzivi, zdravstvo in preobrazba družbenih struktur. Razvoj UI ponuja rešitve za številne sodobne izzive, kar poudarja pomen sodelovanja med raziskovalci, strokovnjaki in odločevalci pri oblikovanju trajnostnih strategij. Zavedamo se, da živimo v obdobju velikih sprememb, kjer je ključno, da z inovativnimi pristopi in poglobljenim znanjem ustvarimo informacijsko družbo, ki bo varna, vključujoča in trajnostna.

V okviru multikonference smo letos združili dvanajst vsebinsko raznolikih srečanj, ki odražajo širino in globino informacijskih ved: od umetne inteligence v zdravstvu, demografskih in družinskih analiz, digitalne preobrazbe zdravstvene nege ter digitalne vključenosti v informacijski družbi, do raziskav na področju kognitivne znanosti, zdrave dolgoživosti ter vzgoje in izobraževanja v informacijski družbi. Pridružujejo se konference o legendah računalništva in informatike, prenosu tehnologij, mitih in resnicah o varovanju okolja, odkrivanju znanja in podatkovnih skladiščih ter seveda Slovenska konferenca o umetni inteligenci.

Poleg referatov bodo okrogle mize in delavnice omogočile poglobljeno izmenjavo mnenj, ki bo pomembno prispevala k oblikovanju prihodnje informacijske družbe. »Legende računalništva in informatike« predstavljajo domači »Hall of Fame« za izjemne posameznike s tega področja. Še naprej bomo spodbujali raziskovanje in razvoj, odličnost in sodelovanje; razširjeni referati bodo objavljeni v reviji *Informatica*, s podporo dolgoletne tradicije in v sodelovanju z akademskimi institucijami ter strokovnimi združenji, kot so ACM Slovenija, SLAIS, Slovensko društvo Informatika in Inženirska akademija Slovenije.

Vsako leto izberemo najbolj izstopajoče dosežke. Letos je nagrado *Michie-Turing* za izjemen življenjski prispevek k razvoju in promociji informacijske družbe prejel **Niko Schlamberger**, priznanje za raziskovalni dosežek leta pa **Tome Eftimov**. »Informacijsko limono« za najmanj primerno informacijsko tematiko je prejela odsotnost obveznega pouka računalništva v osnovnih šolah. »Informacijsko jagodo« za najboljši sistem ali storitev v letih 2024/2025 pa so prejeli Marko Robnik Šikonja, Domen Vreš in Simon Krek s skupino za slovenski veliki jezikovni model GAMS. Iskrene čestitke vsem nagrajencem!

Naša vizija ostaja jasna: prepoznati, izkoristiti in oblikovati priložnosti, ki jih prinaša digitalna preobrazba, ter ustvariti informacijsko družbo, ki koristi vsem njenim članom. Vsem sodelujočim se zahvaljujemo za njihov prispevek — veseli nas, da bomo skupaj oblikovali prihodnje dosežke, ki jih bo soustvarjala ta konferenca.

Mojca Ciglarič, predsednica programskega odbora
Matjaž Gams, predsednik organizacijskega odbora

FOREWORD TO THE MULTICONFERENCE INFORMATION SOCIETY 2025

The 28th International Multiconference on the Information Society takes place at a time of remarkable growth in artificial intelligence, its applications, and its impact on humanity. Each year we enter a new era in which generative AI and other innovative approaches shape the path toward superintelligence and singularity — phenomena that will shape the future of human civilization. The conference is both a traditional scientific forum and an academically open incubator for new, bold ideas and perspectives.

In addition to artificial intelligence, this year's conference addresses other pressing issues of our time: environmental preservation, demographic challenges, healthcare, and the transformation of social structures. The rapid development of AI offers potential solutions to many of today's challenges and highlights the importance of collaboration among researchers, experts, and policymakers in designing sustainable strategies. We are acutely aware that we live in an era of profound change, where innovative approaches and deep knowledge are essential to creating an information society that is safe, inclusive, and sustainable.

This year's multiconference brings together twelve thematically diverse meetings reflecting the breadth and depth of the information sciences: from artificial intelligence in healthcare, demographic and family studies, and the digital transformation of nursing and digital inclusion, to research in cognitive science, healthy longevity, and education in the information society. Additional conferences include Legends of Computing and Informatics, Technology Transfer, Myths and Truths of Environmental Protection, Knowledge Discovery and Data Warehouses, and, of course, the Slovenian Conference on Artificial Intelligence.

Alongside scientific papers, round tables and workshops will provide opportunities for in-depth exchanges of views, making an important contribution to shaping the future information society. *Legends of Computing and Informatics* serves as a national »Hall of Fame« honoring outstanding individuals in the field. We will continue to promote research and development, excellence, and collaboration. Extended papers will be published in the journal *Informatica*, supported by a long-standing tradition and in cooperation with academic institutions and professional associations such as ACM Slovenia, SLAIS, the Slovenian Society Informatika, and the Slovenian Academy of Engineering.

Each year we recognize the most distinguished achievements. In 2025, the Michie-Turing Award for lifetime contribution to the development and promotion of the information society was awarded to **Niko Schlamberger**, while the Award for Research Achievement of the Year went to **Tome Eftimov**. The »Information Lemon« for the least appropriate information-related topic was awarded to the absence of compulsory computer science education in primary schools. The »Information Strawberry« for the best system or service in 2024/2025 was awarded to Marko Robnik Šikonja, Domen Vreš and Simon Krek together with their team, for developing the Slovenian large language model GAMS. We extend our warmest congratulations to all awardees.

Our vision remains clear: to identify, seize, and shape the opportunities offered by digital transformation, and to create an information society that benefits all its members. We sincerely thank all participants for their contributions and look forward to jointly shaping the future achievements that this conference will help bring about.

Mojca Ciglarič, Chair of the Program Committee
Matjaž Gams, Chair of the Organizing Committee

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PREDGOVOR

Digitalni svet danes ni več spremljevalec našega vsakdana, temveč njegov temeljni okvir. Povezljivost, ki je bila nekoč privilegij, postaja osnovna pravica, brez katere si ne moremo več predstavljati dela, učenja, zdravstva, javnih storitev ali kulturnega življenja. Toda prav ta vseprisotnost tehnologije zahteva novo etiko odgovornosti – razvijati moramo digitalne rešitve, ki ne ustvarjajo novih razlik, temveč zmanjšujejo obstoječe.

Osrednja tematika hibridne delavnice DIGIN 2025 – Digitalna vključenost v informacijski družbi je razgrnila široko paleto pogledov na digitalno inkluzijo. Tudi letošnje leto je delavnica potekala v sodelovanju z evropskim centrom virov o dostopnosti – AccessibleEU. Raziskovali smo organizacijske, institucionalne in tehnološke vidike dostopnosti, predstavili orodja za večjo samostojnost uporabnikov, analizirali uporabniško izkušnjo in dobre prakse uporabe umetne inteligence v izobraževanju. V ospredju so bile zgodbe in potrebe slabovidnih, gluhih, oseb z avtizmom, starejših, mladih z različnimi oblikami oviranosti ter študentov, ki jim slovenščina ni materni jezik. Ravno s tem poudarkom smo pokazali, da digitalna vključenost ni enodimenzionalen pojem, temveč kompleksno področje, ki se dotika jezika, psihologije, infrastrukture, izobraževanja in družbenih odnosov.

Poseben pečat je dogodku dala okrogla miza, na kateri so udeleženci z lastnimi izkušnjami pokazali, kaj pomeni živeti v svetu, ki je lahko hkrati povezan in nedosegljiv. Njihovi glasovi so nas opomnili, da digitalna dostopnost ni zgolj tehnološko vprašanje, temveč predvsem vprašanje človeškega razumevanja, empatije in sodelovanja.

Prispevki v letošnjem zborniku ponujajo dragocen vir idej in znanja, ki lahko navdihnejo vse bralce. Z njihovo pomočjo lažje razumemo, kako tehnologija prispeva k višji kakovosti življenja, večji samostojnosti ter enakovrednemu vključevanju v digitalni svet. Prepričani smo, da s tem dogodkom in skupnimi prizadevanji gradimo bolj odprto, dostopno in človeku prijazno digitalno prihodnost.

DIGIN 2025 je več kot dogodek – je zaveza, da digitalna preobrazba ne bo nikogar pustila ob strani.

FOREWORD

The digital world today is no longer a companion to our everyday lives but their very foundation. Connectivity, once a privilege, has become a basic right – one without which we can no longer imagine work, education, healthcare, public services, or cultural life. Yet this very ubiquity of technology demands a new ethic of responsibility – we must develop digital solutions that do not create new divides but rather reduce existing ones.

The central theme of the hybrid workshop DIGIN 2025 – Digital Inclusion in the Information Society opened a broad spectrum of perspectives on digital inclusion. Once again, the workshop was organized in cooperation with the European Accessible Resources Centre – AccessibleEU. We explored organizational, institutional, and technological aspects of accessibility, presented tools that promote user independence, analyzed user experience, and shared good practices in the use of artificial intelligence in education. The focus was on the stories and needs of people with visual or hearing impairments, individuals on the autism spectrum, older adults, young people with various disabilities, and students whose first language is not Slovene. Through this focus, we demonstrated that digital inclusion is not a one-dimensional concept, but a complex field that encompasses language, psychology, infrastructure, education, and social relations.

A special highlight of the event was the roundtable discussion, where participants shared their personal experiences of what it means to live in a world that can be both connected and out of reach. Their voices reminded us that digital accessibility is not merely a technological issue but above all a matter of human understanding, empathy, and cooperation.

The contributions collected in this year's proceedings offer a valuable source of ideas and knowledge that can inspire all readers. They help us better understand how technology contributes to a higher quality of life, greater independence, and equal participation in the digital world. We are convinced that through this event and our collective efforts, we are building a more open, accessible, and human-centered digital future.

DIGIN 2025 is more than an event – it is a commitment to ensuring that digital transformation leaves no one behind.

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Digital Competence in Learners with Disabilities

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Abstract

The study explores the early development of digital competences in adapted educational programs with lower educational standards (NIS) and special education programs (PPVI) in Slovenia. The study focuses on which areas of digital competence institutions prioritize, how these choices are explained, and what training needs teachers identify at the beginning of the process. Data were collected through a questionnaire administered in seven institutions participating in the DigComp PP project. Findings indicate a predominant emphasis on basic digital skills and online safety, while more advanced competencies and specialized assistive tools remain largely absent. Teachers expressed a strong demand for practical training and accessible resources tailored to diverse learning profiles. The study highlights systemic barriers to digital inclusion and underscores the need for targeted, sustainable support to strengthen inclusive and technology-enhanced learning environments.

Keywords

Adapted educational programs (NIS), digital competences, digital inclusion, learners with disabilities, special education programs (PPVI), teacher training.

Introduction

Contemporary digital society is built on the principles of accessibility, inclusion, and fairness. Yet the needs of individuals requiring adapted learning approaches—due to developmental, emotional, or physical challenges—are often overlooked. Among them are children and adolescents enrolled in adapted educational programs with lower educational standards (NIS) and in special education programs (PPVI). In line with the United Nations (2006) Convention on the Rights of Persons with Disabilities, the term learners with disabilities is used to refer to this population. In international literature, these groups are often described within the broader concept of special educational needs (SEN). In the Slovenian context, however, they represent the subgroup of learners whose disabilities require the most extensive curricular and organizational adaptations.

While various adapted programs and support measures, regulated by national legislation and professional guidelines, provide a framework for equitable education, implementation often neglects one key area: the systematic development of digital competences—essential for independent engagement in the digital world. The legislative framework—including the *Placement of Children with Special Needs Act* [1], *Elementary School Act* [2], and relevant national guidelines [3–6]—defines target groups and support measures. However, emphasis remains on basic knowledge and social integration, with digital literacy largely underrepresented.

In analyzing adapted provision, it is important to distinguish between methodological adjustments within the existing curriculum and fully adapted educational programs which involve curricular and goal-related modifications [1]. This distinction shapes the ways in which learners engage with technology in everyday instruction.

In recent years, digital competences have become central to educational strategies both at the EU and national levels. Key documents—such as the *Digital Education Action Plan (2021–2027)* [7], the *Digital Skills and Education Package* [8], and the national strategy *Digital Slovenia 2030* [9]—stress the importance of inclusive digital education and reducing the digital divide. Yet learners with disabilities in NIS and PPVI programs remain persistently underrepresented in these frameworks.

Despite ambitious strategies, the lack of targeted studies and feedback from practice indicates that these learners are often systemically disadvantaged in developing digital competences. Challenges include a lack of suitable materials, limited teacher training, and poorly adapted tools.

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Against this background, the present study explores how digital competences can be developed systematically and sustainably among learners with disabilities in NIS and PPVI programs. The analysis focuses on the competence areas prioritized by institutions, the rationales behind these priorities, and the professional development needs reported by teachers. Data were collected in several institutions participating in the DigComp PP project. The following sections present the study design, describe the needs assessment, and analyze findings on priorities, practices, and challenges identified by participating institutions.

Accordingly, this study addresses the following research questions:

1. Which areas of digital competence are prioritized in institutions implementing adapted educational programs with lower standards (NIS) and special educational programs (PPVI)?
2. What practices and rationales guide the selection of these competences?
3. What professional training needs are identified by teachers working with learners with disabilities?

1 Methodology

The present study draws on data collected during the initial phase of the *DigComp PP – Digital Competences for the Field of Special Needs Education*. The questionnaire used as the basis for the analysis was not part of the project's formal evaluation process but was instead developed as a complementary tool for research and development purposes. The purpose of the questionnaire was to capture initial orientations, exploratory initiatives, and institutional approaches to the integration of digital competences in the education of learners with disabilities.

Data collection took place in January 2025, at a time when the institutions had already joined the project, but core activities had not yet been fully implemented. The questionnaire was intended as a tool to capture early developments and practical challenges, with the purpose of informing the design of targeted support measures in the subsequent phases of the project.

1.1 Sampling and Participants

The study involved seven educational institutions from different regions of Slovenia. All participating institutions, engaged in the DigComp PP project, implement adapted education programs (NIS) or special education programs (PPVI) for learners with disabilities. In each institution, the project coordinator completed the questionnaire after consulting with teaching and professional staff.

1.2 Instrument and Content

The questionnaire was designed using the 1KA online survey tool (Arnes) and included a combination of closed- and open-ended questions. It focused on the following key areas:

- digital tools most frequently used by teachers in working with learners with disabilities,
- areas of digital competence that institutions are currently developing or intend to develop,
- reasons for selecting these areas,
- needs for further professional development among educational staff.

1.3 Data Analysis

The collected data were analyzed using basic descriptive statistical methods (frequencies, percentages). Open-ended responses were examined through qualitative content analysis to identify key themes and patterns in the participants' answers. The aim of the analysis was not to test hypotheses, but rather to gain an understanding of early directions and perceived needs, which would serve as a foundation for guiding the subsequent stages of the project.

1.4 Limitations

The study was conducted on a small, purposively selected sample and at a specific point in time, when the project's activities had not yet been fully operationalized. Nevertheless, the data provides valuable insights into early developmental directions and approaches and can inform practical recommendations within the broader context of developing digital competences among learners with disabilities.

2 Results

The collected data reveal a heterogeneous but recognizable pattern of early initiatives and emerging priorities concerning the integration of digital technologies in the education of learners with disabilities.

2.1 Use of Digital Tools

The following figure illustrates the digital tools most frequently used by participating institutions in their work with learners with disabilities.

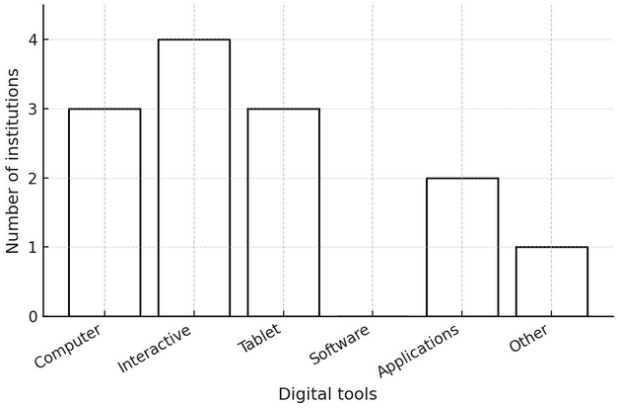

Figure 1: Most Commonly Used digital Tools in Participating Institutions

Note. Interactive – Interactive whiteboard, Software – Software for adapted learning, Applications – Communication and collaboration applications.

Figure 1 presents an overview of the digital tools most commonly used in participating institutions at the time of the survey. The responses indicate a diverse but still relatively conventional digital infrastructure, with interactive whiteboards and tablets being the most frequently mentioned. Tools for

communication and collaboration, such as Microsoft Teams, were also in use, albeit to a lesser extent. In several cases, respondents referred more broadly to devices like desktop computers and projectors, as well as general-purpose software including Microsoft Office and Canva.

Notably, none of the institutions reported the use of specialized educational software designed specifically for adapted learning. This absence may suggest limited availability, accessibility, or integration of such tools into daily pedagogical practice, and points to a potential area for further development.

2.2 Selected Areas of Digital Competence

The figure below provides an overview of the digital competence areas that participating institutions identified as priorities for development in their work with learners with disabilities.

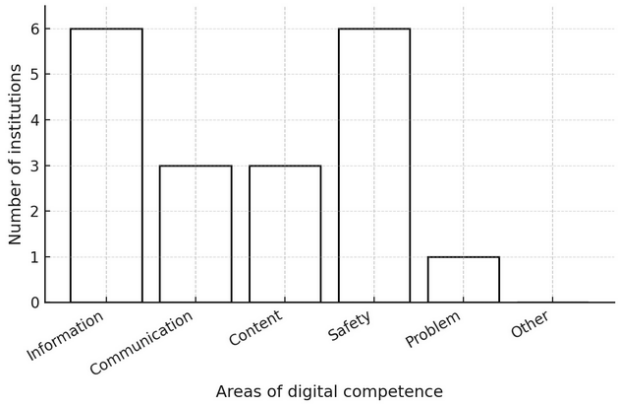

Figure 2: Priority Areas of Digital Competence Development in Participating Institutions

Note. Information – Information and data literacy, Communication – Communication and collaboration; Content – Digital content creation, Safety – Safety and well-being in the digital environment, Problem – Problem solving using digital technologies.

The participating institutions were asked to identify the areas of digital competence they are currently developing or planning to introduce in their work with learners. As shown in Figure 2, the two most frequently prioritized areas were information and data literacy and safety and well-being in the digital environment, each selected by six out of seven institutions. Communication and collaboration and digital content creation were moderately represented, each mentioned by three institutions. Only one institution reported focusing on problem solving using digital technologies.

The results suggest that, at this early stage of implementing digital competence development, institutions are primarily focusing on foundational competencies—navigating digital environments, managing information, and ensuring safe use of technology. These serve as a crucial baseline for the future development of more advanced and autonomous uses of digital tools in both educational and everyday life.

2.3 Reasons for Selecting Digital Competence Areas

The analysis of responses reveals several key motivations behind participating institutions' selection of specific digital competence areas for development among learners with disabilities. While the responses were diverse, four dominant themes emerged.

3.3.1 Developing Basic Digital Skills for Everyday Life. The most frequently cited reason was the importance of equipping learners with essential digital skills to support their autonomy in daily life. Respondents emphasized the need to begin with foundational knowledge—understanding device functions, searching and evaluating information, and using the internet safely:

"We believe that learners need the most support in these areas."
"They need to learn the basics so that we can gradually build their knowledge and skills over the coming years."

3.3.2 Digital Safety as a Prerequisite for Inclusion. A strong emphasis was placed on digital safety, including the protection of personal data, critical evaluation of online content, and awareness of risks. Institutions identified this area as particularly important, given learners' difficulties in judging the appropriateness of digital content:

"Safety and well-being in the digital environment is one of the most important areas."
"A session for learners on online safety—such as truthfulness of information and sharing personal data—would be very welcome."

3.3.3 Alignment with Curriculum and Building on Existing Knowledge. Several institutions justified their choices by referencing curriculum goals and the need to build digital competence progressively:

"Because it aligns with curriculum guidelines, our own interest, and above all, enriches the learning process."
"Learners in adapted educational programs first need to understand the basic functions of digital devices and become familiar with the fundamentals of engaging in a digital environment."

3.3.4 Adapting to Individual Abilities and Needs. A number of responses reflected the necessity of tailoring digital education to the cognitive and developmental capacities of learners in special programs:

"Taking into account the intellectual abilities of our learners and their needs during instruction..."
"Because these areas are the most suitable and necessary for our specific learner population."

These responses indicate that, in the early stages of the project, institutions focused primarily on foundational and safety-related aspects of digital competence. The reasons for this prioritization stem from learners' everyday needs, their developmental characteristics, and the generally low baseline level of digital literacy in these educational programs. Emphasis is thus placed on establishing a solid foundation from which learners can gradually develop more advanced skills and greater independence in navigating the digital world.

2.4 Learner-Centered Teaching

The analysis of responses provided by institutional coordinators indicates a wide range of training needs, reflecting the diverse starting points of participating institutions and the varying levels of digital maturity among teaching staff. The findings highlight a demand for both general and specialized forms of professional development.

3.4.1 Introductory Training in Digital Competence. Several institutions stressed the importance of basic training that would provide teachers with a shared foundation for further work. This suggests significant variability in existing digital skills within teaching teams and the need for a coordinated starting point.

3.4.2 Digital Safety. Respondents proposed expert-led lectures and hands-on workshops aimed at empowering both teachers and learners to navigate digital environments safely and responsibly.

3.4.3 Augmentative and Alternative Communication. Some institutions highlighted the need for specialized training to support learners with significant communication barriers. In such programs, digital tools are seen as essential for enabling participation and expression, requiring targeted knowledge and adaptations.

3.4.4 Practical Tools for Creating Digital Content. Teachers expressed a need for concrete skills in preparing educational materials and digital content tailored to learners with special needs. Examples include video production, animation, content editing, and the use of platforms such as Scratch, Lego robotics, and Minecraft within curricular contexts. These tools present opportunities for engaging learner-centered teaching.

3.4.5 Utilizing Existing Digital Equipment. Several institutions reported having access to digital devices (e.g., interactive whiteboards and tables) but lacking the knowledge to use them effectively. For instance, one institution noted the need for training in interactive whiteboard use, while another mentioned having an interactive table with outdated software and a lack of support for upgrading and training.

The expressed training needs are highly pragmatic and directly linked to everyday pedagogical practice. While some institutions require general introductory support, others have specific demands related to particular tools, communication systems, or the creation of inclusive digital content. These findings underscore the necessity of an individualized, modular approach to professional development, confirming that one-size-fits-all training formats are insufficient. Instead, targeted, needs-based training models are essential to effectively support teaching staff in this context.

3 Discussion

The findings offer important insights into the initial conditions and early institutional approaches to fostering digital competences among learners with disabilities enrolled in NIS and PPVI programs. Most institutions focus on basic digital literacy and safe technology use, which is consistent with the initial goals of the DigComp PP project and reflects the relatively low baseline of digital readiness in these programs.

A notable caution is observed in the introduction of more advanced competencies, such as problem solving with digital technologies. Institutions tend to prioritize foundational skills—functional literacy, information navigation, and digital safety awareness. This is understandable, given that many learners in these programs require gradual progression, concrete examples, and visual support, while existing digital tools are often not tailored to their cognitive or sensory needs.

The absence of specialized tools for adapted learning is a critical issue. The gap is likely attributable to limited access to high-quality content, lack of localization in the Slovenian context, and insufficient resources suitable for lower cognitive levels, rather than resistance to technology itself. Consequently, teachers frequently resort to improvisation with basic tools (e.g., PowerPoint, Canva, interactive whiteboards) or develop content independently. This highlights the necessity of systemic measures to provide accessible, evidence-based tools designed specifically for learners with disabilities.

Differences in digital competence among teaching staff also play a crucial role in determining the extent to which institutions can introduce digital strategies. Teachers consistently highlighted the necessity of professional development that is practice-focused, modular in structure, and responsive to specific learner profiles. Generic training formats appear insufficient; instead, professional development must address specific needs, such as augmentative and alternative communication, digital safety, and the creation of inclusive education.

These findings align with recent international research, which similarly reports limited digital competences among special education teachers and the urgent priority for structured, targeted training [10, 11, 12]. Importantly, digital competence in this context cannot be reduced to technical proficiency alone. It requires pedagogical adaptation and the capacity to use technology in ways that enhance learning and participation for diverse groups of learners. Validated instruments for assessing digital competence in special education provide a solid foundation for targeted training design and help identify areas needing further support [11].

The results highlight important implications for sustainability. Developing digital competences among learners with disabilities supports long-term social inclusion and employability while reducing systemic inequalities. Targeted teacher training strengthens institutional capacity and fosters professional communities of practice.

Although rooted in the Slovenian context, the findings are transferable to other systems facing similar challenges. The prioritization of basic competences, limited availability of specialized tools, and demand for targeted training are internationally recognized issues. The DigComp PP project therefore offers a potential model of good practice, particularly when aligned with established frameworks such as DigCompEdu, UDL, and TPACK.

Achieving digital inclusion for learners with disabilities in NIS and PPVI programs necessitates systematic planning, sustainable institutional support, and structured professional development for teachers. While the early emphasis on basic competences and safety is appropriate, long-term strategies must encompass advanced competences and systematic use of specialized tools. The findings underscore the relevance of the DigComp PP project as a driver of sustainable change and as an example of transferable practice in inclusive, technology-enhanced education.

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A Continent to the State Web Service Integration: a Definition and the Implementation Approach

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Abstract

A new type of web service *IS* [1] integration is discussed, a continent to the state web service integration, dubbed as *k2s*. A definition of this web service type *IS* integration is given, and a general approach about the implementation is discussed. A brief comparison with other types of web service *IS* integrations is given, including but not limited to the global to the state web service integration, dubbed as *g2s*.

Keywords

continent to state information system integration, web services, digital inclusion, *k2s*

1 Introduction

In the global reach of *IT*, two general trends related to *IS* integration are emerging. On one side we have national and multinational companies, with a global reach, where *b2b* [2] integrations are taking place and also *b2c* [3]. On the other side we have a solid trend of public services to be offered in a digital form, to companies *s2b* [4] and consumers *s2c* [5], as well. As there is Single European Act [11] in force, it is clear, further integration processes are taking place.

An example of *k2s* system taken into consideration is *EU-CSW-CERTEX system* [8], commonly known as *CERTEX*. *CERTEX* is a system that connects customs systems with the EU's non-customs systems. This allows Customs authorities across EU to access relevant data within these non-customs systems. Quick access to non-customs systems is crucial for making informed decisions about whether or not to release goods for a specific customs procedure. While *CERTEX* system has several components, we'll be referring to the core *k2s* web service integration part in between non-customs systems on one side, e.g. the *k* part, against the EU member-state *IS*, e.g. the *s* part.

One example of a such non-customs system is *IS* for the importation of certain organic goods with a requirement of meeting the phytosanitary requirements, regulated as [9]. The *EU-CSW-CERTEX system* is in use as a mandatory requirement as of March 2025, but it is clear integration activities within *EU-CSW-CERTEX system* started much earlier, as the integration activities need to be implemented in each and every EU member state.

While the main topic is *k2s* systems, let's mention *g2s* integration system, as we will define it as well. Such an example is *UN/FLUX* standard, regulated as [4]. *UN/FLUX* facilitates the information exchange in between fishing domain entities. These fishing domain entities are fishing vessels, reporting the catch data to their domicile fishery authorities via different communication channels. The data received from fishing vessels at sea is then transferred to the geographically related authority via web services in a store and forward fashion. *UN/FLUX* system is comprised of many communication nodes, all communicating via *HTTPS/SOAP* messages.

2 Definitions

A continent to state web service integration system is the system, which integrates one supra-national authority, with multiple national authorities, to exchange relevant data via web services, whereby the data exchange is confined to a wider geographic region, possibly a continent. All stakeholders operate withing boundaries of their national jurisdictions.

A global to state web service integration system is the system, which integrates various entities, geographically dispersed, to one or possibly multiple state authorities via web services, whereby the data exchange is not limited by any geographic region. The stakeholders are normally bound by international standards and agreements and their jurisdictions are not playing the prerogative role.

3 Results

3.1 Specific requirements

The first and foremost requirement for *CERTEX* was that each software release has a status of *LTS*[6]. So, after the production tape-out it is expected for the version release to stay in production for years to come. There was a practical reason behind the requirement, as the complete EU member state *IS* is to be adapted to be compatible with *CERTEX*. Note, however, while we are discussing about *CERTEX* as *k2s* system, the *IS* of EU member state is really *s2b* or/and *s2c* to users in that particular member state. While the software maintenance for *CERTEX* was planned, retroactive functional upgrades for the version accepted in production were strongly discouraged.

The second requirement for *CERTEX* was two or more EU member states may communicate via *CERTEX*, even if they are at different software releases. It is possible, the web service integration may be degraded to be at the level of the lease capable software release, but in principle, EU member states should not be constrained in any way in intercommunication, while being on different *CERTEX* software releases.

The third requirement for *CERTEX* had a priority set to be more like a *nice to have*, but it was the integral part of the *CERTEX* success. Each and every EU member state may decide to upgrade

[1] The Information System
[2] A business to business integration.
[3] A business to consumer integration.
[4] A state to business integration.
[5] A state to citizens integration.

[6] A Long Term Support release.

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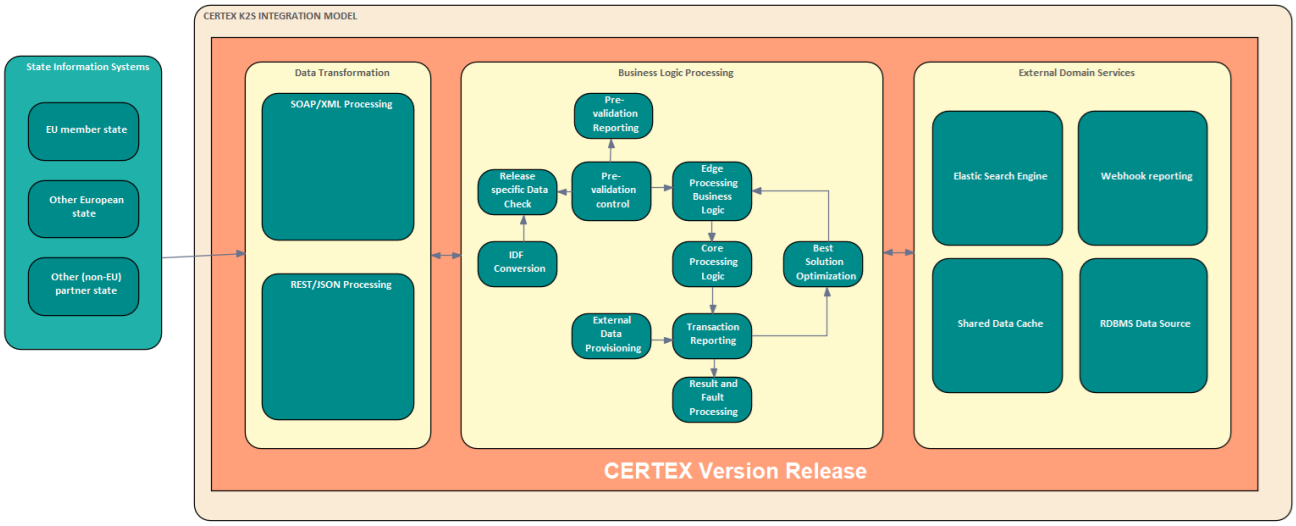

Figure 1: The *CERTEX* single release architecture

it's *CERTEX* release version either to the latest or to a higher version, at very least. But this web service release upgrade should be seamless, without the lengthy data migration, if possible.

3.2 An architectural overview

The complete *CERTEX* implementation relies on one software release, shown in Figure 1. Each release is done approximately every calendar year and since release version 1.0 in 2018, there are now six releases in production use, while the seventh release is in the development phase. All *CERTEX* releases run on *Jakarta EE* [3] server. While particular software releases are loosely coupled, the complete software package is of a monolithic type. From the year 2025 timepoint of view, the loosely coupled software releases would be very appropriate to be implemented with *Kubernetes* [5]. But as the software implementation started in 2018, at that time *Kubernetes* was not sufficiently mature and even if it would be mature enough in 2018, the decision of possible use of *Kubernetes* would require at least one prototype, which in turn, would require a delay of 12 months at very least. There was also an option to do a parallel software development on two different technology platforms - one *Jakarta EE*, as the proven one, and the challenger, namely *Kubernetes*. This, however, would increase the cost of the software development, at least in the initial phase, as two source codebases would be built in parallel. But even this parallel software development might uncover shortcomings on the challenger platform - *Kubernetes*.

3.3 XML Schemas

While the *CERTEX* has implemented the ability to communicate via *HTTP/SOAP* and *REST/JSON* messages, the bulk of messages is exchanged via *HTTP/SOAP*. There are two challenges present while messages are exchanged via *HTTP/SOAP* in between EU member states. One is, the standardized approach with *XML schemas* are needed, in order to standardize on a common messaging format with code lists included. There is a standard present *UN/CEFACT* for a global trade facilitation, defined as [10]. From the implementation perspective, *UNECE XML schemas* are well defined, but rather extensive in length and this presents a challenge to *Java* source code generators for *HTTP/SOAP* message processing. The challenge itself lies in the name-space tracking, whenever the *HTTP/SOAP* message request/response is generated. The *UN/CEFACT* uses name-spaces extensively and it is essential, name-spaces not in use, should not be present in the constructed *XML* message. Out of two *XML Java* code generators, namely *CXF* [2] and *Apache Axis2* [1], the former generates more optimal *XML* messages, while the latter does not track name-space usage very well and the corresponding *XML* messages are larger in size.

3.4 Record locking mechanism

The production version of *CERTEX* releases runs on a cluster of *Jakarta EE*, which are connected with a distributed shared cache. In order to facilitate a proper *ACID* [7] properties of transactional processing a capable record locking mechanism needs to be established. At first, *ACID* properties in *RDBMS* [8] were used. So, an *SQL* database was locking records, on as designed basis. This proved to be insufficient solution, as in the case when two or more parallel *HTTP/SOAP* web service calls were in progress, only the first commit of a web service call would pass, all other web service call transactions were rolled back. This proved to be insufficient from a business perspective. Namely every technical fault at transaction processing was reported to the EU member state authorities and a manual insight was dispatched to resolve the reported technical fault. These manual insights were costly from the human resources perspective, thus, a better collision resolution had to be found.

The solution with a distributed shared cache *Coherence* [7] was found. So, each *CERTEX* web service processing thread attempts to get a lock on the record. This action really implies creating a record in *Coherence* and obtaining a lock on the record in the shared distributed cache. If the *CERTEX* web service processing thread was not successful, a reasonably long lock 30 seconds timeout was used. The distributed shared cache locks proved to resolve processing collisions, however, in *k2s* web service integration systems a performant record locking mechanism is one of critical system components.

[7] Atomicity, Consistency, Isolation, and Durability.
[8] A Relational Database Management System

4 Discussion

In general, *k2s* web service integration systems are very large *IS*s, which connect the continent with states. And example of *CERTEX* integration is set forth and few challenges were present, while the software was developed. The underlying programming language and technologies need to be selected in order to implement a large scale *IS*, what *CERTEX* really is. *Jakarta EE* was selected for *CERTEX*, and this dictates the selection of other, compatible software components, such as *Coherence*. Selecting the *Jakarta EE* framework brings a lot of benefits into the project, such as a wide range of software vendors, even wider set of open-source alternatives. Furthermore, *Jakarta EE* is a widely used framework, thus a lot of practical software development answers can be found on Internet.

Kubernetes however, brings distinguished qualities, which *Jakarta EE* cannot match. *Kubernetes* brings efficient virtualization in a form of running containers within the pod. Furthermore, *Kubernetes* brings a computing resource dynamic scaling and declarative deployments. Furthermore, *Jakarta EE* is a server-side Java standard, comprising of a fixed set of Java specifications, such as *JAX-RS* [9]. This set of standards is versioned with the version of *Jakarta EE*. This is possible, with a distinguished Java library class-loading to upgrade a single standard. This is, however, an elaborate and unstable server configuration process, determining what are Java library class references and loading them, as well. Also, the *Jakarta EE* server includes all afore Java specifications - even if some or many Java specifications are not used, at all. Many software developers consider *Jakarta EE* as overly bloated and difficult to manage. And there isn't just the question of Java specifications, which are included into *Jakarta EE*, but also the inherent software security question. Related to the software security, we can follow a *less is more* imperative. So, less components the *Jakarta EE* server includes, less attack vectors are available to be attacked by hackers.

Is it possible to run *Jakarta EE* based software on *Kubernetes*? This is inherently possible, as many *Jakarta EE* servers maintain multiple managed servers, which may be run within the container. But this setup is not a true Kubernetes-native software program. A *Jakarta EE* compatible software is typically of a monolithic type, with a lot of possible Java modules, which are tightly coupled. A *Kubernetes* system typically inspires loosely coupled, micro-service based set of containers, with specific resource declarations.

It must be noted; *Kubernetes* is not on the same architectural level, as *Jakarta EE*. *Kubernetes* is in fact on the same level, as any enterprise-class, type-1 hypervisor, often referred as the bare-metal hypervisor. A true *Jakarta EE* counterpart is, for example, *Quarkus* [6] serverless environment. The problem with the *Quarkus*, as a viable alternative to *Jakarta EE* is, it is not the only serverless environment available and the list of Java standards available is less strictly defined.

The only natural path forward for *CERTEX* is to port the software from the monolithic *Jakarta EE* based form to the true Kubernetes-native, container-first software architecture. As *CERTEX* is a complex piece of software, the generalized methodology for porting monolithic Java server applications to Kubernetes-native, container-first serverless software. *KAPION R&D group* works extensively on the afore mentioned generalized methodology. A lot of development resources were invested into *Jakarta EE* compatible software. However, as *Kubernetes* offers clear advantages, compared to *Jakarta EE* compatible software, the generalized methodology as indicated above, is of a great interest to the Java software development community. Furthermore, every extensive integration effort, with *CERTEX* integration included, requires extensive use of *IT* computing resources. While *Kubernetes* allows re-active hardware *IT* resource scheduling, further work is needed in the area of pro-active *IT* resource scheduling, based on the *AI* supported future load prediction.

[9] Jakarta RESTful Web Services.

4.1 *CERTEX* wider socio - economic impact

The use of *CERTEX* integration has a prominent socio-economic impact on business within European Union, as the trade is made fairer, goods more accessible to consumers. Furthermore, customs authorities across European Union acquired a detailed information about the trade facilitated. Further use of *CERTEX* interface will have a lasting positive impact on decision-making in the customs clearance process.

5 Conclusions

A new type of web service *IS* integration is present, a continent to the state web service integration, named as *k2s*. As the comparison reasons, a global to the state web service integration, dubbed as *g2s* was present as well. Definitions of both web service integrations were given and an example for *k2s* was present, as well. *CERTEX* is a system that connects customs systems with the EU's non-customs systems. Few *CERTEX* implementation challenges were discussed. For integration projects of such a scale, it is important the adequate *IT* software architecture is selected, where proven Java technologies took a precedence. Thus the *Jakarta EE* architecture was selected. It offers clear advantages in terms of using proven Java technologies, thus no delays are introduced into the software development timeline. However, in a sense disruptive *Kubernetes* emerged as a viable IT architecture substitute to *Jakarta EE* offering better scalability, and better declarative deployment capabilities, among other things. However, as both afore mentioned architectures, namely *Jakarta EE* and *Kubernetes* have a distinctive set of design patterns, a generalized methodology for porting the software from the monolithic server architecture to micro-services based, serverless software. *KAPION R&D group* is currently working on the generalized approach for the afore mentioned methodology.

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Organizational Activities to Promote Health for Older Employees Using Smart Technology

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Abstract

This paper explores how organizations can promote active and healthy ageing among older employees by leveraging smart technologies and artificial intelligence (AI). As the workforce ages, ensuring the physical and mental well-being of older workers becomes crucial for maintaining productivity, intergenerational collaboration, and organizational resilience. Study, based on literature review examines the application of AIpowered tools, mobile apps, wearables, and digital reminders in health promotion programs, showing how these technologies support personalized wellness, behaviour change, and continuous engagement. Evidence suggests that digital interventions significantly improve physical activity, nutrition habits, and self-monitoring among older workers. However, successful implementation depends on supportive leadership, adequate resources, and addressing potential barriers such as digital stress, data privacy concerns, and scepticism about AIdriven solutions. These innovations contribute to workplace environments that support healthy ageing, reduce absenteeism, and enhance employee satisfaction. By adopting age-inclusive digital health promotion strategies, organizations can retain experienced workers, promote intergenerational trust, and ensure equitable access to health resources in a digital age.

Keywords

Digital inclusion, smart technologies, workplace health promotion, older employees, health promotion, active and healthy ageing

1 Active and healthy ageing in organization environment

Employees' well-being is crucial in productive and efficient execution of the organization's day-to-day operations. Businesses must make sure they provide activities that can assist people in pursuing a healthy lifestyle, as people are becoming more concerned about their health with each passing year [1]. As a result, having organizational initiatives that can successfully support both mental and physical health can aid in attracting new talent and retain the current workforce members.

Workers can experience long hours and stressful periods, which can affect their performance and the company's results. Which is why it is of high importance to leverage health promotion programs and activities which can lead to reduced absenteeism, increased productivity and foster a positive work environment. Employees who have their health as a top priority are more likely to be engaged, motivated, and successful in helping the business succeed. Because of its advantages, promotion strategies can also make use of artificial intelligence (AI). AI tools can be used in different forms - of health apps, personalized wellness platforms, wearables, risk assessment platforms. In recent years, AI has been widely used in most business departments to help managers make decisions, generate ideas, and save time on repetitive tasks [2], but possibilities to use AI to promote health can be also used. Leveraging the power of data analysis and analytics, along with AI tools, companies can improve their performance and satisfy customers and employees better. AI-driven analytics can provide personalized wellness programs, virtual mental health support that can offer stress-reducing actions, and regular check-ups to ensure that the employees' well-being is regularly tracked. Programs should cater for all demographics groups but should be available in different formats.

Since older workers are an essential component of the organization process, the organization can focus more on them despite their increased risk of chronic illnesses and declining cognitive abilities [3]. Organizations can address promotion of health for older employees with different digital interventions which stimulate older employees not only to be more physically active, but also to use smart technology in everyday life.

1.1 Smart technology to promote active and healthy ageing

The World Health Organisation [4] defines healthy ageing as "the process of developing and maintaining the functional ability that enables wellbeing in older age." Functional ability is about having the capabilities that enable all people to be and do what they have reason to value. This includes a person's ability to: meet their basic needs; learn, grow and make decisions; be mobile; build and maintain relationships; and to contribute to society.

The risks for older workers are health and functional decline (like chronic conditions, slower physical recovery, musculoskeletal issues); cognitive challenges (like difficulty adapting to rapid technological changes) or psychosocial and

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mental health risks (burnout, isolation, ageism or anxiety about retirement).

In the previous decade, the use of Artificial Intelligence (AI) and Information and Communication Technology (ICT) has become prevalent in our lives. With the most known benefits of saving time and the ability to do repetitive tasks, allowing employees to focus more on creativity and strategizing, companies are implementing new emerging technologies. AI can have both a positive and a negative effect on the employees by using new technologies, however how can AI be used in promotional activities that companies can undertake in order to achieve better results?

AI and ICT are continuously used to communicate knowledge and encourage employees to become more physically active, more mindful and be socially more engaged. A metadata analysis has done research on how social networking sites (SNS) have an affect on mostly the following domains: physical health, sexual health, food safety, health promotion and smoking, which results have shown to be positive in way which the participants have shown changes in their behavior in order to improve their healthy lifestyle [5]. Additionally, studies have shown that programs that encourage active learning and participation have a greater impact on participants than those that only encourage passive learning. An organization has done an experiment where the experimental group went under a medical intervention where they had access to a website and participation in an health intervention, while the control group was just given a handbook, and the results were positively related for the experimental groups as the outcomes were higher scores in healthy nutrition, exercises and a decrease in their body mass index. This effectively has shown that a tailored program for the target audience has positively affected the participants' behavior and contributed to having a better healthy lifestyle with active and engaged learning methods. Another example of how new technologies can help individuals improve their well-being is making customized programs through an application. An application is accessible at any time and is highly portable, allowing for use anytime and anywhere. This enables the employees to track their active behavior outside of work and be more consistent with their goals. Studies have supported that the individuals who were using the application have achieved: greater physical activity by 63 minutes, greater weight loss, significantly improved knowledge score, better diet quality and consistency of maintaining their healthy lifestyle by 63% [6]. However, in many studies stress management is highly unrepresented, as they focus on other primary indicators for physical or mental health.

The application of ICT such as mobile apps, websites, SMS, and social media in promotion of healthy lifestyle, has shown that promotional activities that continuously communicate healthy behavior contributed mostly to physical activity and nutrition, while the reminders built in for consistency, has allowed employees to be more engaged and disciplined in their health related journey, however stress management, selfactualization and interpersonal relationships were not researched enough.

Mental health is vital to our well-being as well as a crucial factor in our private and professional life. Having a good state of mind and a healthy mind allows us to cope with challenges life throws at ourselves as well as how we live our life and the ability to progress in many areas in order to succeed and feel accomplished. People in general often feel stressed and overwhelmed, however many also deal with mental disorders that hinder their day-to-day activities and in a lot of cases their relationships, physical health and professional achievements. Moreover, the environment that a person is working in is highly effective in the employees' mental health. If employees are not taken care of, they may develop unhealthy coping mechanics which can affect their work goals.

Organizations should recognize mental health in the workplace as a crucial part of the employees' success in the three suggested pillars. Companies should have a vision for a psychologically healthy workplace which shows that they recognize the importance of employees' mental health as it is responsible for their operational excellence and organization's success, strategies and policies for the employees on workplace and organizational level that will support prevention and support, and prevention and treatment services that will allow access for mental health care for the employees and their family.

1.2 Challenges in implementing active and healthy ageing with smart technology

Challenges may arise when implementing new organizational activities. One of the most frequent challenges of making a workplace health promotion program, is the hesitation of the employees to participate in those. In this matter, the importance of managers and their encouragement come to light. Studies have shown that employers' leadership style is essential in tackling this problem, as their encouragement to exchange knowledge, change their beliefs and increase their self-efficacy has shown to be the most influential factors in motivating employees to continuously participate in health promotion programs [7]. Furthermore, employees might believe that the organization prioritizes discussing health initiatives over improving their working conditions, which could be an obstacle to participation.

Other major issues that might be hindering progress include a shortage of personnel to run those programs and a lack of funding. Finding an adequate team leads to higher success of the organization, which is why the organization should invest in the right team to carefully curate the right elements of the promotional program, that can be done externally or internally through workshops, however, when it comes to the lack of funding if the organization cannot offer resources at that moment of time, assistance and support may be provided by health organizations, business organizations who offer wellness programs or voluntary staff [8]. On the other hand, the use of apps and smart technologies in the workplace can also make or increase digital stress. Studies have shown that digital stress due to rapid implementation of new technologies, has an impact on employees' job satisfaction, work-life balance, productivity and their performance, as intensified digital communication leads to psychological challenges that are linked to anxiety, depression or burnout [9]. Moreover, contributors to digital stress also relate to inability to distinguish and make boundaries between the employees' personal and professional lives, which can lead to feeling overwhelmed and exhausted.

2 Conclusion

The responsibility for active and healthy ageing is on each individual, but also on organization. The organization should focus on ways to promote the programs that are going to be most effective in order to reach all employees. Organizations are employing health promotion due to both its benefits for the employees and the organization itself; additionally, taking the risk of implementing AI-based technologies to achieve a greater effect. Using AI can be beneficial when it comes to promoting workplace health related programs [10], however employees may be hesitant in participating in or trusting the program. AI chatbots can be trained based on rulebased algorithms where the topics of physical, mental and social health will be covered as well as nutritional advice.

AI has been shown to be successful in this matter, as one study shows that they have effectively promoted healthy lifestyles, smoking cessation, treatment and reduction of substance abuse, all while providing a non-judgmental space [11]. This can be a good idea for the beginning; however, it is not recommended to fully trust it but track that advice with caution. On the other hand, the problem with data privacy arises, hence it is important for the organization to have their chatbot incorporated in their system so that private information will not be let out to the public. Consistent promotion of active and healty ageing can also be done through an app, where the employees can access fitness programs tailored to them as well as topics related to mental health. An interesting aspect of this can be the gamification of certain elements. This can be a program where employees can connect with each other and foster healthy competition. Additionally, employees can gather points and achieve levels which can help them feel more accomplished and successful in which they will experience a dopamine hit. This will encourage them to continue in their fitness journey as they themselves can feel and see the progress that they have made. Another effective health promotion is building smart reminders in the employees' computer where they will be notified based on an algorithm for drinking water, taking a break, stretching or lunch time. Those reminders will notify the employees that they can take a short break to step back and ease their mind, with a relaxing activity, which can be flexible and each person can modify the settings according to their preferences [12]. Moreover, algorithms can be used to predict burnouts, based on how few employees take breaks and whether they are overworked.

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With introducing and promoting smart technology in organization environment to promote acitve and healty ageing we can introduce older employees to use smart technology, increase intergenerational collaboration and trust and take proactive approach in programmes for active and healthy ageing. But there must allways be also place for social contacts – smart technology can not be replacement for social contacts, but our tool.

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Vloga akademskih knjižnic pri digitalni vključenosti raziskovalcev v manjših raziskovalnih okoljih

The Role of Academic Libraries in Promoting Digital Inclusion of Researchers in Small Research Environments

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Povzetek

Članek temelji na sistematičnem pregledu literature (SLR) in predstavitvi mikro-časovnice kot praktičnega orodja ter obravnava vlogo akademskih knjižnic kot dejavnika digitalne vključenosti v okviru upravljanja raziskovalnih podatkov v manjših raziskovalnih okoljih. Poudarja, kako knjižnice s svojimi storitvami, usposabljanji in lokalno prilagojenimi strategijami prispevajo k zmanjševanju digitalne vrzeli ter omogočajo vključevanje raziskovalcev v načela odprte znanosti tudi v okoljih z omejenimi viri.

Abstract

The paper is based on a systematic literature review (SLR) and the presentation of a micro-timeline as a practical tool. It examines the role of academic libraries as a factor of digital inclusion in the context of research data management in small research environments. It highlights how libraries contribute to reducing the digital divide through services, training, and locally adapted strategies, enabling researchers to engage with open science principles even in resource-limited settings.

Ključne besede

Akademske knjižnice, digitalna vključenost, upravljanje raziskovalnih podatkov, odprta znanost, manjša raziskovalna okolja

Keywords

Academic libraries, digital inclusion, research data management, open science, small research environments

1 Uvod

Manjše raziskovalne institucije, kot so fakultetni laboratoriji in inštituti, se pogosto srečujejo z izzivi pri izvajanju praks odprte znanosti in upravljanja raziskovalnih podatkov (RDM). V tem kontekstu akademske knjižnice predstavljajo pomembno priložnost za spodbujanje digitalne vključenosti – zlasti v okoljih, kjer raziskovalcem primanjkuje dostopa do IT podpore, specializiranih orodij ali usposabljanja.

2 Metodološki okvir in praktična osnova

Mikro-časovnica temelji na rezultatih sistematičnega pregleda literature, ki je zajemal 70 virov med letoma 2014 in 2025, in je bil izveden z uporabo orodij EndNote in Parsif. Poleg teoretičnega okvirja je bil pri razvoju upoštevan tudi praktični vidik: izkušnje iz pilotne postavitve repozitorija z uporabo Dataverse [1] ter lokalne potrebe raziskovalcev na Univerzi v Mariboru (UKM). Namen časovnice je bil razviti preprosto, a uporabno orodje, ki raziskovalce vodi skozi ključne faze RDM brez zahteve po naprednem tehničnem znanju.

Poleg sistematičnega pregleda literature smo pri razvoju mikro-časovnice upoštevali tudi praktične izkušnje iz pilotne postavitve repozitorija na osnovi Dataverse [2]. Ta POC test je vključeval tesno sodelovanje med knjižnico in IT strokovnjaki, ki so poskrbeli za tehnične rešitve, kot so integracija podatkovnih virov, varnost in uporabniška prilagoditev, kar je bistveno pripomoglo k uspešni implementaciji.

3 Vloga knjižnic pri digitalni vključenosti

Knjižnice že danes nudijo številne storitve, ki pripomorejo k zmanjševanju digitalne neenakosti, kot kažejo tudi evropske študije o razvoju RDM storitev v knjižnicah [3]:

- **Usposabljanje raziskovalcev** za pripravo DMP (Data Management Plan).
- **Dostop do infrastrukture** (npr. repozitoriji).
- **Svetovanje** pri uporabi metapodatkovnih standardov, arhiviranju podatkov in pravnih vidikih.
- **Informacijska in podatkovna pismenost**, zlasti pri mlajših raziskovalcih.

Tako knjižnice vstopajo v vlogo **digitalne knjižnice kot aktivne soustvarjalke raziskovalnega okolja**, saj z usmerjenimi storitvami omogočajo dostop do znanstvenih praks tudi raziskovalcem v okoljih z omejenimi viri.

Knjižnice s svojo ponudbo storitev sodelujejo z IT strokovnjaki pri razvoju in upravljanju podatkovnih platform, kot

DIGIN 2025, 18 September 2025, Maribor, Slovenia

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je Dataverse, kar omogoča raziskovalcem preprost dostop do podatkov, napredno analitiko in skladnost z zahtevami odprte znanosti. S takšnim sodelovanjem IT in knjižnice skupaj skrbijo za celostno digitalno vključenost ter zmanjšanje tehnoloških ovir za manjše raziskovalne skupine.

Za učinkovitejšo organizacijo teh storitev in dolgoročno načrtovanje podpore se knjižnice lahko oprejo na strukturirane modele, kot sta Piramida in RISE, ki sledita v nadaljevanju.

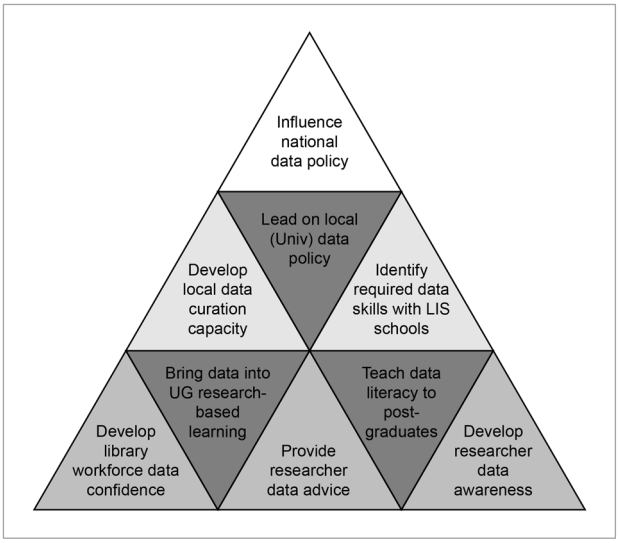
4 Modeli podpore: piramida in rise

Akademske knjižnice se lahko pri razvoju RDM storitev oprejo na dva pomembna okvirja. **Piramidni model** [4] knjižnicam omogoča razvrstitev storitev na operativno, taktično in strateško raven, s čimer lažje določijo prioritetne dejavnosti tudi v pogojih omejenih virov.

Po drugi strani **okvir RISE** [5] ponuja konkretno orodje za **samooceno institucionalne pripravljenosti**, razdeljeno na štiri stebre: strategija in politika, tehnična infrastruktura, usposabljanje in pravni/etični okvir. Ta model knjižnicam omogoča strateško načrtovanje razvoja RDM storitev.

Okvir RISE, ki ga uporabljajo knjižnice za samooceno, je uporaben tudi za IT oddelke, saj omogoča celovito oceno pripravljenosti na strateški, tehnični, izobraževalni in pravni ravni. Tako lahko knjižnice in IT enote razvijajo usklajene modele podpore, ki so še posebej pomembni za manjša raziskovalna okolja z omejenimi viri.

Oba pristopa omogočata knjižnicam, da vlogo podpore raziskovalcem utemeljijo na strukturiranih pristopih, prilagojenih tudi manjšim okoljem.



Slika 1: Piramidni model RDM storitev za akademske knjižnice, ki prikazuje operativne, taktične in strateške ravni, vir: [4]

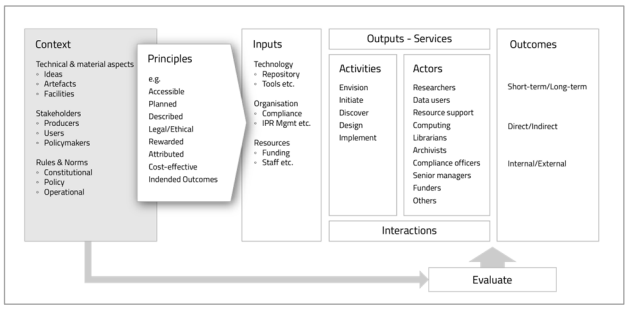
5 Procesni modeli razvoja rdm storitev

Učinkovit razvoj storitev upravljanja raziskovalnih podatkov (RDM) zahteva strukturiran pristop, ki upošteva institucionalne značilnosti, vire in deležnike. V nadaljevanju so predstavljeni ključni modeli, ki ponujajo oporne točke za knjižnice, še posebej v manjših raziskovalnih okoljih.

5.1 Model razvoja storitev po Whyte & Allard

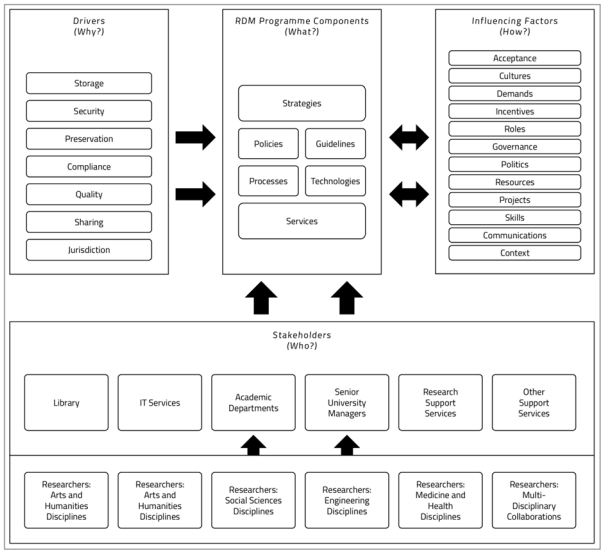
Model, ki ga predstavljata Whyte in Allard [6], opredeljuje razvoj RDM storitev kot **procesno pot**, kjer se institucionalni kontekst in načela pretvarjajo v konkretne storitve. Ključni elementi modela vključujejo:

1. **Kontekst**: institucionalno okolje, obstoječa infrastruktura, kultura ravnanja s podatki.
2. **Načela**: vrednote, kot so odprtost, trajnost in sodelovanje
3. **Vložki**: človeški in. tehnični viri.
4. **Izhodi/servisi**: storitve za raziskovalce (npr. pomoč pri DMP, repozitoriji).
5. **Rezultati**: boljše ravnanje z raziskovalnimi podatki, skladnost z zahtevami financerjev.



Slika 2: Proces razvoja storitev upravljanja raziskovalnih podatkov, vir: [6]

5.2 Knjižnično usmerjen model



Slika 3: Knjižnično usmerjen model institucionalnega RDM, vir: [7]

Pinfield s sodelavci [7] ponuja **širši pogled**, ki temelji na štirih stebrih:

1. **Kaj (komponente)**: katere storitve in aktivnosti razvijati.
2. **Zakaj (gonila)**: zakonodajne zahteve, odprti dostop, dolgoročno hranjenje podatkov.

3. **Kako (dejavniki vpliva)**: vloge, viri, usposobljenost, komunikacija.
4. **Kdo (deležniki)**: IT služba, raziskovalci, pravna pisarna, knjižnica.

Model jasno nakaže, da knjižnice niso edini akter, ampak del širšega institucionalnega ekosistema.

5.3 Model zrelosti RDM storitev

Za ugotavljanje trenutnega stanja in načrtovanje razvoja RDM storitev je uporaben tudi **zrelostni model**, ki ga predlagajo Cox in sodelavci [8]. Z njim lahko knjižnice ocenijo svojo razvojno fazo glede na:

- institucionalno strategijo,
- razpoložljivo infrastrukturo,
- kompetence osebja,
- obseg storitev.

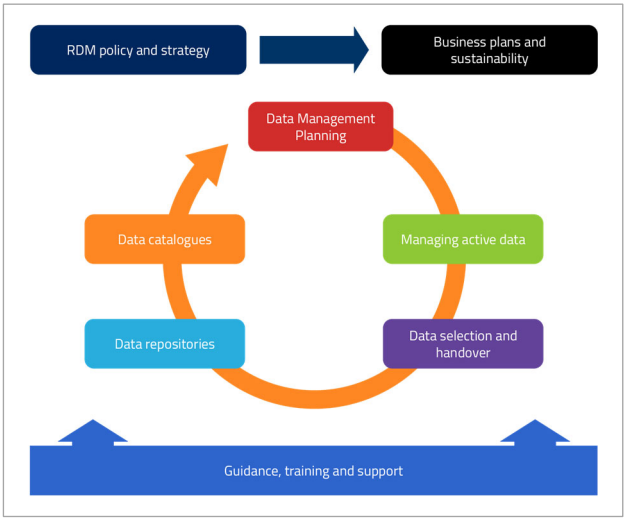
5.4 Model RDM skozi celoten življenjski cikel raziskave

Curdt [9] je na osnovi longitudinalne raziskave razvil model, ki prikazuje, kako naj RDM storitve spremljajo **celoten raziskovalni proces** – od zbiranja podatkov do njihove delitve in ponovne uporabe. Tak pristop pomaga knjižnicam načrtovati podporo, ki je skladna z znanstveno prakso.

5.5 Samoevalvacija z RISE

Kot praktično orodje za oceno institucionalne pripravljenosti se priporoča uporaba **okvira RISE** [5]. Ta ni model v klasičnem smislu, a ponuja **strukturiran način refleksije** trenutnega stanja in vrzeli v štirih kategorijah:

- strategija in politika,
- tehnična infrastruktura,
- usposabljanje in ozaveščanje,
- pravni in etični vidiki.



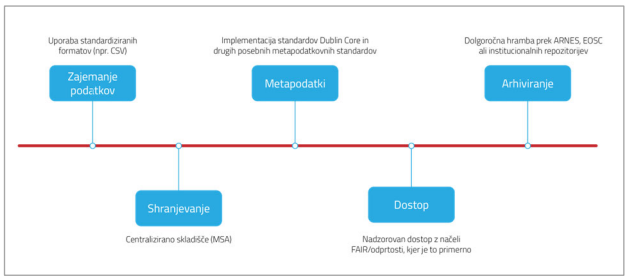
Slika 4: RISE – okvir za samooceno raziskovalne infrastrukture na štirih ključnih področjih, vir: [5]

6 Mikro-časovnica kot praktično orodje podpore

Na podlagi sistematičnega pregleda literature in izkušenj iz prakse (UKM) je bil razvit model **mikro-časovnice**, ki v kompaktni obliki prikazuje ključne faze ravnanja z raziskovalnimi podatki za vsak posamezen primer:

- zajem podatkov,
- shranjevanje,
- opis z metapodatki,
- dostop,
- arhiviranje.

Časovnica služi kot **hiter referenčni pripomoček** za raziskovalce in podporno orodje za knjižničarje. V okoljih z omejenimi kadrovskimi in tehničnimi sredstvi predstavlja nizkotehnološko, a visoko učinkovito obliko podpore. Časovnica temelji na procesnih modelih razvoja knjižničnih storitev [10], vendar je bila prilagojena lokalnemu okolju in dejanskim potrebam raziskovalcev.

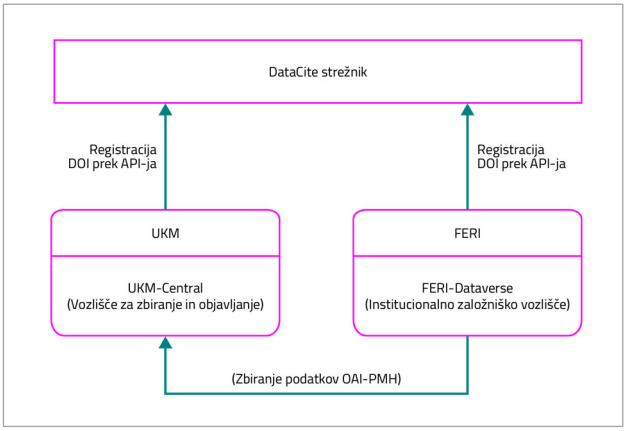


Slika 5: Primer raziskovalne mikročasovnice

V pilotnem primeru s platformo Dataverse so bili koraki mikročasovnice podprte z IT storitvami: tehnična integracija zajema, avtomatizacija opisa podatkov z metapodatki ter varno arhiviranje. Ta praktični primer kaže, kako lahko knjižnice in IT skupaj prispevajo k učinkovitemu upravljanju raziskovalnih podatkov.

Za potrebe testiranja decentraliziranega pristopa k ravnanju z raziskovalnimi podatki je bila izvedena simulacija federacije dveh Dataverse instanc – **UKM-Dataverse** kot *Harvesting and Publishing Node* ter **FERI-Dataverse** kot *Institutional Publishing Node*. Oba sistema sta neodvisno povezana z **DataCite strežnikom** za dodeljevanje trajnih identifikatorjev (DOI), med seboj pa sta povezani prek protokola **OAI-PMH**, ki omogoča zbiranje in indeksacijo metapodatkov.

Ta shema ponazarja, kako je mogoče vzpostaviti decentralizirano, a interoperabilno okolje, ki podpira načela odprte znanosti in omogoča hkrati lokalno suverenost nad podatki ter globalno iskanje in deljenje.



Slika 6: Federacija Dataverse instanc z uporabo OAI-PMH in povezavo do DataCite, vir [2]

7 Zaključek

Knjižnice niso zgolj podporna infrastruktura, temveč aktivne soustvarjalke digitalno vključujočega raziskovalnega okolja. Z lokalno prilagojenimi pristopi, kot je mikro-časovnica, in ciljno usmerjenim usposabljanjem knjižničarjev, lahko postanejo ključni akter pri vključevanju vseh raziskovalcev v odprto znanost – ne glede na velikost institucije, dostop do sredstev ali tehnično opremljenost.

Za trajnostni razvoj RDM storitev v manjših raziskovalnih okoljih je nujno tesno sodelovanje med knjižnicami in IT oddelki, kar potrjuje tudi primer Dataverse projekta. Takšen interdisciplinarni pristop omogoča učinkovito zmanjševanje digitalne vrzeli, krepi digitalno pismenost raziskovalcev in spodbuja udejanjanje načel odprte znanosti.

Za prihodnost razvoja RDM storitev v Sloveniji bo ključno nadaljnje povezovanje med knjižnicami, raziskovalnimi uradi in IT sektorji – ob podpori sistemskih strategij, ki digitalno vključenost postavljajo v ospredje.

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Mobilna aplikacija za podporo samostojnosti na področju vsakdanjih rutin mladostnikov z avtizmom in/ali ADHD

Mobile Application to Support Independence in Daily Routines of Adolescents with Autism and/or ADHD

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Abstract

To support increased independence among adolescents with impaired executive functions, especially those with autism and/or ADHD, we developed, tested, and evaluated a pilot mobile application. Based on theoretical foundations, our own research, and expert recommendations, the app offers visual and time-based structuring of routines, tracking progress through a *Pomodoro* [1] timer and a reward system. The application was tested over 14 days by 12 adolescents and 2 young adults (11 male, 3 female): 6 with autism only, 1 with ADHD only, and 7 with both, using their own smartphones or tablets. After the trial users rated its usability, benefits, and motivational impact very positively, with special praise for the innovative real-time visual timer (calendar) that improves time awareness. They also suggested additional features, such as audio alerts outside the app, integration with other digital tools, and various forms of rewards. This analysis of the pilot version calls for further research with more users facing executive function challenges, including those transitioning to independent living for the first time while studying or working, and longer-term monitoring of app usage to assess its effectiveness.

Keywords

Adolescent independence, digital support, mobile application, executive functions, autism, ADHD

1 Introduction

Adolescents with autism and/or ADHD, despite average or high intellectual abilities, often struggle with daily tasks due to impairments in *executive functions* such as planning, organization, self-control, and self-regulation [3, 4, 5]. These difficulties include poor behavioral adaptation and issues with inhibiting behaviors [6], affecting organizational skills [7] and the performance of everyday tasks such as morning routines, hygiene maintenance, money management, and keeping things in order [8, 9]. As a result, these adolescents often rely heavily on parental support, which hinders their independence and creates family tensions [10]. To ease the transition to independent living, adolescents need tools that provide visual support and help with time management through reminders. Mobile apps, a readily accessible support form, can boost adolescent independence and reduce parental strain [11]. However, many existing solutions lack empirical evidence on their effectiveness [12]. Involving adolescents in developing these tools increases their motivation, trust, and engagement [13, 14].

Autism, with a prevalence of 3.8% in children in the USA in 2020 [15], is medically defined as a spectrum of disorders in social communication, interaction, and repetitive behaviors [5]. The social model and neurodiversity theories, however, view autism as a neurological difference, a natural variation in brain development, with both challenges and strengths, many of which are socially conditioned [16, 17]. With appropriate support, individuals with milder impairments can live independently, aided by technologies that enhance self-monitoring strategies, communication, and social interaction [18, 19].

Attention Deficit Hyperactivity Disorder (ADHD), a developmental neurological condition, involves difficulties with attention, hyperactivity, and impulsivity, impacting functioning in various environments [5]. Diagnosed in 5.6% of youth aged 12 to 18, ADHD often co-occurs with autism [15]. Digital support can help improve self-regulation, attention, and task optimization in individuals with ADHD as well [20].

The aim of this research was to develop, test, and evaluate a mobile application designed to support adolescents with autism and/or ADHD in independently carrying out everyday routines. We set three objectives: (1) to identify the challenges and needs of adolescents with autism and/or ADHD in becoming independent in daily routine tasks, (2) to develop and test a mobile app to support their independence in organizing and performing such routines, and (3) to assess the usability of the developed mobile application.

*Title Note: The research was conducted as part of a master's thesis at the Faculty of Education, University of Primorska [1].

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[1] Pomodoro (Italian for "tomato") is a timer used in mobile apps, based on a time management technique with work intervals and short breaks, developed by Francesco Cirillo in the 1980s. The name comes from a tomato-shaped kitchen timer Cirillo used [2].

To achieve the first goal, we prepared two questionnaires (for parents and adolescents) and included 12 families with 11 adolescents aged 13 to 16 and one young adult (aged 19), diagnosed with autism and/or ADHD. We found that perceptions of challenges in completing tasks often differed between adolescents and parents. While adolescents believed they completed most tasks independently, parents emphasized the need for constant prompting and help in structuring activities. Both groups reported challenges in attention, forgetfulness, motivation, and time perception, especially during school learning. Adolescents often experience parental supervision as burdensome or unnecessary, which leads to conflicts. Personal responses revealed inner struggles such as anxiety, impulsivity, and, among girls, perfectionism, indicating a need for a more sensitive and individualized approach.

2 Development of the Mobile Application *Pica*

For the second objective, we aimed to develop a mobile application to support the independence of adolescents with autism and/or ADHD, based on both theoretical and empirically identified needs. During its design and development, we carefully considered expert guidelines for creating such applications and actively involved adolescents, who made significant contributions to the content and functionality.

2.1 Analysis of User Needs and Desires

Every development process starts with analyzing user needs [21]. We summarized these needs based on expert literature on organizational challenges for adolescents with autism and/or ADHD, and supplemented them with our own research from questionnaires for adolescents and parents (first objective). From the synthesis of both sources, we identified three key challenges: (1) difficulties with organizing and executing routines, (2) poor time awareness, and (3) dependence on parental reminders. These challenges guided the design of the application: (1) structuring daily activities, (2) visual time representation, and (3) reminders and motivation for less preferred tasks. Upon reviewing and testing a sample of existing applications for organizational and time orientation support, we found that while these applications offer similar features, they do not provide users with a clear sense of task duration and available time in a day. Therefore, we placed the development of time awareness at the core of our application.

Adolescents involved in the study played a key role in shaping the application. They were invited to give suggestions through semi-structured interviews during a focus group on the Zoom platform. Suggestions included gamification and rewards, direct voice interaction with the app, collaboration with parents on assigned tasks and work quality, visual customization based on individual needs, time adjustments, and reminders to improve focus. These suggestions were analyzed and meaningfully incorporated into the app's development within available resources.

2.2 Expert Recommendations

Boulton et al. [22] in the first systematic review of mobile applications and digital resources for children with developmental difficulties concluded that there is a lack of methodologically sound research on the effectiveness of digital interventions for adolescents with autism and ADHD, which complicates to provide the expert recommendations to families with respect to apps or digital resource. Powell et al. [23] evaluated ten popular applications for children with ADHD and found that they do not meet users' complex needs and are not methodologically well evaluated.

The development of quality digital interventions requires collaboration with experts and users, supported by health, academic, and governmental institutions [14, 22]. Despite limited evidence of effectiveness, research emphasizes the importance of appropriate content, user interface, reminders, and interactive conversational assistants [14], as well as co-creation with adolescents, which enhances their trust and motivation [13, 14].

Based on discussions with clinicians and adolescents, Powell et al. [23] outlined the following guidelines for designing apps for adolescents with ADHD: (1) Apps should have a simple interface for easy use. (2) They should be visually attractive and content-related to users' experiences and challenges. (3) They should address symptoms, such as managing inattention, hyperactivity, and impulsivity, while offering strategies to improve organizational skills. (4) Content and language should be age-appropriate. (5) A reward system should be included to encourage regular use. (6) Apps should promote users' social development rather than hinder it.

We followed these recommendations as closely as possible, considering research limitations and the project's goals. Some recommendations, such as the interactive conversational assistant, were not implemented due to technical and financial constraints. Additionally, we did not include features for promoting social relationships, as this goes beyond the scope of the research.

2.3 Application Development and Description

Based on the identified needs and expert recommendations, as well as adolescents' desires, we developed a pilot mobile application with the working title *Pica*, designed to support adolescents with autism and/or ADHD who struggle with executive function deficits, particularly in planning and executing daily routines and managing time orientation.

2.3.1 Development Environment of the Pica App We developed the *Pica* app using the Flutter framework and the Dart programming language, which allows for the development of applications for both Android and iPhone. The application can also be run on personal computers or as a web application. For Apple devices, Xcode must be installed, and for Android devices, Android Studio. The program code, consisting of approximately 8,300 lines, was designed, programmed, tested, and debugged in Microsoft Visual Studio Code from October 2024 to May 2025.

2.3.2 Access to the Pica App. For Android devices, the application is available as the installation file *pica<version_num>.apk*, accessible at the following link (which also includes a detailed description of the app in Slovene): https://drive.google.com/drive/folders/1j2hlxfSmtJzRlObZDOdpsX90jl3cIAaF.

For iPhone devices, the application is available on the App Store. Since the name *Pica* was already used, we symbolically named the app: *Pizza Pomodoro Time*, available at: https://apps.apple.com/si/app/pizza-pomodoro-time/id6745557246.

2.3.3 Description of the Pica App. The name has a double meaning: (1) It is an acronym in Slovene for "Support for the Execution of Target Activities" (in Slovene: *Podpora Izvedbi Ciljnih Aktivnosti*). (2) Visually, the app resembles a sliced pizza. As a symbolic motivational reward for successfully completed routines, we also included a pizza-building mechanism: each task within a routine represents one slice of pizza.

Due to atypical time perception in adolescents with autism and/or ADHD, especially in estimating time intervals [24, 25], we developed an innovative digital calendar (Figure 1, left). This calendar, in the form of time strips, enables real-time visual monitoring of time and supports event sequence understanding. It is color-coded, adjustable (stretchable/compressible), and allows customization of time units (year, month, day, hour, minute, second) (Figure 1, middle).

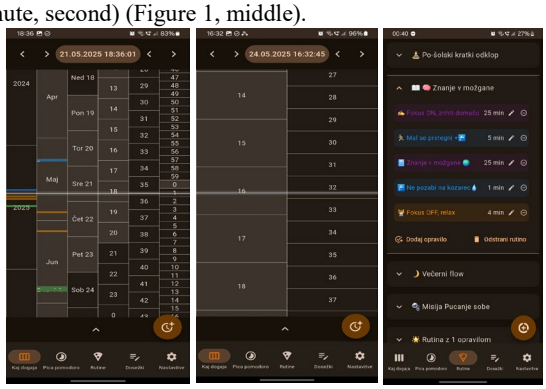

Figure 1: Screenshots of: linear calendar with time tracks (left), adjustable time unit display (center), routine-creation page (right)

For supporting weak organizational skills, the application includes routines made of consecutive tasks with defined durations but no fixed start or end times (Figure 1, right). When the first task begins, the *Pomodoro timer* starts (Figure 2, left). Visual cues, color coding (lighter shades for elapsed time), and sound alerts encourage timely completion. Each completed task is marked, and the user is rewarded with a slice of pizza (Figure 2, middle). Upon completing the entire routine, a visual-audio congratulations message is displayed (Figure 2, right), along with the full pizza as a reward. This system enhances focus, improves planning, and encourages consistent daily routine execution.

Figure 2: Screenshots of: routine execution page (left), reward page (middle), visual-audio congratulation message upon completing a routine (right)

2.4 Testing of the App and Usability Evaluation

The application was tested for two weeks. We invited participants from the first phase of the research, along with additional families, resulting in 14 participants: 12 adolescents (aged 13–16; 10 male, 2 female) and 2 young adults (male, 19; female, 28). During personal interviews, we introduced the app's functionalities to them, clarified testing expectations, and checked whether the application was successfully installed.

After the testing, two questionnaires (for adolescents and parents) were administered to assess the usability of the *Pica* app and to achieve the third research objective. All adolescents (n=14) rated the app positively based on their initial impressions. They described it as useful, modern, interesting and convenient, although a bit complex initially. They highlighted its assistance in organising daily tasks and recognized its potential.

More than half of the adolescents used the pre-set routines or modified them, which shows their supportive value. Those who created their own routines (almost half entered at least three) emphasized the need for even more customisation, for example enabling to copy tasks or entire routines. It emerged that we should more explicitly encourage parental involvement in planning rouitnes, as this was taken too much for granted. However, the high number of routines created indicated the potential of the app for structuring the day. It would be beneficial to allow more time for the roll-out and to provide additional user support.

Adolescents and parents rated the app's functionalities on a 5-point Likert scale. Most rated all features highly (4 or 5), with particular praise for the innovative calendar. Most also agreed that the rewards motivated them to use the routines daily. However, 13 out of 14 participants missed reminders when leaving the app. Parents positively evaluated key functionalities: 85% highlighted the importance of sound alerts and colours, and the same percentage said that the calendar in the form of moving timelines was visually more effective than a traditional one.

Adolescents and parents also assessed the app's usability for challenges such as planning, time orientation, independence, studying, tidying up, and evening routines. Most adolescents (9/14; 64%) and parents (12/13; 93%) believe the app improves planning and task execution. The majority also noted improved time awareness (adolescents 79%, parents 85%), greater independence (71% adolescents, 85% parents), and faster evening routines (71% adolescents, 92% parents).

For learning challenges, half of the adolescents reported better concentration, with 39% of parents felt the opposite. Opinions were divided on motivation to learn: 36% of adolescents felt the app could not help, while 61% of parents disagreed. When it comes to tidying up the room, 62% of parents and 43% of adolescents find the app useful.

Overall, the analysis shows that both adolescents and parents recognize the *Pica* application as a promising tool for supporting organization, daily tasks, and time orientation, which can foster greater independence and reduce reliance on parental support.

2.5 Suggestions for Future Development

We gathered opinions and suggestions for the future development of the *Pica* app at each developmental stage. Initially, we asked participants about their functional

expectations, which we incorporated into the app's development. During testing, they provided feedback and improvement suggestions. Afterward, we collected their opinions via questionnaires, including open-ended questions about perceived strengths and suggestions for further development.

The most frequent suggestions for improvement included the desire for sound alerts that would work outside the app, which was proposed by nearly all participants. This functionality would help to remind users to start a routine and to maintain their attention during the routine. Suggestions also included better integration with other tools, such as alarms and calendars, and synchronization with educational platforms (e.g., e-Assistant) and family apps for greater control over data input (e.g., FamilyLink and FamilyWall).

Additional suggestions include integrating calendar events with the pomodoro timer for better task planning, increasing the variety of rewards, enabling task copying, and changing the visual design of the app to keep it engaging for users.

For further development, it would be sensible to test the app with more users over a longer time period, to involve additional programmers in the development to manage the complexity of the code, and to look for funding opportunities through project calls in the field of digital support for mental health. With additional resources and development opportunities, the app could include additional functionalities such as gamification, integration with e-Assistant, diary notes, user choice rewards, and integration with other digital tools and applications to further improve user experience and support effectiveness.

3 Conclusion

Adolescents with autism and/or ADHD face numerous challenges due to weak executive functions, making it difficult for them to develop independence, follow routines, organize tasks, and manage time. To help overcome these challenges, we developed and tested the *Pica* mobile app, which supports the organization of daily life, and we analyzed its effectiveness.

In conclusion, the *Pica* app has already successfully fulfilled its primary purpose in the pilot version, as it has been evaluated as a valuable support for the participating adolescents with autism and/or ADHD in their daily routines. The development of the pilot application could be continued, upgraded, and eventually included as a assistive technology in the daily life of neurodiverse adolescents or individuals with executive function challenges. The app also has potential for a wider range of users who could benefit from such a tool to organize daily tasks and improve time awareness with an innovative real-time calendar.

Acknowledgments

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Digitalna orodja za vključujočo navigacijo in informiranje - dostopne QR kode

Digital Tools for Inclusive Navigation and Information - Accessible QR codes

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Povzetek

QR-kode (Quick Response v nadaljevanju QR-kode) so uveljavljeno orodje za hitro posredovanje digitalnih informacij, vendar njihova uporaba ni samoumevno dostopna vsem. Osebe s senzorno in kognitivno oviranostjo – slepi, slabovidni, gluhi, naglušni ter osebe z motnjami v duševnem razvoju – pogosto naletijo na resne omejitve pri zaznavanju, interpretaciji ali interakciji z običajnimi QR-kodami. V članku obravnavamo dostopne QR-kode (Accessible QR codes v nadaljevanju AQR-kode), ki temeljijo na načelih univerzalnega oblikovanja in digitalne vključenosti ter omogočajo univerzalni dostop do vsebin.

Raziskava temelji na kombinaciji sistematičnega pregleda literature, konceptualne analize potreb treh ciljnih skupin in študije primera naprednega sistema NaviLens. Predstavljene so ključne tehnološke značilnosti AQR-kod, kot so zaznavanje z razdalje, samodejna navigacija, uporaba znakovnega jezika, lahko berljivega besedila ter zvočnih povratnih informacij. Raziskali smo tudi mogoče manipulacije in zlorabe.

Hipoteza je, da AQR-kode pomembno izboljšajo dostop do informacij v javnem prostoru ter prispevajo k samostojnosti in vključevanju uporabnikov. V sklepnem delu so predstavljane smernice za implementacijo AQR-kod v slovenskem prostoru, kot tudi zaščita pred zlorabami ter priporočila za vzpostavitev testnih okolij in pilotnih projektov.

Ključne besede

QR koda, AQR kode, dostopnost, digitalna orodja, participacija

Abstract

QR codes (Quick Response) are an established tool for quickly sharing digital information, but their use is not automatically accessible to everyone. People with sensory and cognitive disabilities, the blind, visually impaired, deaf, hard of hearing, and people with intellectual disabilities often encounter severe limitations in perceiving, interpreting, or interacting with conventional QR codes. This article discusses Accessible QR codes (AQR) based on the principles of universal design and digital inclusion, which enable universal access to content.

The research is based on a comprehensive combination of a systematic literature review, a conceptual analysis of the needs of three target groups, and a case study of the advanced NaviLens system. The key technological features of AQR codes are presented, such as distance detection, automatic navigation, use of sign language, easy-to-read text, and audio feedback. We also investigated possible manipulations and abuses.

The hypothesis is that AQR codes significantly improve access to information in public spaces and contribute to user independence and inclusion. The concluding part presents guidelines for the implementation of AQR codes in Slovenia, as well as robust protection measures against abuse and recommendations for setting up test environments and pilot projects, ensuring a secure and successful implementation.

Keywords

QR code, AQR code, accessibility, digital tools, participation

1. Uvod

Hitro odzivne kode (ang. Quick Response - QR) [1] so postale uveljavljeno digitalno orodje za hitro posredovanje informacij uporabnikom prek pametnih naprav. QR-kode delujejo kot učinkovita vez med fizičnim in digitalnim svetom, saj omogočajo neposreden dostop do spletnih vsebin, multimedijskih gradiv in uporabniških vmesnikov [2][3][4][10]. Uporabljajo se na različnih področjih kot so promet, kultura, turizem, zdravstvo, trgovinske dejavnosti in tako pogosto dopolnjujejo fizično označevanje prostora z dodatnimi informacijami [6][7][8][9][10].

Kljub razširjenosti pa QR-kode niso samoumevno dostopne vsem. Njihova uporaba predpostavlja določene senzorične in kognitivne sposobnosti, kot so vid in razumevanje kompleksnih informacij. To predstavlja pomembno oviro za različne uporabniške skupine, med katerimi so slepe in slabovidne osebe,

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gluhe in naglušne osebe ter osebe z motnjami v duševnem razvoju.

V Sloveniji živi okoli 170.000 invalidov ali 8,5 % celotne populacije. Če dodamo populacijo starejših, (skoraj 20 % prebivalcev je starejših od 65 let) vidimo, da omogočanje multimodalne mobilnosti ni samoumevno, ampak je slednje predpogoj za opravljanje aktivnosti oseb z različnimi oviranostmi v mikro in makro prostoru. Podatki nam pokažejo, da se skoraj 45 % slovenskega prebivalstva uvršča med ranljive skupine udeležencev v prostoru [11]. Ti podatki opozarjajo na nujnost razvijanja rešitev, ki omogočajo vključujoč dostop do prostora in informacij v vseh segmentih javnega življenja.

Na podlagi predstavljenih teoretskih izhodišč je bila oblikovana hipoteza, da dostopne QR-kode, oblikovane v skladu z načeli univerzalnega oblikovanja, pomembno izboljšajo dostop do informacij v javnem prostoru ter prispevajo k samostojnosti in vključevanju uporabnikov.

2. Teoretično ozadje in metodologija

Za razumevanje AQR-kod je nujno najprej osvetliti koncept univerzalnega oblikovanja, ki predstavlja temeljni okvir za zagotavljanje enakopravnega dostopa do prostorov, storitev in digitalnih orodij. Koncept, sprva razvit na področju arhitekture, se je v zadnjih desetletjih razširil na oblikovanje produktov, storitev in informacijskih tehnologij, kjer pridobiva poseben pomen v kontekstu digitalne vključenosti. Prav univerzalno oblikovanje ponuja načela, s katerimi lahko klasične QR-kode nadgradimo v AQR-kode, ki omogočajo uporabo tudi osebam s senzornimi in gibalnimi oviranostmi ter prispevajo k večji enakosti pri uporabi prostorov.

2.1 Univerzalno oblikovanje in digitalna vključenost

Načela univerzalnega oblikovanja izhajajo iz ideje, da naj bodo prostori, storitve in tehnologije zasnovane tako, da jih lahko uporabljajo vsi ljudje, ne glede na njihove fizične, senzorične ali kognitivne zmožnosti [12]. Sedem osnovnih načel univerzalnega oblikovanja (enakost uporabe, prilagodljivost uporabe, enostavna in intuitivna uporaba, zaznavne informacije, strpnost do napak, majhen fizični napor ter ustrezna velikost in prostor za uporabo) omogočajo razvoj rešitev, ki so vključujoče in trajnostne.

2.2 Dostopne QR-kode (AQR) kot tehnologija

Pri QR-kodah to pomeni, da morajo biti zasnovane tako, da omogočajo različne modalitete dostopa: zaznavanje z razdalje, uporabo zvočnih povratnih informacij, prilagoditev v znakovni jezik, uporabo lahko berljivega besedila ter podporo multimodalnim vmesnikom. AQR-kode so tako nadgradnja klasičnih QR-kod, saj upoštevajo načela univerzalnega oblikovanja in omogočajo univerzalni dostop do informacij tudi skupinam, ki so sicer pogosto izključene iz digitalnih rešitev.
AQR-kode nadgrajujejo klasično zasnovo z upoštevanjem načel univerzalnega oblikovanja, kar pomeni, da so namenjene vsem uporabnikom, ne glede na njihove telesne ali kognitivne zmožnosti. Tabela 1 prikazuje primerjavo med klasično QR-kodo in AQR-kodo. Gre torej za primerjalno tabelo, ki pojasnjuje ključne razlike v oblikovanju in zaznavanju.

Tabela 1: Vizualna zasnova in zaznavanje

Vidik	Klasična QR-koda	Dostopna QR-koda (AQR)
Oblika	Črno-bela kvadratna matrika, občutljiva na svetlobo	Barvna kodna struktura (npr. NaviLens), optimizirana za zaznavo
Zaznavna razdalja	20–50 cm (odvisno od kamere)	Do 15 m, tudi v gibanju
Zahteva po ostrenju	Da, potrebna je statična kamera	Ne, zajem deluje v gibanju brez ostrenja
Usmerjanje kamere	Potrebna natančna poravnava	Samodejna zaznava kode brez poravnave

2.3 Metodološki pristop

Raziskava temelji na kombinaciji analitično-deskriptivne metode ter študije primera. Uporabljeni metodološki sklopi so sistematični pregled literature (Scopus, Web of Science, Google Scholar), konceptualna analiza potreb treh ciljnih skupin (slepi in slabovidni, gluhi in naglušni, osebe z motnjami v duševnem razvoju) ter študija primera naprednega sistema NaviLens prikazanih v tabeli 2.

Tabela 2: Pregled izvedenih metodoloških sklopov

Metodološki sklop	Osnovni namen	Metode in orodja	Rezultati
Sistematični pregled literature	Kritična presoja teoretičnih ter empiričnih spoznanj o AQR	Pregled baz Scopus, Web of Science, Google Scholar	Opredeljeni raziskovalni viri
Študija primera NaviLens	Razumevanje delovanja ter uporabniške učinkovitosti naprednega sistema AQR	Tehnično-primerjalna analiza; dokumentna analiza	Model strukture sistema; seznam dobrih praks implementacije
Primerjal-na analiza ciljnih skupin	Preslikava potreb slepih, gluhih in oseb z motnjami v duševnem razvoju	Analiza zakonodaje (ZIMI); sinteza smernic WCAG 2.2, Easy-to-Read	Tabela »potrebe funkcionalnosti AQR« priporočila za prilagoditve vsebin

2.3.1 Sistematični pregled literature

V raziskavi smo izvedli ciljno usmerjen pregled literature s področij digitalne dostopnosti in univerzalnega oblikovanja, QR-kod in njihovih tehničnih modifikacij za večjo dostopnost.
Uporabili smo baze podatkov in uradne objave mednarodnih organizacij (npr. WHO, EU Agency for Fundamental Rights). Rezultat pregleda je sistematična zbirka sedmih člankov, od katerih smo analizirali šest primerov s področja knjižnic in zdravstva ter enega iz trgovskega sektorja.

2.3.2 Konceptualna analiza ciljnih skupin

Za razumevanje uporabe AQR-kod je bilo potrebno razčleniti potrebe treh ključnih ciljnih skupin uporabnikov: slepih in slabovidnih, gluhih in naglušnih ter oseb z motnjami v duševnem razvoju. Analiza je temeljila na zakonodajnih in strokovnih smernicah (ZIMI, WCAG 2.2, Easy-to-Read) ter obstoječih praksah vključevanja v digitalne storitve.

Slepi in slabovidni
Primarne potrebe slepih in slabovidnih so prostorska orientacija, zaznavanje okolice in zvočni dostop do informacij. Funkcionalnosti AQR-kod so samodejno zaznavanje kode z razdalje in v gibanju, govorni izhod (sintetizator govora) in zvočna navigacija (npr. »levo 2 m do vhodnih vrat«).

Primer: NaviLens omogoča zvočno navigacijo v metroju Barcelona, ki vodi uporabnika s prostorskimi navodili.

Gluhi in naglušni
Primarne potrebe so vizualna in znakovna komunikacija, podnapisi, jasna opozorila. Funkcionalnosti AQR-kod so video prikazi v znakovnem jeziku (Slovenski znakovni jezik), podnapisi in vizualna opozorila, prikazovanje navodil v slikovno-grafični obliki. Primer: v bolnišnici Gregorio Marañón AQR-kode omogočajo prikaz video vsebin v znakovnem jeziku.

Osebe z motnjami v duševnem razvoju
Primarne potrebe so poenostavljena razlaga, vizualna podpora, strukturirane informacije. Funkcionalnosti AQR-kod so lahko berljivo besedilo (Easy-to-Read standard), uporaba enostavnih simbolov in piktogramov, linearna struktura navodil (korak za korakom). Primer: navodila v čakalnicah (»pojdi na pult A, vzemi listek, počakaj«) lahko AQR-koda predstavi v obliki slik in kratkih povedi.

2.3.3 Študije primera: NaviLens

Za podrobnejše razumevanje delovanja AQR kod smo izbrali sistem NaviLens[1], ki trenutno predstavlja eno najbolj razvitih dostopnih tehnologij na področju digitalnega označevanja in navigacije [14]. Analizirali smo tehnične lastnosti sistema (barvna koda, zajem v gibanju, multimedijska podpora), ter povzeli praktične implementacije v različnih okoljih (javni promet, zdravstvo, kultura) in odzive.

NaviLens je španska inovativna rešitev, ki je bila razvita v sodelovanju z organizacijami slepih in slabovidnih (ONCE – *Organización Nacional de Ciegos Españoles*) in omogoča navigacijo ter dostop do informacij prek vizualno optimiziranih kod. Sistem deluje v povezavi z aplikacijo na pametnem telefonu, ki samodejno prepozna posebno barvno kodo, brez potrebe po ročnem iskanju ali natančnem usmerjanju kamere [14].

Slika 1: Implementacija NaviLens na podzemni železnici in avtobusnih postajališčih. Vir:Navi Lens

Primer implementacije: na železniških postajah v Barceloni[2] so NaviLens kode namestili na stebre in ob robove peronov; aplikacija vodi slepega uporabnika z usmerjenimi zvočnimi navodili (npr. »kodna oznaka 3 metra pred vami, levo 30°«), ob kliku pa se predvaja video s podatki o naslednjem vlaku v španskem znakovnem jeziku (LSE). Ostale možnosti so obravnavane v tabeli 3.

Tabela 1: Možnosti v različnih kontekstih

Področje	Lokacije	Funkcija AQR	Specifična prilagoditev
Javni promet	Metro Barcelona, NYC MTA	Informiranje in usmerjanje	Zvočna navigacija + znakovni jezik
Kultura	Muzej Prado, Museo Tiflológico	Opis eksponatov, digitalni vodiči	QR z opisi v Braillovi pisavi in TTVS*
Zdravstvo	Hospital Gregorio Marañón	Oznake oddelkov in informacijskih točk	Video s prevodom v SSZJ*; lahko berljivo
Trgovina	Carrefour (Španija)	Branje kod izdelkov in navodil	Prepoznavanje embalaže z zvočnimi podatki

*TTVS – talni taktilni vodilni sistem, *SSZJ – Slovar slovenskega znakovnega jezika

3. Rezultati

V skladu z metodološkimi sklopi, so rezultati raziskave strukturirani v tri vsebinske sklope: (1) ugotovitve sistematičnega pregleda literature, (2) konceptualno analizo potreb ciljnih skupin ter (3) študijo primera NaviLens. V nadaljevanju podrobneje predstavljamo rezultate posameznih sklopov.

1.1 Ugotovitve sistematičnega pregleda literature

Sinteza obravnavanih študij pregleda literature pokaže, da imajo QR-kode pomemben potencial za uporabo v knjižnicah in širše, vendar njihova uveljavitev še vedno zaostaja za tehnološkimi zmožnostmi. Ugotovljeno je, da je stopnja ozaveščenosti med knjižničarji in uporabniki razmeroma visoka, vendar pa je njihova dejanska uporaba še omejena zaradi pomanjkanja integracije in ozaveščanja. Ključni dejavniki, ki vplivajo na sprejemanje QR-kod, so zaznana koristnost, enostavnost uporabe, kakovost storitve in interaktivnost. Pregled literature potrjuje, da imajo QR-kode velik potencial za izboljšanje dostopa do informacij, a hkrati razkriva vrzeli, zlasti na področju raziskav uporabniške izkušnje ter praktične integracije v javne storitve [15].

3.2 Konceptualna analiza potreb ciljnih skupin

Iz primerjalne analize treh ciljnih skupin je razvidno, da imajo vse skupine specifične zahteve, ki jih klasične QR-kode ne morejo zadovoljiti. AQR-kode s podporo multimodalnim funkcionalnostim (zvok, video, lahko berljivo besedilo, simboli) omogočajo, da se posameznim potrebam ustrezno prilagodijo. Tabela 2 jasno prikazuje, da AQR-kode združujejo različne

[1] Dostopno na spletišču: https://www.navilens.com/en/

[2] Dostopno na spletišču: https://www.tmb.cat/en/get-to-know-tmb/transport-network-improvements/other-improvements/navilens-intelligent-tags

načine komunikacije v enotno tehnologijo, ki omogoča univerzalni dostop do informacij. S svojimi multimodalnimi funkcionalnostmi (zvočni dostop, video v znakovnem jeziku, lahko berljivo besedilo) neposredno odgovarjajo na specifične zahteve slepih in slabovidnih, gluhih in naglušnih ter oseb z motnjami v duševnem razvoju. Rezultati tako potrjujejo raziskovalno hipotezo, da AQR-kode, zasnovane v skladu z načeli univerzalnega oblikovanja, omogočajo univerzalni dostop do vsebin v javnem prostoru.

3.3 Študija primera NaviLens

Študija primera NaviLens je pokazala, da je AQR-kode mogoče uspešno uvesti v praksi. Sistem omogoča zaznavanje kod na razdalji do 15 m, samodejno poravnavo, uporabo zvočnih in vizualnih povratnih informacij ter zaščito pred zlorabami. Tabela 3 prikazuje uporabo v prometu, kulturi, zdravstvu in trgovini. Večplastnost uporabe omogoča različnim uporabnikom lažjo orientacijo ter uporabo prostora, hkrati tudi dokazuje, da je uporabna za vse uporabnike. AQR-koda ni torej namenjena zgolj osebam z različnimi omejitvami, temveč jih s pridom uporabljajo vsi uporabniki.

4. Diskusija

Na podlagi rezultatov sistematičnega pregleda literature, konceptualne analize potreb ciljnih skupin in študije primera NaviLens v nadaljevanju podajamo celovito razpravo, ki povezuje ugotovitve treh metodoloških pristopov.

4.1 Primerjava rezultatov vseh treh metodoloških pristopov

Rezultati treh uporabljenih metodoloških pristopov se medsebojno dopolnjujejo in skupaj ustvarjajo celovito sliko o potencialih in omejitvah AQR-kod. Sistematični pregled literature razkriva, da so QR-kode že uveljavljene v različnih sektorjih, kot so promet, zdravstvo, izobraževanje in kultura, vendar njihova uporaba za izboljšanje dostopnosti ranljivih skupin ostaja parcialna in nesistematična. Konceptualna analiza potreb treh ciljnih skupin je pokazala, da klasične QR-kode ne zadostujejo, saj predpostavljajo senzorične in kognitivne zmožnosti, ki jih vsi uporabniki nimajo. AQR-kode z multimodalnimi funkcionalnostmi te pomanjkljivosti učinkovito presegajo. Študija primera NaviLens pa predstavlja empirični dokaz, da je takšne prilagoditve mogoče uspešno udejanjiti v praksi: sistem se že uporablja v javnem prometu (Barcelona metro), kulturnih ustanovah (Muzej Prado) in trgovini (Carrefour).

4.2 Kritična presoja omejitev raziskave

Kljub pozitivnim ugotovitvam raziskava izkazuje več omejitev. Prvič, študija primera se je osredotočila zgolj na en referenčni model (NaviLens), kar omejuje širšo posplošitev ugotovitev. Drugič, analiza potreb ciljnih skupin temelji predvsem na konceptualnem okviru in mednarodnih smernicah (WCAG, Easy-to-Read, ZIMI), brez obsežnejšega empiričnega testiranja z dejanskimi uporabniki. Pregled literature je razkril, da se QR-kode v veliki meri obravnavajo v komercialnem in tržnem kontekstu, manj pa v raziskavah, ki bi celovito ocenjevale njihovo dostopnost za ranljive skupine.

4.3 Odgovor na hipotezo

Hipoteza raziskave je bila, da AQR-kode pomembno izboljšajo dostop do informacij v javnem prostoru ter prispevajo k samostojnosti in vključevanju uporabnikov. Rezultati raziskave to hipotezo potrjujejo. Sistematični pregled literature kaže na široko prepoznan potencial QR-kod, konceptualna analiza potreb uporabnikov potrjuje, da AQR odgovarjajo na specifične zahteve treh ciljnih skupin, medtem ko študija primera NaviLens empirično dokazuje izvedljivost in učinkovitost takšnih rešitev v praksi. Na osnovi tega lahko zaključimo, da AQR niso zgolj tehnična nadgradnja klasičnih QR-kod, temveč tudi pomembno orodje za spodbujanje digitalne vključenosti in pravičnosti.

4.4 Implikacije za prakso in nadaljnje raziskave

Ugotovitve raziskave imajo pomembne implikacije za prakso in prihodnje raziskave. Za prakso to pomeni, da bi morale nacionalne institucije vključiti AQR v smernice za dostopnost in digitalizacijo javnega prostora ter spodbuditi pilotne projekte v prometu, zdravstvu in kulturi. Ključno je interdisciplinarno sodelovanje razvijalcev, oblikovalcev, urbanistov, arhitektov ter organizacij oseb z oviranostmi pri sooblikovanju tovrstnih sistemov. Za raziskave pa se odpirajo štiri ključne smeri in sicer: (1) empirično testiranje uporabniških izkušenj z vključevanjem ciljnih skupin v realnih okoljih, (2) širitev nabora primerov dobre prakse izven NaviLens, (3) razvoj odprtih in standardiziranih AQR-protokolov ter (4) kritična analiza dolgoročnih učinkov AQR na samostojnost, mobilnost in družbeno vključenost uporabnikov.

4.5. Možnost zlorabe

QR-kode so zaradi preprostega kreiranja in uporabe postale zelo priljubljene in se jih pogosto uporablja za različne, predhodno opisane, namene. Prav zaradi svoje priljubljenosti pa so postale tudi neredka tarča zlorab in zlonamerne uporabe. Ljudje smo se v zadnjih letih naučili kako pregledovati spletne povezave v phishing mailih, sporočil in spletnih straneh za lažnimi povezavami. QR-kode pa te spletne povezave zakrijejo in že samo skeniranje QR-kode lahko sproži prenos škodljive kode na mobilno napravo.

QR Code Phishing krajše označujemo z enakovrednima izrazoma QRishing oz. Quishing[3]. Z izrazoma označujemo vrsto kibernetskega napada, pri katerem zlonamerne osebe uporabljajo ponarejene QR-kode, da posameznike zvabijo na zlonamerne spletne strani ali jih prepričajo, da prenesejo škodljivo vsebino.

Poznamo statične in dinamične QR-kode, ki se med seboj razlikujejo glede na stopnjo ranljivosti. Statične QR-kode se po kreiranju ne spreminjajo. Primarno jih uporabljamo za deljenje spletnih strani, kontaktnih informacij, Wi-Fi gesel in podobno. Načeloma so ranljive le v primeru, če napadalci pridobijo kontrolo nad spletnim mestom URL (angl. uniform resource locator) povezave v QR-kodi. Dinamične QR-kode omogočajo večjo fleksibilnost saj je mogoče posodobiti URL povezavo. Uporabljamo jih v primerih kjer je zahtevana pogosta

[3] Dostopno na spletišču: https://www.malwarebytes.com/cybersecurity/basics/quishing

posodobitev vsebine URL povezave. Takšni primeri so informacije o dogodkih, promocijske ponudbe ali spremljanje zalog v realnem času. V primeru, ko napadalci pridobijo nadzor nad upravljanjem z dinamično QR-kodo, po svoji želji spremenijo URL povezo, ki osebe nato po skeniranju QR-kode preusmeri na zlonamerne spletne strani.

Zagotavljanje varnosti uporabe QR-kod je večplastno. Velik korak k varni uporabi QR-kod lahko storimo že sami uporabniki. Priporočeno je, da ne uporabljamo nepreverjenih QR-kod, pred potrditvijo preverimo URL povezavo povezano s skenirano QR-kodo. Na spletih straneh pa ne vpisujemo svojih osebnih ali bančnih podatkov, ki teh podatkov ne potrebujejo, še posebno, če ne poznamo pošiljatelja. Nenazadnje pa tudi, da ne prenašamo nobenih vsebin s sumljivih spletnih strani. Kreatorjem QR-kod pa se priporoča uporaba priznanih orodij za kreiranje QR-kod, zaščita pomembnih informacij z uporabniškim imenom in geslom ali kriptiranjem podatkov ter redno preverjanje stanja QR-kode.

Ali predhodne ugotovitve pomenijo, da je uporaba NaviLens AQR-kod nevarna? Odgovor je ne. Mobilna aplikacije NaviLens ima vgrajeno zaščito pred AQRishing posegi. Aplikacija po branju AQR-kode preveri ali se je zgodila potencialna manipulacija skenirane AQR-kode in v primeru zaznane manipulacije prepreči odpiranje vsebovanih spletnih strani ali posredovanja podanih informacij.

5. Zaključek

Raziskava je obravnavala AQR-kode kot tehnološko rešitev, ki temelji na načelih univerzalnega oblikovanja in digitalne vključenosti. Na osnovi kombinacije treh metodoloških pristopov smo dobili celovit vpogled v potenciale in omejitve AQR-kod.

Rezultati potrjujejo raziskovalno hipotezo, da AQR-kode pomembno izboljšajo dostop do informacij v javnem prostoru ter prispevajo k večji samostojnosti in družbeni vključenosti uporabnikov. Tako jim zagotavljajo enakovredno dostopnost in uporabo prostora ter informacij. Literatura kaže na široko prepoznan potencial AQR-kod, a tudi na pomanjkanje sistematičnih raziskav o dostopnosti. Analiza potreb ciljnih skupin je razkrila, da lahko AQR-kode z multimodalnimi funkcionalnostmi (zvočna navigacija, video v znakovnem jeziku, lahko berljivo besedilo) učinkovito odgovarjajo na specifične zahteve slepih in slabovidnih, gluhih in naglušnih ter oseb z motnjami v duševnem razvoju. Študija primera NaviLens pa je empirično potrdila, da so takšne rešitve izvedljive in uspešne v praksi.

Predlog za prihodnji razvoj in implementacijo:

1. Upoštevanje odprtih standardov AQR kod, skladnih z evropskimi in mednarodnimi smernicami ter omogočanje integracije z nacionalnimi sistemi dostopnosti (npr. Slovar slovenskega znakovnega jezika).
2. Pilotni projekti v javnih ustanovah (zdravstvo, promet, kultura) za testiranje uporabnosti in prepoznavnosti dostopnih kod z vključitvijo ciljnih uporabnikov.
3. Vzpostavitev interdisciplinarnega sodelovanja med razvijalci, urbanisti, arhitekti, oblikovalci storitvenega in informacijskega oblikovanja, organizacijami oseb z oviranostmi in zakonodajalci.
4. Vključitev participativnih metod v načrtovanje informacijskih točk, ki temeljijo na AQR, z vključitvijo oseb z različnimi oblikami oviranosti že v fazi načrtovanja, prototipiranja in testiranja.
5. Vključitev AQR v načrte za digitalizacijo urbanega prostora in kot obvezni del smernic za dostopnost javnih storitev, skladno z ZIMI, ZDSMA ter pravilnikom o univerzalni gradnji in uporabi objektov.

Poseben pomen za prihodnost ima vključevanje uporabniških skupin v sooblikovanje tehnologij ter usklajenost z zakonodajnimi in etičnimi okviri, kot so Konvencija o pravicah invalidov [16], Konvencija o dostopu do informacij, udeležbi javnosti pri odločanju in dostopu do pravnega varstva v okolijskih zadevah [17], Aarhuška konvencija [18] in načela univerzalnega oblikovanja [19].

V prihodnosti AQR ne bo le orodje za tehnično izboljšanje orientacije ali podajanje informacij, temveč temeljni del infrastrukture vključujočega mesta – mesta, ki razume, da dostopnost ni le funkcija, ampak tudi kultura vključevanja, udeležbe in spoštovanja raznolikosti.

Zahvala

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Interoperable Total Conversation

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Abstract

The European Accessibility Act (EAA) requires that wherever real-time video communication is provided, Total Conversation must be supported. Total Conversation enables simultaneous exchange of real-time text (RTT), video and voice, providing inclusive and flexible communication for all. This paper discusses the work of the project ETSI STF 674 and its development of the ETSI ES 204 009 standard on Interoperable Total Conversation. It presents performance requirements for each media modality, integration with assistive technologies, test methods for video quality, and the importance of interoperability and relay services. The implementation of Total Conversation ensures compliance with EU accessibility laws and enhances usability in a broad range of communication contexts.

Keywords

Total Conversation, Real-Time Text, Voice Communication, Interoperability, Accessibility

1 Introduction

Inclusive and accessible communication technologies are not only a matter of equity but are increasingly becoming a legal obligation across the European Union. The European Accessibility Act (EAA), adopted in 2019, mandates that certain digital products and services - including those used for communication - must be accessible to all individuals, regardless of their disabilities. A central requirement of the EAA is the support for Total Conversation (TC) in any context where real-time video communication is offered. This includes customer service platforms, emergency communications, conferencing systems, and any ICT-based interpersonal communication service.

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Total Conversation is defined as the simultaneous, synchronized provision of three media modalities - real-time text (RTT), video and voice. When fully integrated, these media support diverse communication preferences and needs, such as sign language over video, speech supported by lip-reading, and typed text for individuals who are deaf, hard of hearing, deafblind, or have speech and cognitive impairments. Rather than treating these communication modes as separate alternatives, TC ensures they are available concurrently and interoperable, enabling flexible and responsive conversations adapted to the users' abilities.

While individual components like video calls or text chat systems are widely deployed, the combination of modalities in a synchronized and interoperable manner has not been consistently implemented across platforms and services. The lack of interoperability also hinders effective communication between different systems, vendors, and devices - an issue particularly problematic in emergency contexts, transnational communication, and public services.

To address this, ETSI TC Human Factors (HF) initiated multiple projects aimed at translating the legal obligations of the EAA into technical requirements. One of these, Special Task Force 674 (STF 674), is responsible for developing the standard ETSI ES 204 009 [1], which defines the functional, media, and interoperability requirements for Total Conversation systems. It complements other standards work such as ETSI EN 301 549 (accessibility requirements for ICT products and services) [2] and ETSI ES 202 975 (relay service specifications) [5], forming a coherent standards ecosystem aligned with regulatory and user needs.

This paper provides an overview of the ETSI ES 204 009 standard, elaborates on the minimum performance levels necessary for usable TC services, presents easy-to-implement test methodologies to verify conformance, and highlights the importance of ensuring interoperability across services. It also explores integration with assistive technologies such as hearing aids and relay services and outlines practical scenarios where TC brings significant value.

2 Components of Total Conversation

Total Conversation is built upon three core media streams (real-time text, video and voice) that are delivered in parallel and are functionally integrated between two or more user equipment (Fig. 1):

- **Real-Time Text (RTT):** Unlike instant messaging or email, RTT allows users to transmit each character as it is typed, creating a live and dynamic text flow. This enables tight interaction, clarifications, and even interruption—key aspects of natural conversation.
- **Video:** This channel primarily serves sign language communication, non-verbal cues such as facial expressions and gestures, and lip-reading for users with residual hearing. It plays a critical role for the deaf and hard-of-hearing community and must be of sufficient quality to support complex sign articulation and facial grammar.
- **Voice:** The voice channel remains vital for many users, including those with visual or cognitive disabilities. Wideband audio enhances intelligibility and makes communication more natural, especially in challenging environments or over mobile networks.

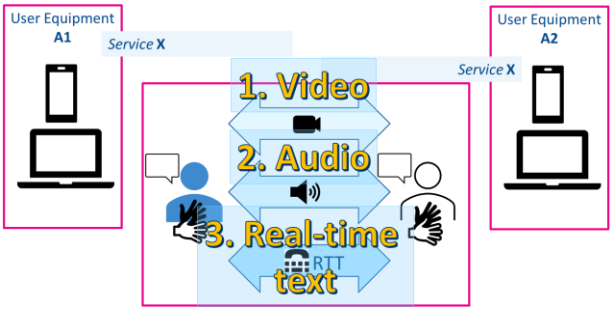

Figure 1: Components of Total Conversation

The value of TC lies not only in providing these media independently but in combining them in a way that allows users to shift seamlessly between modalities or use them concurrently. This flexibility is essential in mixed-ability communication scenarios and ensures redundancy if one channel is impaired [6].

3 Interoperability considerations

The effectiveness of Total Conversation hinges not only on the quality of individual media streams but also on their interoperability across platforms, networks, and devices. Interoperability is essential to ensure that communication can occur seamlessly between users regardless of their service provider, geographic location, or technical infrastructure. Without interoperability, the fragmentation of services would result in digital exclusion, especially in scenarios requiring urgent or cross-border communication.

The ETSI ES 204 009 standard defines a set of interoperability requirements that enable real-time text, video, and voice to be exchanged using established communication protocols. It promotes the use of SIP (Session Initiation Protocol), IMS (IP Multimedia Subsystem), and WebRTC (Web Real-Time Communication) as foundational signaling and media transport frameworks. These technologies support dynamic media negotiation, allowing devices and services to determine the most appropriate encoding and channel configurations during call setup. This ensures that participants can successfully exchange synchronized real-time text, video, and voice, regardless of the underlying system implementations.

Media stream compatibility is ensured through alignment on common codecs and formats. For voice, wideband codecs such as AMR-WB and Opus are recommended due to their robustness in variable bandwidth conditions and their superior audio clarity. For video, H.264 is a widely supported codec that balances quality and compression efficiency, while for real-time text, the standardized RTP payload format defined in RFC 4103 is used [4], allowing immediate character-by-character transmission over IP networks.

Interoperability also depends on effective session negotiation. Using Session Description Protocol (SDP), endpoints can exchange capabilities such as supported codecs, resolution, frame rates, and synchronization tolerances. The ETSI ES 204 009 ensures that these mechanisms are harmonized, reducing the risk of call failures or degraded media performance due to incompatible configurations.

A significant challenge in TC is achieving interoperability not only between devices of the same type but across heterogeneous systems. For example, a call initiated from a WebRTC browser must be able to connect with a SIP-based desktop phone or a mobile application, with full support for all three TC modalities. This requires robust gateway implementations and adherence to interface profiles defined in the standard.

Furthermore, the standard addresses interoperability in addressing and routing. It supports both E.164 telephone numbers and URI-based identifiers (such as SIP URIs), making it possible to contact TC endpoints from traditional voice networks as well as IP-based applications. This flexibility is particularly crucial for integrating TC into public services such as emergency response systems and governmental communication platforms.

Cross-vendor interoperability testing is a vital implementation step. The ETSI ES 204 009 encourages conformance testing, reference implementations, and public testing events to validate interoperability among different vendors and service providers.

4 Performance requirements

To be effective, Total Conversation must adhere to strict quality of service (QoS) criteria that support human factors in communication. Video must provide a minimum spatial resolution of QVGA (320x240 pixels), a frame rate of at least 20 fps, and end-to-end latency below 400 msec. These specifications ensure that fast gestures and subtle facial expressions remain discernible and are not lost due to compression or jitter. In practical terms, this means that users engaging in sign language conversations must be able to see hand shapes, movements, facial expressions, and gaze direction with clarity. Loss of visual fidelity can significantly impair the grammatical and semantic meaning of sign language.

Real-Time Text must be delivered with under 1 second of delay, support at least 30 characters per second throughput, and be fully compliant with Unicode for multilingual and symbol-

rich communication. This allows for responsiveness, including overlapping dialogue, corrections, and incremental feedback, which are vital in dynamic conversation. Inadequate RTT performance can lead to conversational breakdowns and exclusion from interactive discussions.

Voice should operate within a frequency band of 250 Hz to 7,000 Hz with minimal compression artifacts, ensuring the intelligibility of a wide range of vocal tones, especially for users with hearing impairments who rely on residual hearing or hearing aids. Latency should be maintained below 400 milliseconds to avoid echoing, speaker overlapping, and degraded user experience, particularly in multilingual or moderating calls.

Synchronization of video and audio must stay within ±100 msec to preserve lip-sync, which is critical for users who lip-read or use speech-reading techniques. Asynchrony between modalities reduces the effectiveness of multimodal communication and may result in reduced comprehension or fatigue over long calls.

These values were derived from user studies, practical experience, and ITU-T recommendations, particularly H-Series Supplement 1, which focuses on the technical requirements that support the perceptual needs of users engaging in sign language and lip-reading communication [3]. Compliance with these parameters ensures not only legal adherence but also a user experience that supports autonomy, agency, and inclusion.

5 Integration with assistive technologies

For Total Conversation to be truly inclusive, it must work in harmony with the wide variety of assistive technologies used by people with disabilities. The effectiveness of TC is amplified when the real-time text, video, and voice channels are compatible with user-specific devices and support tools that enhance communication based on individual needs.

One of the most critical integrations is with **hearing aids and cochlear implants**, which often rely on Bluetooth connectivity or telecoil (T-coil) systems to receive audio directly from digital devices. Emerging technologies such as Auracast™ Bluetooth LE Audio allow group broadcasting, making it possible to seamlessly connect to public or shared audio systems, such as in classrooms or conference settings. Ensuring low-latency, high-fidelity audio from the TC system into these devices significantly improves the accessibility of spoken communication.

For users who are blind or deafblind, **screen readers and Braille displays** provide essential access to real-time text. TC systems must ensure that RTT content is presented in a way that is compatible with screen reading software, with proper semantic structure, keyboard navigation, and timely character transmission.

Users with complex communication needs may depend on **Augmentative and Alternative Communication (AAC) devices**, which enable them to construct and transmit messages through symbol boards, text-to-speech systems, or visual interfaces. A well-designed TC service allows for these devices to input into the voice channel via synthesized speech, or directly into the RTT stream, without introducing latency or requiring manual transcription.

Moreover, TC systems must be controlled via **accessible user interfaces** that meet the requirements of the ETSI EN 301 549. This includes support for keyboard navigation, voice commands, magnification, high-contrast modes, and alternative input devices. System setup, call controls, and media selection must be operable without vision, hearing, or precise motor control.

Beyond hardware and software compatibility, **personalization** plays a key role. Users should be able to configure the prominence and layout of modalities based on their preferences—such as enlarging the video feed for sign language, prioritizing RTT over voice, or adjusting caption position and font.

6 Relay services and modality conversion

Relay services are essential components of the Total Conversation ecosystem, enabling accessible communication between users who rely on different modalities. These services function as real-time intermediaries that convert between speech, text, and sign language, ensuring that all participants can engage effectively, regardless of their abilities or communication preferences.

Video Relay Services (VRS) connect sign language users with hearing individuals by incorporating a live sign language interpreter into the communication loop. The interpreter receives the video stream from the signing user, translates it into spoken language, and transmits it to the hearing person, while simultaneously converting spoken replies into sign language. VRS is particularly important for users who communicate primarily through national or regional sign languages, and it requires high-quality video transmission to support accurate interpretation.

Text Relay Services (TRS) enable users who communicate via text to interact with voice telephone users. This can be facilitated by a human relay operator who voices the typed messages and types back the spoken responses, or by automated systems with speech-to-text and text-to-speech capabilities. TRS must support real-time interaction, minimize delays, and protect user privacy and data.

Captioned Telephony is another form of relay service that provides a live transcription of the spoken content during a voice call. It benefits users who can speak but have difficulty hearing, by overlaying real-time text captions of the other party's speech. These captions are typically generated by either human captioners or automated speech recognition systems and are displayed synchronously with the voice channel.

The effectiveness of relay services depends on several factors, including low latency, high accuracy, robust data security, and compliance with accessibility and privacy regulations. The ETSI ES 202 975 standard outlines the functional and quality requirements for implementing reliable and interoperable relay services within the context of Total Conversation.

Furthermore, modality conversion must be seamless, meaning that users should not experience noticeable interruptions or mismatches when transitioning between modes. The system should support smooth transfers between modalities within the same call session, for example, shifting from text to video or adding a voice channel, without requiring disconnection or renegotiation.

7 Application scenarios

Total Conversation has widespread applicability and supports full participation in many areas of modern life by making real-time communication accessible and inclusive.

In **emergency communications**, Total Conversation enables direct, multimodal contact with public safety answering points (PSAPs). A deaf or speech-impaired individual can initiate a call using real-time text, video, and voice as needed. Sign language users can communicate with interpreters, while text can provide clarity or serve as a fallback. Visual information allows emergency personnel to assess scenes, verify distress signals, and provide visual guidance - capabilities impossible with voice-only communication.

In **education and e-learning**, TC creates accessible virtual classrooms and lecture environments. Deaf and hard-of-hearing students can follow spoken content via real-time captions or sign language and interact via RTT. Teachers can use TC platforms to provide differentiated instruction tailored to communication preferences. Moreover, students with cognitive or speech disabilities can participate using AAC devices integrated into TC sessions.

Telehealth and remote care benefit from TC through improved doctor-patient interactions, especially where patients have sensory or speech impairments. Patients can describe symptoms using video, confirm prescriptions in text, and receive visual reassurance. For mental health services, TC supports rapport-building with facial expressions, tone of voice, and real-time emotional feedback—all essential elements in therapeutic contexts.

In **professional collaboration**, TC bridges communication gaps in mixed-ability work environments. It ensures that meetings, interviews, and team discussions include all participants equally. For example, a deaf employee can engage via sign language while receiving spoken input through captions or RTT. The combination of modalities reduces misunderstandings and supports accurate documentation of decisions.

Social inclusion is another vital domain. Total Conversation allows family members with different abilities to stay connected in a rich and natural way. Elderly individuals with hearing loss, young children learning to type, and multilingual family members can all participate in one conversation using the mode that suits them best. Social services and community events can also be made accessible through TC, fostering engagement and civic participation.

As the digital landscape evolves toward hybrid, remote, and inclusive communication, Total Conversation stands out as a technology that supports equity, autonomy, and human connection. By enabling flexible and barrier-free participation in daily life, it reinforces the right to communicate for all.

8 Conclusion

Interoperable Total Conversation is a cornerstone for inclusive communication in the digital age. By integrating synchronized real-time text, video, and voice and aligning with the European Accessibility Act, it enables a communication paradigm where everyone - regardless of sensory, cognitive, or linguistic ability - can fully participate in society. The ETSI ES 204 009 standard, developed by STF 674, provides a practical foundation for achieving this interoperability and accessibility across diverse systems and platforms.

The implementation of TC contributes to a communication infrastructure. It ensures that users can engage in both casual and critical conversations - from contacting emergency services to participating in professional meetings or accessing telehealth consultations - using the modality that best suits their needs at any moment.

Furthermore, Total Conversation is more than a technological solution; it reflects a broader societal shift toward inclusivity and digital equity. By embracing standardized performance metrics, interoperability protocols, and integration with assistive technologies, TC systems can reduce barriers, enhance quality of life, and support equal opportunities in education, employment, healthcare, and beyond.

Going forward, continued collaboration among policymakers, standardization bodies, service providers, and accessibility advocates will be essential to scale adoption, ensure consistent implementation, and refine technical solutions. As digital communication evolves, Total Conversation should remain a guiding principle for designing accessible, future-proof communication environments that serve everyone. With ETSI ES 204 009 and aligned standards, service providers can implement reliable, high-quality, and accessible real-time communication. The success of TC depends on adherence to technical standards, support for assistive technologies, and a commitment to cross-platform interoperability.

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Digital Engagement of d/Deaf and Hard of Hearing TikTok Users: Insights from the Current Literature

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ABSTRACT

This paper explores the digital engagement of the d/Deaf and hard of hearing individuals on TikTok. While the platform provides captioning of videos, some accessibility challenges persist. These include inconsistent captioning, deficient synchronization, and limited support for sign language content. Although video format prevails, the d/Deaf and hard of hearing users actively use TikTok to build communities and raise awareness through content. In our study, we conceptually reviewed current literature on inclusivity and accessibility of TikTok's design and provided recommendations for improved user experience for these users.

KEYWORDS

d/Deaf and hard of hearing; social media; TikTok, user experience

1 INTRODUCTION

Worldwide, there is a significant increase in the prevalence of hearing loss among the population. Currently, over 5% of the world population, i.e., 430 million people, have a disabling hearing loss, which requires rehabilitation [1]. It is estimated that by 2050, nearly 2.5 billion people are projected to have some degree of hearing loss [1]. In Slovenia, approximately 1,500 deaf individuals reside, and about 1,000 of them use Slovenian Sign Language as their primary language [2].

Deafness and hearing loss are commonly considered disabilities primarily due to their impact on social connectedness [3][4]. Individuals who are d/Deaf and hard of hearing (d/DHH) frequently experience social isolation. Hearing or access to auditory information plays a vital role in establishing relationships, shaping self-esteem, and enabling individuals to function effectively across different contexts, including educational and workplace settings [4][5]. Social media has become a powerful catalyst for change, as it allows individuals and communities to establish connections and communicate with peers in different ways. For d/DHH individuals, accessibility on social media thus represents a crucial point to be able to equally participate in communicating and engaging with content.

Major social media platforms like TikTok can be crucial in providing an inclusive digital space for (d/DHH) individuals. Features like auto-captions, sign language videos, written descriptions and comments, and text adaptability (i.e., adjustable font size, contrast, dark mode) can address their specific communication needs [6]. d/DHH individuals frequently face challenges in digital environments, such as the widespread use of videos without captions [7][8][9]. In 2019, the European Parliament and the Council of Europe introduced the European Accessibility Act (Directive 2010/13/EU) to improve the regulation of captions on digital platforms operated by public broadcasters. The Act (Article 3) defined audiovisual media services broadly as "*services transmitted by electronic communications networks which are used to identify, select, receive information on, and view audiovisual media services".* Their distinct feature is that they provide *"features, such as subtitles for the deaf and hard of hearing, audio description, spoken subtitles and sign language interpretation."*. [10]. Thus, this definition includes video platforms, such as TikTok.

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In this paper, we aim to synthesize findings from the empirical literature to provide an insight into the digital engagement of d/DHH individuals on TikTok. Digital engagement on social media has been understood as diverse behaviours like extending reach (sharing or forwarding), affective evaluations (liking), and deliberation (commenting) [11]. Accordingly, we understand digital engagement both as active and passive consumption of the content on TikTok, where users view, like, comment, share or save the content, or they use specific features like creating duets.

2 NEEDS AND REQUIREMENTS OF DEAF AND HARD OF HEARING INDIVIDUALS

According to WHO, hearing loss may affect one or both ears and is classified in the following categories: *normal hearing* (10–15 dB)*, slight or minimal hearing loss* (16–25 dB), *mild hearing loss* (26–40 dB), *moderate hearing loss* (41–55 dB), *moderately severe hearing loss* (56–70 dB), *severe hearing loss* (71–90 dB), *profound hearing* loss (≥91 dB) [1].

People identified as hard of hearing (HoH) may have mild to severe hearing loss. They typically communicate using spoken language and often use assistive devices, such as hearing aids and cochlear implants, or they use subtitles. Their hearing loss ranges from below 40 dB (mild) to over 80 dB (severe). In Slovenia, individuals with more than 95% hearing loss who retain speech and auditory function are also classified as HoH [1]. On the other hand, d/Deaf individuals usually have profound hearing loss, meaning they hear very little or nothing at all. They often rely on sign language for communication [1].

Similar to hearing individuals, d/DHH individuals use social media to connect with their peers. They primarily rely on content that includes captions or text transcripts to access educational and informational material [12][13][14]. Technology serves as an essential tool for social inclusion of these individuals into both their own communities and wider society [15][16]. d/DHH individuals also use digital media for text-based communication [14] [17] as well as for accessing video content through social media platforms where subtitles and transcripts are available. They can also make video calls in sign language [12][13][14]. Moreover, they use social media to reduce loneliness, expand extensive social networks, and seek emotional support [18][19].

3 SOCIAL MEDIA AND THE CONCERN FOR USERS WITH DISABILITIES

Social media encompasses a wide range of internet applications based on Web 2.0 principles, which encourage the creation and exchange of user-generated content [20]. Social media extends beyond social network sites to include blogs, professional and corporate networks, collaborative projects, forums, microblogs, and virtual worlds [21][20]. Kietzmann et al. [22] classified social media using a "honeycomb framework" of seven functional building blocks: Identity, conversations, sharing, presence, relationships, reputation, and groups. This framework can be used to describe the user experience of any social media platform.

The fundamental concept behind social media is participation, sharing, and collaboration [20]. Thus, users are not only content consumers, but also content creators. This is particularly true for younger generations who grew up during the rise of digital media and are accustomed to their interactive nature. Social media enables the exchange of information in various formats, allowing content to be created and shared in the form of text, images, video, and audio [23]. They also provide personalised services and give communication power to users, who use their online profiles to interact with one another and share uncensored user-generated content [24].

One of the currently very popular social media platforms is TikTok. It was launched in China in 2016 under the name Douyin. It quickly gained popularity in China, and in 2017, an international version was launched globally. By 2023, TikTok had been downloaded more than three billion times [25][26]. It has established itself as an innovative platform for creating, sharing, and discovering short videos [27]. TikTok's features are designed to facilitate interaction among users and include: *duets* (users can create videos alongside content from other creators), *stitch* (users can clip a scene from another user's video and integrate it into their own), *commenting* (users can comment on videos and respond to comments with new videos), *voice-over* (videos can be enhanced with voice-overs or audio captions) [28].

Social media platforms have shown efforts to accommodate users with disabilities with initiatives, such as the implementation of automatic and manual subtitles for video content (e.g., on YouTube, Facebook, and Instagram), audio descriptions, and text transcripts, which are especially beneficial for d/DHH users [14]. In line with this, TikTok also provides: *auto captions* (transcription of audio in videos to text), and *manual caption creation* (users can add their own captions to videos) [28].

One of the key concerns for d/DHH users on social media is the loss of audio information in video content. Closed captions provide synchronous text display conveying auditory information, including non-verbal cues such as speaker identification [29]. To ensure fully accessible information, captions also include nonverbal elements such as music, sound effects, and paralinguistic signs (intonation, emphasis, speaker details such as male or female voice) [30].

Subtitles can be categorised as open or closed, depending on whether users can toggle them on or off. They can appear in different styles. Zarate [31] identifies four types: (1) scroll-up captioning, (2) pop-up captioning, (3) paint-on captioning (built as speech is delivered), and (4) cinematic captioning, as well as (5) dynamic captioning, where subtitles appear in sync with sounds, highlight spoken words, and visually reflect volume changes. It is important to note that conventional subtitling often fails to convey crucial information needed by d/DHH individuals to fully perceive visual content. The reason lies in complexity of human speech that carries meaning beyond words, while subtitles typically do not capture: (1) prosody (how loud, melodic, or fast the voice is), (2) voice quality (whether it sounds old or young), (3) the speaker's mood (tired, excited), or even (4) emotions (anger, joy, sadness) [30]. Despite advances in captioning methods, users still face challenges, e.g., when several characters appear in a scene and it is unclear who is speaking, which makes comprehension difficult [30].

Technology plays a crucial role in the inclusion of d/DHH individuals into society, and its design should avoid isolating users due to sensory impairments. These efforts not only improve

communication of d/DHH individuals but also enhance access to education, information, and digital social life [12][14][16].

4 LITERATURE INSIGHTS: THE DIGITAL ENGAGEMENT OF d/DHH TIKTOK USERS

4.1 Barriers to the Digital Engagement of d/DHH

d/DHH users face many content consumption barriers, such as frequent absence of captions in spoken or audio-based content. This leads to frustration with the inaccessibility of uncaptioned or audio-centric content [32]. Across social media platforms, studies have demonstrated that standard metrics such as Word Error Rate (WER) correlate poorly with real-world usability for d/DHH individuals [33]. Even when captions had the same WER, d/DHH users found some captions to be much harder to understand than others. Captions were rated as less usable when they missed important elements like speaker identification or nonverbal sounds. Similarly, [34] showed that metrics, such as WER and automated scores, do not reflect how d/DHH viewers experience captions. Instead, factors like how well the captions are timed, how easy they are to read, and whether they include errors in presentation play a much bigger role in user satisfaction.

While TikTok encourages open-captioning (i.e. captioning that cannot be turned off or hidden), there is an absence of standardised captioning practices, which results in varied accessibility. When d/DHH users use captions, they report on readability issues with font choices, inconsistent timing, and substandard audio representation. Although TikTok introduced automatic captioning features in 2021, user-generated captions vary in accessibility [35].

4.2 Opportunities for the Digital Engagement of d/DHH through Content Creation

Despite the challenges, TikTok enables the creation of communities for d/DHH users. By combining sign language, visual storytelling, and creative captioning, they reach both d/DHH and hearing audiences. Their content includes topics such as deaf awareness, entertainment, personal experiences, and advocacy, often incorporating multiple modalities, from captions, sign language, to limited use of audio, which enhances inclusivity [36]. Consequently, the multimodal interactions can bridge the differences between Deaf and hearing users, which contributes to the social inclusion of d/DHH individuals [37].

There are also some risks associated with social media use among d/DHH adults. Schäfer and Miles [38] surveyed German d/DHH adults, showing that higher usage correlated with greater self-reported social isolation and lower self-esteem. While platforms like TikTok offer new forms of digital participation and identity expression, they may also exacerbate feelings of social isolation if accessibility barriers persist. d/DHH users were reported to use social media less frequently than their hearing peers, which might be due to challenges with primarily audio-based formats.

5 LESSONS LEARNED FROM THE LITERATURE AND THEIR IMPLICATIONS

5.1 Lessons Learned from the Literature

The literature suggests the duality of TikTok as both a promising platform for digital inclusivity and an environment with accessibility barriers for d/DHH users. Although TikTok provides auto-captioning and allows manual captions, there is a lack of standardised practices. Captions often have poor readability, are inconsistently synchronised with audio, and lack contextual audio representation [35]. Moreover, generated captions do not reliably include critical information such as speaker identity or emotional tone. These elements are essential for d/DHH users' comprehension [31][36]. Mere technological provision of captioning tools is thus insufficient without design refinements that are centred on usability for d/DHH users.

In the past years, d/DHH users demonstrated innovative uses of TikTok's capabilities. Many creators have combined sign language with visual capabilities, and different captioning formats to increase content accessibility and connect to d/DHH audiences [36][37]. These practices can foster community-building and expression of identity for users with disabilities.

When examining TikTok, the absence of inclusivity can disincentivise d/DHH user engagement. Since captions are not by default enabled and the content layout is not friendly to sign language, d/DHH users are accommodated less. This contributes to lower participation and experiences of social exclusion. Accordingly, d/DHH often consume less content on TikTok than hearing users, potentially due to video and audio-dominant affordances of the platform [38]. While social media can provide community building and support, the isolation due to inaccessibility is a threat to d/DHH users [39]. For instance, increased screen time without accessible content can negatively impact self-esteem and exacerbate social disconnection [38].

5.2 Implications and Recommendations

Based on the abovementioned literature insights on the digital engagement of d/DHH TikTok users, we suggest the most important recommendations to enhance the accessibility and inclusivity of TikTok for d/DHH users:

(a) Platforms could prioritise the development of inclusive captioning standards as a core design feature rather than an optional add-on (e.g., captions are synchronised accurately with spoken or signed content, formatted for readability, and enriched with contextually relevant information).

(b) Platforms could support the production of multimodally accessible content. This includes offering caption editors with automatic synchronisation and real-time preview functionalities, tools for layering visual elements such as sign language and written captions, and features that facilitate the alignment of spoken and signed language.

(c) Recording interface could be optimised to accommodate sign language communication, as d/DHH users currently face challenges when attempting to record sign language content. Platforms could provide intuitive recording tools with framing that captures the upper body, gesture-sensitive features and background stabilisation, as proposed by Mack et al. [32].

(d) Accessibility could be integrated as a default into the platform. This could include persistent caption toggles and preferences, allowing users to tag content as containing signed or captioned material, and improving the visibility of accessible and d/DHH-authored content.

In the future, it would be intriguing to examine whether the implementation of these recommendations actually contributed to higher levels of digital engagement among d/DHH users.

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Poznavanje možnosti uporabe navidezne resničnosti v vzgoji in izobraževanju mladih z avtizmom*

Understanding the Potential of Virtual Reality Use in the Education of Youth with Autism

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Povzetek

Prispevek obravnava poznavanje, uporabo in stališča strokovnih delavcev o možnostih uporabe navidezne resničnosti (VR) v izobraževanju mladih z avtizmom. Kvantitativna empirična raziskava, izvedena marca 2025, je zajela 116 strokovnih delavcev z različnih področij, ki imajo izkušnje z delom z osebami z avtizmom. Rezultati kažejo, da se VR pri delu z osebami z avtizmom uporablja zelo redko, večina anketiranih pa samoocenjuje poznavanje VR kot nizko do zmerno. Med zaznanimi prednostmi izstopajo varno in prilagojeno učno okolje, višja motivacija učencev ter možnosti za razvoj socialnih in komunikacijskih veščin. Glavne ovire predstavljajo pomanjkanje opreme, neustrezna usposobljenost strokovnih delavcev in visoki stroški nakupa ter vzdrževanja VR opreme. Kljub temu večina izraža pripravljenost za vključevanje VR v svoje delo, ob zagotovitvi ustrezne podpore in usposabljanja. Ugotovitve kažejo na potencial VR kot podporne tehnologije v izobraževanju oseb z avtizmom, hkrati pa opozarjajo na potrebo po sistemskih ukrepih za njeno širšo implementacijo.

Ključne besede

Navidezna resničnost (VR), avtizem, vzgoja in izobraževanje, strokovni delavci, ovire in podpora.

Abstract

This paper explores professionals' understanding of potential, use, and attitudes toward virtual reality (VR) technology in the education of youth with autism. A quantitative empirical study conducted in March 2025 included 116 professionals from various fields, all with experience working with individuals on the autism spectrum. The results show that VR is used very rarely in this context, and most respondents rate their familiarity with the technology as low to moderate. Key advantages identified include a safe and adaptable learning environment, increased student motivation, and opportunities to develop social and communication skills. The main barriers reported are a lack of equipment, insufficient professional training, and high costs associated with purchasing and maintaining VR systems. Nevertheless, the majority of respondents expressed a willingness to incorporate VR into their professional practice, provided that appropriate support and training are available. The findings highlight the potential of VR as a supportive technology in the education of individuals with autism, while emphasizing the need for systemic measures to enable its broader implementation.

Key words

Virtual reality (VR), autism, education, professionals, barriers and support.

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1 Uvod

Uporaba navidezne resničnosti (VR) se izkazuje kot ena izmed zelo obetavnih sodobnih metod tudi na področju izobraževalnega in terapevtskega dela z osebami z avtizmom, saj omogoča učinkovitejše, prilagodljive in personalizirane pristope k učenju. Prednost uporabe VR je ustvarjanje nadzorovanih, varnih in ponovljivih učnih situacij (npr. ponovljive simulacije socialnih, komunikacijskih ali senzoričnih situacij) v realističnih, a nadzorovanih virtualnih učnih okoljih. Takšna oblika podpore posameznikom s specifičnimi potrebami pogosto presega zmožnosti tradicionalnih pristopov, saj omogoča višjo stopnjo prilagodljivosti, ponovljivosti in nadzorovanosti učnih izkušenj [2, 3, 4].

1.1 Avtizem

Za osebe z avtizmom, ki je razvojno nevrološka motnja, je značilno, da pogosto doživljajo težave v socialnih interakcijah, komunikaciji, prilagoditvenih spretnostih in v razumevanju vsakodnevnih situacij [5, 6], zato je zanje možnost postopnega učenja novih veščin preko realističnih simulacij in brez nenadzorovanih in nepredvidljivih zunanjih okoliščin in pritiska, dobrodošla. Varnejše učno okolje lahko bistveno poveča njihovo motivacijo za učenje in stopnjo uspešnega prenosa naučenih veščin v resnično življenje [7]. V VR okolju lahko učitelji učenje bistveno bolj personalizirajo in prilagodijo težavnost nalog, nadzorujejo zunanje dražljaje in spremljajo napredek v varnem in strukturiranem kontekstu, kar še dodatno povečuje učinkovitost takšnega pristopa pri mladih z avtizmom [8].

1.2 Navidezna resničnost (VR)

VR označuje stanje, kjer je uporabnik popolnoma potopljen v računalniško generirano tridimenzionalno okolje. To omogoča simulacijo realističnih scenarijev ali oblikovanje povsem novih

virtualnih svetov, v katerih uporabnik lahko interagira z okoljem [9]. V zadnjem desetletju se VR vse bolj uveljavlja kot inovativno orodje v izobraževanju. VR učna okolja (VRLE – Virtual Reality Learning Environments) so interaktivna učna okolja, ki omogočajo izvajanje nalog, reševanje problemskih situacij in razvoj specifičnih veščin prek ponovljivih, nadzorovanih in prilagojenih učnih izkušenj [8, 10]. Do pojava VR so bile tovrstne situacije večinoma predstavljene s sliko ali z besedilom, le redko pa tudi z uporabo zvoka ali videoposnetkov. VR pa omogoča vključevanje več modalnosti (vizualne, zvočne, prostorske), učinkovito prilagajanje situacij značilnostim, potrebam in predznanju posameznega učenca. Učencem nudi aktivno vlogo pri manipulaciji z objekti v virtualnem učnem okolju, kar prispeva k večji individualizaciji, angažiranosti in aktivnosti v učnem procesu [11].

Kljub številnim prednostim je razširjenost uporabe VR, zlasti na področju učnega dela z osebami z avtizmom, še vedno nizka. Med najpogostejšimi ovirami so izpostavljeni visoki stroški nakupa in vzdrževanja opreme, pomanjkanje usposobljenosti strokovnih delavcev, pomanjkanje uporabniške podpore ter šibko institucionalno podporo pri strateškem načrtovanju implementacije VR tehnologij v sistemsko urejene terapevtske in izobraževalne prakse [12, 13].

2 Problem, namen in cilji raziskave

V prispevku predstavljamo rezultate raziskave, kjer nas je zanimalo, v kolikšni meri so strokovni delavci v vzgoji in izobraževanju seznanjeni z uporabo VR, kako pogosto (če sploh) jo vključujejo v svoje delo, katere prednosti in slabosti pri tem prepoznavajo ter kako se njihova mnenja razlikujejo glede na nekatere demografske dejavnike.

Cilj je bil pridobiti vpogled v trenutno stanje uporabe VR na področju dela z osebami z avtizmom v Sloveniji ter ugotoviti, ali in v kakšni meri obstaja potencial za njeno širšo implementacijo v prihodnosti. Postavili smo dve raziskovalni hipotezi: H1: Po mnenju strokovnih delavcev se VR pri delu z osebami z avtizmom pogosto uporablja. H2: Večina strokovnih delavcev samoocenjuje poznavanje VR kot dobro. Zanimalo pa nas je tudi mnenje anketiranih strokovnih delavcev glede koristi rabe VR za osebe z avtizmom ter s kakšnimi ovirami se lahko soočajo.

3 Metodologija raziskovanja

V kvantitativni empirični raziskavi smo uporabili deskriptivno in kavzalno-neeksperimentalno raziskovalno metodo. Raziskovalni vzorec je bil neslučajnostni, priložnostni, in je vključeval 116 strokovnih delavcev, od katerih so vsi imeli izkušnjo dela z osebami z avtizmom. Med udeleženci je bilo 106 žensk (91,4 %) in 10 moških (8,6 %). Po izobrazbi je bilo največ inkluzivnih pedagogov 38 (32,7%), 28 specialno-rehabilitacijskih pedagogov (24,1 %), 29 drugih pedagogov (razredni pouk, predšolska vzgoja, pedagogika; 25 %) in 21 drugih strokovnih delavcev (psihologi, zdravstveni delavci, delovni terapevti ipd.; 18,1 %). Največ udeležencev je imelo manj kot 5 let delovnih izkušenj (23,3 %), skupini s 6–10 let ter 11–20 let delovnih izkušenj sta bili enako zastopani, vsaka z 19,8 %. Sledili so udeleženci z 21–30 let delovnih izkušenj (19,0 %), medtem ko je imelo več kot 30 let delovnih izkušenj najmanj sodelujočih (18,1 %).

Za zbiranje podatkov smo uporabili spletno anketo, pripravljeno v aplikaciji 1-KA. Anketo smo pripravili namensko za to raziskavo in je bila strukturirana v dva sklopa. Prvi je zajemal demografske podatke, drugi pa se je osredotočal na poznavanje potencialnih možnosti uporabe VR, pogostost uporabe VR in stališča do VR. Vprašanja so bila različnih tipov, zaprta z enim ali več možnimi odgovori, 5-stopenjska Likertova lestvica, in odprta vprašanja (dodatna pojasnila, možnosti in osebne izkušnje pri odgovorih »Drugo«). Anketiranci so bili povabljeni k sodelovanju preko pedagoških skupin na platformi Facebook ter preko elektronskih naslovov šol, kjer se izobražujejo mladostniki z avtizmom). Zbiranje podatkov je potekalo v mesecu marcu 2025. Udeležba v raziskavi je bila prostovoljna in anonimna, skladna z etičnimi načeli raziskovanja.

Zbrane podatke smo obdelali in analizirali z uporabo statističnega programa IBM SPSS Statistic 26, pri čemer so bile izvedene analize deskriptivne statistike.

4 Rezultati in razprava

4.1 Pogostost uporabe VR med anketiranimi pri delu z osebami z avtizmom

Podatki so pokazali, da se VR pri delu z mladimi z avtizmom v vzgoji in izobraževanju uporablja zelo redko, lahko rečemo celo izjemoma. Kar 47,4 % anketiranih je namreč navedlo, da VR ne uporabljajo, 49,1 % pa jo uporabljajo le redko (nekajkrat letno). Le štirje strokovni delavci (3,4 %) VR uporabljajo občasno (nekajkrat mesečno), nobeden pa redno (vsaj enkrat tedensko). V enakih deležih so tudi seznanjeni z dostopnostjo opreme, 47,4 % jih na svojem delovnem mestu nima VR opreme, 49,1 % jih ne ve, če je v ustanovi sploh dostopna, le 3,4 % pa VR opremo ima. Ti podatki kažejo na zelo omejen dostop in uporabo VR v praksi pri nas, zato hipotezo 1: »Po mnenju strokovnih delavcev se VR pri delu z osebami z avtizmom pogosto uporablja.« zavrnemo.

4.2 Samoocena poznavanja VR med anketiranimi

V H2 smo predvidevali, da večina strokovnih delavcev samoocenjuje poznavanje VR kot dobro, vendar se je izkazalo drugače in smo hipotezo zavrnili. Praktične izkušnje z VR ima le desetina (10,3 %) anketiranih, ti so ocenili, da dobro ali zelo dobro poznajo VR, petina jih VR sploh ne pozna (19,8 %), dve tretjini jih nima izkušenj, od teh jih je 35,3 % ocenilo, da VR pozna malo, 34,5 % pa da zmerno (Tabela 1).

Tabela 1: Število (f) in strukturni odstotek (f %) samoocene poznavanja VR

Samoocena poznavanja navidezne resničnosti	f	f(%)
Sploh ne poznam – nimam znanja/izkušenj z VR.	23	19,8
Malo – slišal/a sem, a nimam izkušenj z uporabo.	41	35,3
Zmerno – seznanjen/a z osnovami, a brez izkušenj	40	34,5
Dobro – poznam osnove in sem jo že uporabil/a	10	8,6
Zelo dobro – imam znanje in izkušnje z uporabo VR	2	1,7
Skupaj	116	100,0

4.3 Mnenja anketiranih o prednostih in ovirah uporabe VR pri delu z osebami z avtizmom

Anketiranci so lahko izbirali med vnaprej navedenimi prednostmi uporabe VR z možnostjo, da so lahko dodali še svoje predloge pod »Drugo«. Rezultati so prikazani v Tabeli 2. Kot najpogosteje prepoznano prednost (26,3 %) so anketirani izpostavili prilagojeno in varno okolje za učenje (26,3 %). Ta prednost vključuje tudi možnost personalizacije učnih nalog in vsebin, kar poudarjajo tudi drugi avtorji [13], ki navajajo, da VR omogoča varno izvajanje nalog, prilagajanje zahtevnosti in vsebinskega konteksta ter ponavljanje z možnostjo vizualne in slušne povratne informacije v realnem času. Takšna zasnova prispeva k izboljšanju kakovosti učenja ter povečuje občutek varnosti in zadovoljstva pri izvajanju nalog, kar je povezano z večjo motivacijo, ki jo naši anketirani z 20,6 % prepoznajo kot drugi najpomembnejši dejavnik. S 15,6 % sledijo prednosti, povezane s senzorno stimulacijo in sprostitvijo, kar je posebej pomembno pri posameznikih z avtizmom, ki sicer zelo pogosto doživljajo senzorno preobremenjenost. Na četrtem mestu (14,4 %) je bil izpostavljen doprinos VR k razvoju socialnih in komunikacijskih veščin, saj omogočanje ponavljanja virtualnih socialnih interakcij v varnem in strukturiranem učnem okolju omogoča boljše razumevanje in spodbuja komunikacijo. Nadalje 12,5 % anketirancev prepoznava prednost ponovljivega izvajanja aktivnosti brez zunanjih pritiskov iz okolja, kar lahko prispeva k učinkovitejšemu učenju oseb z avtizmom. Nekateri anketiranci žal niso prispevali svojih mnenj glede prednosti, 10,6 % jih je namreč pod »Drugo« zapisalo, da nimajo mnenja, ker VR ne poznajo, le en izmed njih je izpostavil uporabo VR v povezavi in podpori z manualno terapijo.

Tabela 2: Število (f) in strukturni odstotek (f %) odgovorov anketiranih o prednosti pri uporabi VR z osebami z avtizmom.

Prednosti uporabe VR z osebami z avtizmom	f	f(%)
Prilagojeno in varno okolje za učenje.	42	26,3
Večja motivacija uporabnikov.	33	20,6
Senzorna stimulacija ali sprostitev.	25	15,6
Boljši razvoj socialnih in komunikacijskih veščin.	23	14,4
Možnost ponavljanja aktivnosti brez pritiskov iz okolja.	20	12,5
Drugo.	17	10,6
Skupaj	160	100,0

Udeležence smo povprašali tudi o zaznanih ovirah za vključevanje VR pri delu z osebami z avtizmom. Kot najpomembnejše ovire so izpostavili pomanjkanje ustrezne opreme (35,9 %) ter neustrezno usposobljenost strokovnih delavcev (33,5 %). Med pogoste ovire so navedli tudi visoke stroške opreme in vzdrževanja (16,2 %) ter pomanjkanje institucionalne podpore za sistematično uvajanje VR (5,4 %). Pet anketirancev (3 %) je izrazilo dvom v pripravljenost oseb z avtizmom za uporabo VR, medtem ko so pod možnostjo »Drugo« nekateri navedli nepoznavanje tehnologije ali opozorili na tveganje, da bi lahko VR pri posameznikih spodbudila pretirano željo uporabe VR.

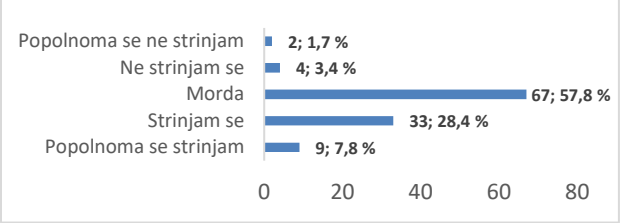
Tudi raziskave v literaturi poudarjajo, da je za učinkovito implementacijo VR ključno ustrezno opismenjevanje in usposabljanje strokovnih delavcev o potencialih in načinih uporabe VR [14] ter redno vzdrževanje opreme [12]. Visoki stroški, povezani z uporabo VR (npr. nakup VR očal in vzdrževanje sistema), so tudi pogosto navedeni kot pomembna ovira [7, 8], kar dodatno poudarja potrebo po zagotavljanju sistemske in finančne podpore pri uvajanju tovrstnih tehnologij [13].

Tabela 3: Število (f) in strukturni odstotek (f %) odgovorov anketiranih o ovirah pri uporabi VR z osebami z avtizmom.

Ovire pri uporabi VR z osebami z avtizmom	f	f(%)
Pomanjkanje ustrezne opreme.	60	35,9
Pomanjkanje usposobljenosti strokovnih delavcev.	56	33,5
Visoki stroški opreme.	27	16,2
Sprejemanje tehnologije s strani oseb z avtizmom.	5	3,0
Nezadostna podpora institucij.	9	5,4
Drugo.	10	6,0
Skupaj	167	100,0

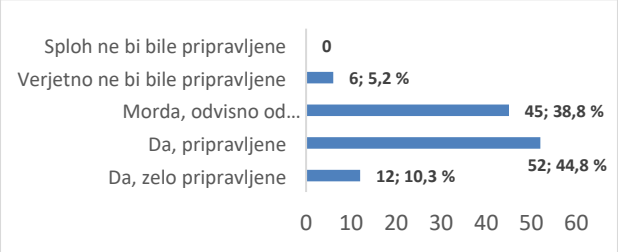
4.4 Mnenja anketiranih glede koristi in pripravljenosti oseb z avtizmom za uporabo VR

Glede koristi pri razvoju socialnih, komunikacijskih in življenjskih spretnosti oseb z avtizmom ugotavljamo, da so sodelujoči, kljub pomanjkanju lastnih izkušenj z uporabo VR, večinoma naklonjeni njeni rabi. Večina anketiranih (57,8 %) meni, da bi bila uporaba VR morda koristna, dodatnih 36,2 % pa se s to trditvijo (popolnoma) strinja. Le 5,1 % sodelujočih izraža (popolno) nestrinjanje, kar nakazuje splošno pozitivno naravnanost do uporabe VR kot podpornega orodja pri izobraževalnem in terapevtskem delu z osebami z avtizmom.



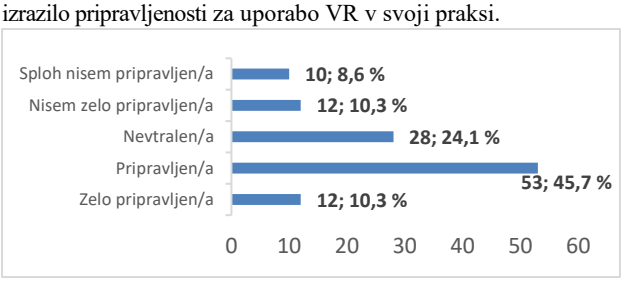
Slika 1: Strinjanje glede koristi VR za razvoj socialnih, komunikacijskih in življenjskih spretnosti oseb z avtizmom

Glede pripravljenosti oseb z avtizmom za uporabo VR večina anketirancev meni, da bi se bili ti posamezniki (zelo) pripravljeni vključiti v takšno obliko aktivnosti (55,1 %), medtem ko jih 38,8 % poudarja, da je to povsem odvisno od posameznika, 5,2 % anketirancev pa izraža dvom o pripravljenosti oseb z avtizmom za uporabo VR. Ti rezultati so skladni s pričakovanji, saj študije kažejo na visoko stopnjo zanimanja in spretnosti oseb z avtizmom za uporabo digitalnih tehnologij, kar je pogosto povezano z njihovo usmerjenostjo k strukturiranim, predvidljivim, ponovljivim in vizualno podprtim interakcijam [3, 4].



Slika 2: Mnenje o pripravljenosti oseb z avtizmom za uporabo VR

Spodbudna je tudi ugotovitev, da so anketirani, kljub omejenemu poznavanju VR, v večini (56,0 %) (zelo) pripravljeni vključiti VR v svoje strokovno delo, če bi imeli na voljo ustrezno opremo in možnost usposabljanja. Nevtralen odnos do vključevanja je izrazilo 24,1 % anketirancev, medtem ko 18,9 % anketirancev ni izrazilo pripravljenosti za uporabo VR v svoji praksi.



Slika 3: Pripravljenost strokovnih delavcev za uporabo VR pri svojem delu ob ustrezni opremi in usposabljanju

5 Sklep

Ugotovitve naše raziskave jasno kažejo, da je uporaba VR pri delu z osebami z avtizmom v Sloveniji še v začetni fazi. Poznavanje uporabe VR med strokovnimi delavci, ki delajo z osebami z avtizmom v Sloveniji, je večinoma nizko do zmerno, praktična uporaba VR pa je zelo redka. Kljub temu večina sodelujočih izraža pripravljenost za vključevanje VR v svoje strokovno delo, ob pogoju, da bi bila na voljo ustrezna oprema in strokovno usposabljanje. Med zaznanimi prednostmi VR izstopajo varno in prilagojeno učno okolje, večja motivacija učencev ter možnosti za razvoj socialnih in komunikacijskih veščin. Najpogosteje navedene ovire pa vključujejo pomanjkanje opreme, nezadostno strokovno usposobljenost ter visoke stroške nabave in vzdrževanja opreme. Za širšo implementacijo bi bilo potrebno zagotoviti večjo dostopnost opreme, ponuditi ciljno usmerjena izkustvena izobraževanja za strokovne delavce ter oblikovati smernice za uporabo VR v učne namene, da bi dosegli večjo učinkovitost in varnost pri delu z ranljivimi skupinami, kar poudarjajo tudi drugi avtorji [13, 14].

Kljub dragocenim vpogledom je treba rezultate interpretirati ob upoštevanju omejitev raziskave. Vzorec anketirancev ni reprezentativen, kar omejuje možnosti za posploševanje ugotovitev na širšo populacijo strokovnih delavcev. Raziskava temelji na samooceni in ne zajema računalniškega predznanja sodelujočih, ki so bile večinoma ženske, kar lahko vpliva na izkušnje in poznavanje VR, izražena stališča in zaznane ovire.

Za nadaljnje raziskovanje bi bilo smiselno vključiti večje in reprezentativne vzorce ter kombinirati kvantitativne in kvalitativne pristope, kar bi omogočilo globlji vpogled v izkušnje in zaznave strokovnih delavcev glede uporabe VR pri delu z osebami z avtizmom. Za razvoj praks bi bile posebej koristne eksperimentalne študije, ki bi primerjale izkušnje in učinke različnih vrst VR intervencij pa tudi longitudinalne študije, ki bi preučevale dolgoročne učinke uporabe VR na učne in socialne izide.

Rezultati pričujoče raziskave nakazujejo potencial VR kot podporne tehnologije v izobraževanju oseb z avtizmom ter hkrati opozarjajo na potrebo po sistemski podpori za njeno širšo in smiselno implementacijo.

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Digital Exclusion and the Experience of Being Phubbed

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Abstract

The study sought to investigate the reaction to being phubbed by conversational partners. Data for this study were collected using focused silent observation of individuals being phubbed in public settings, such as outside cafes. The focused silent observation was carried out using an observational checklist, which was implemented using Qualtrics. 105 observations were recorded using the Qualtrics observational checklist. The findings of this study revealed that the majority of phubbing incidents occurred when there were between 11 and 20 people present. The vast majority of these incidents involved dyads. The study findings also revealed that young people aged 18–24 and 25–34 were phubbed more than other age groups, and the vast majority of phubbees were female. Of the 105 observations recorded, the majority of phubbing incidents were actively initiated by the phubber—that is, they were not in response to a phone notification. The analysis of data also showed that the majority of phubbers were observed scrolling through their social media feeds, with fewer instances involving texting or phone calls. Most of those who experienced being phubbed did not display any visible reaction other than feeling socially excluded, and only a small portion showed a noticeable negative response. Reactions of those phubbed varied: some individuals continued engaging with the phubber as if the phone was not in use, while others appeared visibly unhappy or awkwardly occupying themselves by looking at their surroundings to appear busy. A number of those phubbed reacted by also using their phones ('revenged phubbed'). Overall, the findings of the study revealed that phubbing has a more disruptive impact on dyadic interactions than on interactions in group settings. Phubbing has been found to be associated with intensifying feelings of social exclusion. The findings of this study support this association.

Keywords

Digital exclusion, phubbing, being phubbed, qualitative, focused observation, dyads, phubber, phubbee, smartphones

1. Introduction

Smartphones have become nearly inseparable companions in everyday life, yet their constant presence often interferes with the quality of face-to-face communication, raising important questions about how technology reshapes our social interactions. It is now exceedingly common for people meeting in person to ignore each other with their smartphones. This social behaviour is referred to in the literature as phubbing [4]. Phubbing can make the person being ignored with a smartphone feel digitally excluded [4]. The digital exclusion arises not because the person being ignored does not have a smartphone, but because the person who ignored them prioritised the smartphone over face-to-face interaction. The research on phubbing is growing at a rate comparable to the rate at which this phenomenon is increasing in prevalence [7]. The literature on parental phubbing has expanded rapidly in recent years, with a number of studies recently looking at this issue, including [16, 19, 29, 32, 33]. That said, the recent literature shows that researchers remain curious about the predictors of this behaviour and the effects of being phubbed on the phubbed individual. A number of recently published studies focused on the association between phubbing and the individual factors that predict it, such as fear of missing out [23, 28], addiction to the smartphone [29], addiction to social media [30], self-esteem [12], loneliness [8], and personality types [26]. Arenz and Schnauber-Stockmann [7] took a holistic view to what predicts phubbing behaviour. Their meta-analysis has revealed that while there are 10 higher-level predictor categories of phubbing behavior, namely [1] sociodemographics, [2] personality, [3] technology-related norms and experiences, [4] technical equipment, [5] smartphone and [6] Internet use, [7] problematic use, [8] well-being, [9] psychopathology, and [10] resilience, problematic smartphone use, smartphone addiction, internet addiction, and SNS addiction are the strongest predictors of phubbing. With respect to phubbing effects, the latest research shows that there is a positive correlation between phubbing and severe depression and that young women under 25 years old show higher levels of 'somatic symptoms' than men in the same age group [13] suggesting that phubbing can affect not only psychological well-being, but it can also affect physical well-being. One line of research on phubbing that continues to be neglected is understanding the experience of being phubbed, especially using qualitative research methods. Qualitative research methods can offer rich descriptions of the observed or lived experience of those being phubbed [4]. In his book, 'The Psychology of Phubbing', Al-Saggaf [4] has specifically called for research that investigates the experience of being phubbed using qualitative research methods. This study answers this call. The aim of this study is to investigate the reaction to being phubbed. This study will investigate this reaction using silent observation.

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2. Related Work

The experience of being phone snubbed (known in the literature as 'phubbed' in favour of a smartphone is becoming increasingly common in today's society [4]. The experience of being phubbed is associated with numerous negative consequences. According to Roberts and David [25], being phubbed can lead to feelings of social exclusion, lower relationship satisfaction, and increased smartphone dependency. Furthermore, their study found that the more frequently an individual reported being phubbed by their partner, the more likely they were to report symptoms of depression and anxiety. The experience of being phubbed can also have a negative effect on individual well-being and relationship quality [18], highlighting the need for individuals to be mindful of their phone use in social situations and to prioritise meaningful in-person interactions. Privileging online interaction over co-present interaction can make the person being phubbed to feel left out [4]. The person being phubbed can use their smartphone too to go online. But that is not what they want. What they want is probably to have a face-to-face conversation. The digital exclusion caused by phubbing is introducing a divide between those who favour the use of smartphones and those who prefer in-person social interaction.

Researchers used a variety of methods to investigate the experience of being phubbed. These methods include naturalistic observation [24], video recordings [11], and self-report surveys [3], which all have contributed to improving the understanding of the experience of being phubbed in social situations. However, qualitative research methods remain underrepresented as a method for studying this topic. One of the few studies that used a qualitative method was Radesky et al. [24] study. Radesky et al. [24] used naturalistic observation to examine the impact of smartphone use on face-to-face conversations. They found that individuals' use of phones during conversations led to a decrease in conversation quality and engagement between individuals. Radesky's et al. [24] study suggests that the use of smartphones during social interactions can negatively impact the quality of communication, highlighting the importance of limiting phone use during face-to-face conversations.

Another study that used observation as a method of data collection is Courtright and Caplan [11] study. This study used video recordings to observe how smartphones' use affects the dynamics of social interactions. They found that smartphone use can interrupt the flow of conversation, lead to a lack of eye contact, and diminish the quality of communication between individuals [2].

While research on the experience of being phubbed has shed light on several associated aspects, especially its negative consequences, there are still some gaps in our understanding of this phenomenon. For example, numerous studies have focused on the effects of phubbing in romantic relationships, with less attention given to the impact of phubbing in other types of relationships, such as friendships or family relationships [4]. Additionally, most studies have relied on self-report measures, which may not always accurately capture the subjective experience of being phubbed [4]. Addressing these gaps in future research could provide a more nuanced understanding of how phubbing affects those at the receiving end (the phubbees) [4].

Several factors have been identified in the research that can trigger phubbing behaviour. One of the most significant factors is the individual's level of attachment to their smartphones, which can lead to an excessive focus on the device and a corresponding decrease in attention to interpersonal communication [9]. Another factor is the social norms around smartphones' use in a particular context, which can influence the perceived acceptability of phubbing behaviour [17]. The individual's level of self-control, stress levels, and the availability and importance of the communication being received on the smartphone can also trigger phubbing [15]. Another significant factor is the fear of missing out (FOMO) on what friends are up to [27].

What is not clear from the literature is how the person being phubbed reacts to the experience. Individuals who are phubbed may experience a range of emotions, such as annoyance, frustration, and disappointment [21]. They may also feel disrespected or that they are unimportant [21], which can harm the relationship between the phubber and the person being phubbed [10]. Phubbing can also make the individual being phubbed feel socially excluded [22]. In response to being phubbed, individuals may attempt to draw the phubber's attention back to the interaction or may simply disengage from the interaction [31]. Some individuals may also engage in retaliatory phubbing, using their own mobile device to ignore or distract the phubber [31]. Overall, research suggests that being phubbed can elicit negative emotional responses from individuals and may have implications for the quality of interpersonal communication and relationships. This study will investigate the reaction to being phubbed. The aim of this study is to investigate this reaction using silent observation.

3. Methodology

Silent observation is a method that involves observing social interactions without intervening or interacting with the individuals being studied [14]. This method has several advantages when it comes to studying the experience of being phubbed. One advantage is that it allows for naturalistic observation, which means that individuals are observed in their everyday environment without the influence of an observer's presence or interference [14]. Additionally, silent observation can provide a non-intrusive way to study the phenomenon of phubbing, without the need for participants to provide self-reports or be interrupted during their social interactions [2]. This can increase the validity and reliability of the study's findings by reducing the risk of participant reactivity or demand characteristics [20]. Overall, the use of silent observation as a method for studying the experience of being phubbed can provide a unique and valuable perspective on the reaction to being phubbed by conversational partners.

While silent observation has some advantages as a method for studying the experience of being phubbed, it also has several limitations. One limitation is that it can be difficult to obtain a representative sample of participants, as individuals who are aware that they are being observed may behave differently than they would in their natural environment [6]. Additionally, silent observation may not capture the subjective experiences of individuals being phubbed, as it relies solely on the observation of behaviour and does not provide insight into individuals' internal experiences or emotions [6]. Moreover, silent observation may not be feasible or ethical in all situations, as it requires access to private spaces and the ability to observe

individuals without their knowledge or consent [6]. Finally, silent observation can be time-consuming and resource-intensive, requiring trained observers to record and analyse data over an extended period [1]. Despite these limitations, silent observation can still provide valuable insights into the experience of being phubbed, especially when used in conjunction with other research methods.

Data for this study were collected using focused silent observation of individuals being phubbed in public settings, such as outside cafes, by their conversational partners. Data collection for this study was carried out in line with the ethics approval (Protocol number H23549) from the Charles Sturt University Human Research Ethics Committee (HREC). Data collection began on 25 May 2023 and stopped on 19 April 2025. The focused silent observation was carried out using an observational checklist of a pre-prepared set of structured questions that guided what to observe. The silent observation focused only on answering the observational checklist structured questions. Irrelevant behaviours that do not link to the guiding questions were ignored. The observational checklist was implemented using Qualtrics. The observational checklist consisted of three groups of observational questions. The first group of questions focused on capturing information about the setting where the phubbing incident occurred. The second group of observational questions focused on the phubber's act. The third group of observational questions focused on the reaction of the person being phubbed. Each question in the observational checklist was accompanied by a set of pre-determined relevant response options, which were used to prepopulate the observational checklist. The observational checklist also contained a textbox for textually recording qualitative observations of the incidents of phubbing.

The process of observation outside cafes took place as follows. The researcher in this project would enter a café and order a coffee. The researcher would then sit at a table outside the café and take out his phone. If, while sipping his coffee and scrolling through his phone, he observed an individual, or a group of individuals, in front of him being phubbed by another person or more, he would record the incident by filling out the observational checklist. A total of 105 observations were recorded in public places (outside cafes). After finishing his coffee, the researcher would simply leave the café.

4. Findings

The study sought to investigate the reaction to being phubbed by conversational partners in public settings (outside cafes). 105 observations were recorded using the Qualtrics observational checklist. As mentioned above, the observational checklist consisted of three groups of observational questions.

The first group of questions focused on capturing information about the setting where the phubbing incident occurred. The first question in this group asked about the number of people present in the public place at the exact moment the phubbing took place. In 55.2% (N=58) of the incidents, there were between 11 and 20 people present, but in 21.9% (N=23), there were more than 30+ people outside the café where phubbing occurred. In 15.2% (N=16) and 7.6% (N=8) of the phubbing incidents, there were between zero and 10 and between 21 and 30, respectively (see Figure 1 below). It appears the majority of phubbing incidents occurred when there were between 11 and 20 people present outside a café. It is not clear why this size of people in a public place was associated with the majority of phubbing cases, but it is possible that a mid-sized group offers a sense of safe invisibility or optimal anonymity in that if someone engaged in phubbing a conversational partner, the phubber may think other people present may not notice because the attention is not focused on them. In a small group setting, phubbing is more obvious and socially awkward. On the other hand, in a large group setting, the space itself feels less intimate and more demanding of attention.

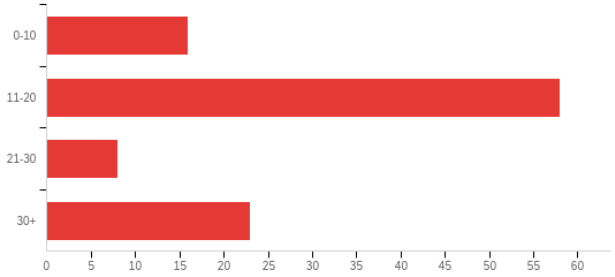

Figure 1: The number of people present in the public place

A key question in this group of questions asked about the number of people involved in the phubbing incident. The pre-determined responses for this question ranged from two individuals (a dyad) sitting together, to a group of three people, and a group of four people. The vast majority of phubbing incidents, 76.2% (N=80), involved dyads, with only 21% (N=22) of the incidents involving three people (see Figure 2 below). This may suggest that phubbing socially excludes those closet, as Al-Saggaf [5] has previously found.

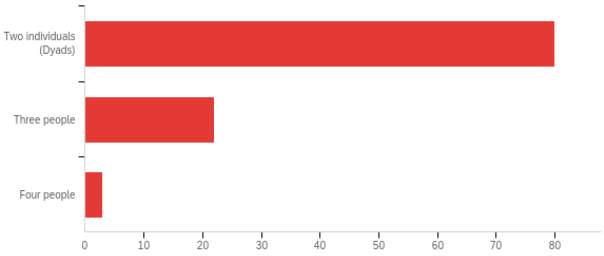

Figure 2: The number of people involved in the phubbing incident

The question relating to the presenting age of the individual being phubbed revealed that young people aged 18-24 and 25-34 were phubbed more than other age groups 24.8% (N=26) and 25.7% (N=27) respectively. While people aged 35-44 were phubbed 20% (N=21) of the time, people aged 45-54 were phubbed less frequently 15.2% (N=16), compared to their younger counterparts (see Figure 3 below). This finding suggests that romantic partners and close friends, who 'go out' for coffee together, phub each other the most.

The observational checklist also captured the presenting gender of the individual being phubbed. The vast majority of phubbees 63.8% (N=67), were females, with the remaining 36% (N=38) being male (see Figure 4 below). This suggests females are subject to being phubbed more than their male counterparts.

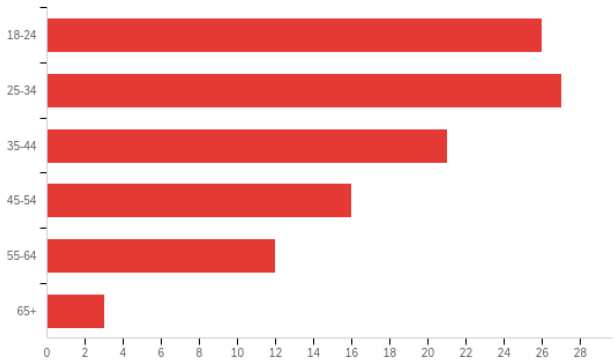

Figure 3: The presenting age of the individual being phubbed

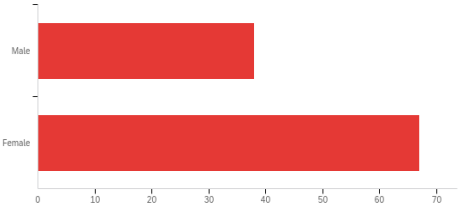

Figure 4: The presenting age of the individual being phubbed

The second group of observational questions focused on the phubber's act. Phubbing incidents were initiated in two forms: active or passive. Phubbing was initiated either by the phubber, i.e. not in response to a form of notification that the phubber had received (active form), or by the phubber in response to a form of notification that the phone had sent (passive form). Of the 105 observations recorded, 78.1% (N=82) were actively initiated by the phubber, that is, not in response to a phone notification, and only 12.4% (N=13) were triggered by a phone notification, 9.5% (N=10), were classified as 'Unsure' (see Figure 5 below). This finding suggests that in the case of those observed, phubbing was largely an active act that took place unprovoked.

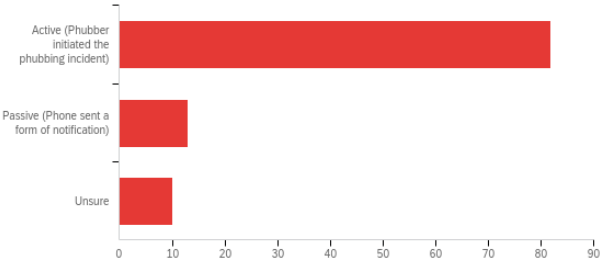

Figure 5: How phubbing was initiated

The observational checklist captured the duration of phubbing using three options: Momentarily (<15 seconds), Quick (>15 seconds and <45 seconds), and Long (> a minute). 71.4% (N=75) of the observed incidents of phubbing lasted more than a minute. That is, the phubbing of those observed suddenly pulling their phones and starting to use them during their face-to-face conversations with others, was not momentarily, to attend to an urgent matter; rather it was long. Only 6.7% (N=7) and 21.9% (N=23) of the phubbing was Momentarily and Quick, respectively (see Figure 6 below). This suggests in the case of those observed, the phubbing was persistent. That phubbing lasted more than a minute suggests that the phubber disengaged from their face-to-face conversation, leaving their conversational partner on their own. Phubbing is strongly linked with social exclusion [22, 25]. While the phubber is digitally included, the person being phubbed is socially excluded.

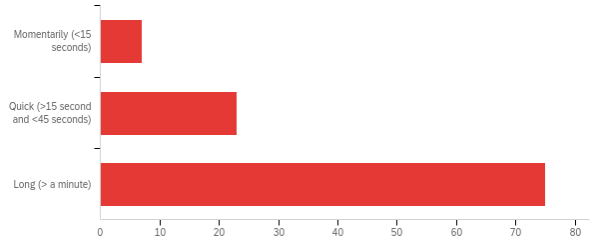

Figure 6: Duration of phubbing

The observational checklist included the possibility to record the phubber's act immediately 'prior' to suddenly pulling their smartphone and starting to use it. The options to choose from to capture this act included seeking permission from the phubbed person, seeing a phone alert (like the phone is lit, vibrates, or produces a sound, or ring), and whether or not the phubber had said something before phubbing their conversationalist. None of these options, however, was deemed relevant to the observed incidents. For this reason, 79% (N=83) of the observed incidents were recorded under 'Other'. Given that the act took place in a split second, it was difficult to record explanatory notes regarding the nature of this act prior to engaging in phubbing others. The observational checklist also included the possibility to record the phubber's act immediately after' suddenly pulling their smartphone and starting to use it. The options to choose from to capture this act included beginning to scroll through their social media feeds, starting texting, starting to talk on the phone, getting closer to the co-present person and showing them their phone. The frequency analysis revealed that 31.4% (N=33) of the phubbers were observed scrolling through their social media feeds immediately 'after' pulling their smartphone, 14.3% (N=15) were observed texting, and 12.4% (N=13) were observed talking on the phone. Of the 105 observations recorded, 33.3% (N=35) were categorised 'Other' than above, either because the observed act did not match any of the options for this category or because of the difficulty of observing such a fleeting act.

The third group of observational questions focused on the reaction of the person being phubbed. The first category aimed at capturing the individual being phubbed (phubbee) immediate reaction when another person they were with face-to-face suddenly pulled their phone and started using it. 58.1% (N=61) did not show any observable reaction and therefore their response was classified as Neutral. On the other hand, 33.3% (N=35) showed a noticeable negative reaction and only 8.6% (N=9) showed a visible positive reaction (see Figure 7 below). That the majority's response to being phubbed was neutral suggests that phubbing is becoming a normalised behaviour.

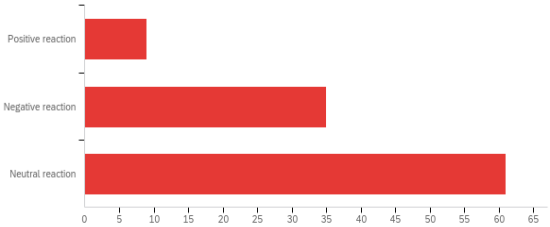

Figure 7: Reaction to being phubbed

The second category in this group aimed at capturing the phubbee's immediate response to being phubbed. Only one phubbee was observed asking the phubber to stop the phubbing, and two became confrontational with their phubber and while 17% (N=18) reacted to being phubbed by using their phone too, the vast majority, 80% (N=84) did not show any visible reaction, other than being observed feeling socially excluded. This social exclusion introduced by phubbing is creating a divide between people who prefer to be digitally included and those who prefer to be included in the co-present interaction.

Qualitative observations of the incidents of phubbing were also recorded textually via the observational checklist. The qualitative observations offered a more nuanced understanding of how individuals react to being phubbed. The recorded reflections captured a composite scene in which multiple interactions occurred simultaneously within a shared public space. In several instances, children—including those in prams—appeared to be overlooked by their caregivers, who were focused on their phones. One mother, for example, was observed crossing a street diagonally while carrying a baby in her left arm and scrolling through her phone with her right hand as the traffic light turned green. Similarly, some elderly individuals were observed being ignored by their adult children, who were engrossed in their devices. Among those observed being phubbed, reactions varied. Some continued engaging with the phubber as if the phone use was not occurring, while others appeared visibly uncomfortable, awkwardly occupying themselves by looking around or attempting to appear busy. But these were all observed feeling socially excluded. It appears that while phubbing has made the phubber digitally included, it has excluded the person being phubbed from the face-to-face interaction. In this sense, phubbing can be considered as a manifestation of a divide where one's need to be digitally included is making another socially excluded. A number of individuals responded by also using their phones, a form of reciprocal behaviour sometimes referred to as "revenge phubbing." In several cases, phubbers invited those they were previously ignoring to view something on their phone screens. This gesture often prompted a positive response and appeared to energise the conversation. A small proportion of individuals showed visible signs of dissatisfaction when their conversational partners became distracted by their phones. The data also suggest that phubbing has a more disruptive impact on dyadic interactions than on group settings. In group conversations, if one person disengaged by using their phone, the remaining individuals could often continue interacting face-to-face. In contrast, in one-on-one conversations, the phubbed individual was left to either mimic phone use or seek distraction elsewhere to manage the social discomfort. Overall, while the use of the phone during a face-to-face conversation did make the person being phubbed feel socially excluded, most participants calmly managed the discomfort associated with the experience of being phubbed, suggesting that such phone use is not widely perceived as a transgression against social norms of interaction.

5. Conclusion

The study sought to investigate the reaction to being phubbed by conversational partners. In line with the ethics approval from HREC for this study, data for this study was collected using focused silent observation of individuals being phubbed in public settings, such as outside cafes. The focused silent observation was carried out using an observational checklist, which was implemented using Qualtrics. 105 observations were recorded using the Qualtrics observational checklist.

It appears the majority of phubbing incidents occurred when there were between 11 and 20 people present in a public place. The vast majority of these incidents involved dyads. Observations revealed that young people aged 18–24 and 25–34 were phubbed more than other age groups, and the vast majority of phubbees were female. Of the 105 observations recorded, the majority of phubbing incidents were actively initiated by the phubber—that is, they were not in response to a phone notification. In most cases, phubbing was not prompted by a phone alert such as a lit screen, vibration, sound, or ringtone. The data analysis showed that the majority of phubbers were observed scrolling through their social media feeds, with fewer instances involving texting or phone calls. Most of those being phubbed did not display any observable reaction (other than feeling socially isolated), and only a small portion showed a noticeable negative response. Reactions to being phubbed varied: some individuals continued engaging with the phubber as if the phone use was not occurring, while others appeared visibly uncomfortable, awkwardly occupying themselves by looking at their surroundings to appear busy. A number of individuals reacted to being phubbed by also using their phones—a form of reciprocal behaviour sometimes referred to as "revenge phubbing. The observations also revealed that phubbing has a more disruptive impact on dyadic interactions than on interactions in group settings.

While much of the existing scholarship views phubbing as a social behaviour that impacts the person being phubbed, given that phubbing socially isolates the phubbee, it can also be conceptualised as a divide between those who crave digital connection all the time and those who value face-to-face interaction. This divide is not caused by a lack of access to a smartphone, internet connectivity or digital literacy. It is caused by the phubber's need to be digitally included, even if it is at the expense of excluding a co-present conversational partner. In this sense, the smartphone, which connects, also disconnects. Further research is needed to properly investigate how phubbing can be framed as a divide.

Two limitations of this study need to be outlined. First, the set of relevant response options that accompanied the observational checklist questions was not comprehensive enough to capture the subtleties associated with the phubbing experience. On the other hand, if the set of response options was exhaustive, the observational checklist would have taken longer to fill. Given that the phubbing incidents happened fast, the recording of observations needed to be done quickly to avoid undermining the accuracy of the data. Second, because what was to be observed occurred quickly and, as already established, the recording of observations needed to be done fast, it was not possible to offer detailed qualitative observations in the available textbox. This limited the depth of the textual qualitative observations. Recording the phubbing incidents by video and then entering the textual qualitative observations would have resulted in rich data enough to offer a 'thick' description of the reaction to being phubbed. But doing so would have violated the privacy of those observed. It is recommended that the observational checklist be

used in conjunction with another qualitative research method, such as semi-structured interviews. Combining these two techniques can allow researchers to capitalise on the strengths of each while minimising their individual weaknesses. That being said, this study should be considered significant as it is the first that adopts an observational checklist to explore the range of reactions to be phubbed in public places.

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Artificial Intelligence Tools and Frameworks for Inclusive Digital Education: Benefits and Challenges

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Abstract

Artificial Intelligence (AI) is emerging as a powerful driver of inclusive digital education. This study examines how AI supports accessibility, personalization, and engagement, while also addressing the challenges of infrastructure, teacher readiness, and ethical use. Using a systematic review of literature and a structured inventory of AI tools, we analyzed benefits across students, teachers, and institutions. Findings show that AI enhances learning through assistive technologies, adaptive pathways, and teaching efficiency, but risks such as bias, privacy concerns, and unequal access remain. We conclude that AI can significantly advance equity in education, provided it is embedded in inclusive pedagogical frameworks and supported by responsible governance and teacher training.

Keywords

artificial Intelligence in education; inclusive digital education, accessibility, universal design for learning

1 Introduction

Inclusive digital education uses digital technologies to ensure equitable access, enabling learners with diverse needs to participate fully. The COVID-19 pandemic exposed both the potential of online learning and systemic disadvantages for students with special educational needs and disabilities (SEND). For these learners, digital education helps overcome barriers, while higher education institutions (HEIs) increasingly aim to design ecosystems that anticipate diversity rather than respond retroactively [1, 2].

The UN Convention on the Rights of Persons with Disabilities affirms the right to inclusive, equitable education [3]. Adaptive platforms and assistive tools support flexible teaching and more engaging learning, improving outcomes [4, 5]. UNESCO defines inclusion as reducing exclusion and increasing participation [2], while frameworks such as the EU Digital Education Action Plan [1] guide practice. AI enhances accessibility with screen readers, transcription, and translation, while adaptive environments personalize instruction. Students benefit from tutoring, gamification, and feedback; teachers gain administrative relief and curriculum support [4]. Yet, inclusion requires structural pedagogical and cultural changes [6], which AI can support only within responsible frameworks. Challenges include algorithmic bias, non-inclusive datasets, opaque processes, and privacy concerns [5]. Without safeguards, AI may reinforce inequalities or diminish the human role. Structured AI literacy is therefore vital [7]. Ultimately, AI offers both opportunities and risks, but when aligned with policy frameworks and backed by training, transparency, and accountability, it can complement human teaching and foster adaptive, inclusive education [6].

2 Theoretical Backgrounds

Inclusive digital education enables students with and without disabilities to learn together meaningfully. International frameworks highlight that students with diverse needs should be supported through inclusive environments that anticipate barriers rather than react after exclusion has occurred [2]. The UN Convention on the Rights of Persons with Disabilities obliges states to ensure inclusive, equitable education [3], while UNESCO views inclusion as addressing learner diversity through participation and reduced exclusion [2]. Research confirms benefits not only for students with disabilities but also for broader social acceptance [5, 6].

Inclusion requires more than placement in mainstream classrooms. Studies emphasize structural changes in curriculum and pedagogy [6], while others stress that digital inclusion demands access to devices, high-quality content, connectivity, and digital literacy beyond basic infrastructure [5]. At the policy level, the EU's Digital Education Action Plan (2021–2027) emphasizes accessible, high-quality education [1]. The European Agency for Special Needs and Inclusive Education outlines multi-level action from pedagogy and learner skills to teacher literacy and institutional support.

Students with Special Educational Needs and Disabilities (SEND) form a diverse group requiring tailored support for equitable education. The UN Convention on the Rights of Persons with Disabilities affirms this right [3], and UNESCO stresses adapted environments [2]. At the European level, SEND is defined broadly, covering physical, cognitive, and socio-emotional barriers [1]. Flexible frameworks are needed to enable participation, while national guidelines specify provision "different from or additional to that normally available" [1].

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SEND is typically classified into groups such as cognitive and learning disabilities, sensory and physical impairments, social and emotional needs, communication difficulties, and multiple or complex needs.

Digital content accessibility ensures that all learners, including those with disabilities, can engage with educational resources. UNESCO stresses that participation depends on removing such barriers [2]. Challenges vary: visually impaired learners need alt text and contrast, hearing-impaired students require captions, those with cognitive disabilities struggle with complex layouts, and motor-impaired learners face difficulties when only precise input is required. Accessible practices such as captions, simplified navigation, and screen reader compatibility align with recommendations for universal access [5] and benefit all students. Research shows they improve engagement, usability, and inclusivity [8]. Embedding accessibility from the start helps institutions meet legal and ethical standards while fostering equity and participation.

Universal Design for Learning (UDL) is a framework designed to remove barriers to participation by proactively creating flexible teaching methods, materials, and assessments. It is based on three principles: multiple means of representation, multiple means of action and expression, and multiple means of engagement. Research shows that UDL benefits all learners by improving motivation, equity, and outcomes [5, 8]. Extended models add strategies like flexible pacing, individualized content, and self-assessment [8]. UDL assumes variability as the norm, shifting focus from deficits to diversity [6]. Policy frameworks, including the EU Digital Education Action Plan [1], recognize UDL as central to high-quality, accessible digital education. Integrated with AI tools, UDL strengthens inclusive practice by combining flexibility, accessibility, and innovation [2, 4].

3 Methods

The study applied a structured review of literature, following established principles of systematic reviews but adapted to the scope of this research. Publications were retrieved mainly from five key sources—UNESCO, UNICEF, EU policy documents, peer-reviewed journals, and proceedings of major international conferences—and supplemented with targeted desk research. In total, 47 publications meeting the inclusion criteria were analyzed. Studies and policy reports were included if they explicitly addressed AI in education, inclusivity, and accessibility, and if they were published within the past ten years.

The research followed a dual approach consisting of: (1) a structured literature review of studies and policy reports from the above sources [1, 2, 3, 4, 11]; and (2) an inventory and taxonomy of AI tools. The analysis of the literature examined applications, benefits for students, teachers, and institutions, as well as challenges across technological, pedagogical, and ethical dimensions.

The second component mapped AI tools, following UNICEF's definition [11], including tutoring systems, chatbots, dashboards, adaptive platforms, and automated assessment tools [12]. Using a taxonomy, tools were grouped into student-, teacher-, and institution-focused categories [4], with details on use, source, and licensing. Emerging solutions were tracked through online repositories such as There's an AI for That [13]. Comparing both components revealed recurring themes: benefits such as accessibility, personalization, and efficiency, and challenges including infrastructure, ethics, teacher readiness, and bias. This dual approach ensured triangulation between theory and practice for evaluating AI in inclusive education.

4 Results

The analysis of the literature and the structured review of AI tools revealed both significant benefits and notable challenges of artificial intelligence in inclusive education.

4.1 Benefits of AI for Inclusive Education

Figure 1 illustrates the main benefits of AI for inclusive education, showing how accessibility, personalization, and participation are supported across different learner groups.

Figure 1: Benefits of AI for Inclusive Education

AI enhances inclusivity by offering accessibility tools, adaptive technologies, and multilingual support that enable diverse learners to participate on equal terms [5, 8]. Assistive solutions such as text-to-speech, speech-to-text, real-time captioning, and voice assistants improve access for students with visual, auditory, or language impairments, while real-time translation supports non-native speakers [8]. Adaptive learning systems tailor instruction to individual needs, providing summaries, study guides, and formative assessments that deliver feedback and allow students to progress at their own pace [9]. Generative AI also adapts content to cultural and linguistic contexts, ensuring representation for marginalized groups. At the same time, AI-supported collaborative platforms foster participation in projects and discussions across backgrounds and locations [5]. In addition, AI fosters inclusion through learning analytics that help identify students at risk and enable timely support, while also informing institutional decision-making on curriculum design, accessibility compliance, and resource allocation. By aligning with international agendas such as the EU Digital Education Action Plan and UNESCO's framework on equity and participation, AI thus contributes to inclusivity not only at the classroom level but also within broader educational systems [1, 2, 5].

4.2 Benefits for Students

The results show that AI enhances students' learning through personalization, engagement, and improved outcomes. Four main benefits were identified. Adaptive platforms such as ALEKS and Knewton adjust difficulty in real time, while AI tutors and assistants provide tailored explanations and support

for brainstorming, writing, and research [12, 9]. Gamification, interactive quizzes, and simulations increase motivation and sustain attention, with real-time feedback keeping learners active [10]. AI also simplifies complex concepts, generates summaries, and supports research, improving comprehension and performance [5, 9]. For students with special needs, tools like predictive text, speech synthesis, and accessible formats enable participation, while collaborative platforms foster teamwork [8]. Figure 2 presents the key advantages of AI for students, including personalization, engagement, and improved learning outcomes.

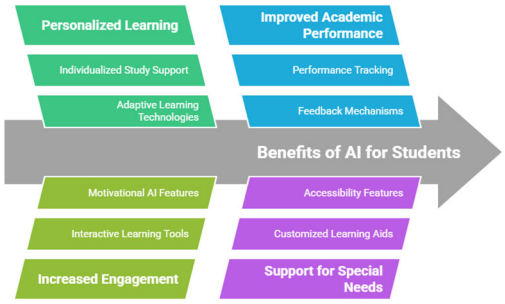

Figure 2: Benefits of using AI for students

4.3 Benefits for Teachers and Instructors

For educators, the adoption of AI provides both practical and pedagogical advantages. Figure 3 summarizes the main benefits of AI for teachers and instructors, organized into seven clusters: administrative efficiency, professional growth, adaptive teaching and curriculum design, student monitoring and feedback, inclusive and accessible education, dynamic pedagogy and engagement, and evidence-based decision making. Together, these categories illustrate how AI reduces workload, supports professional development, enables personalized and inclusive teaching, and strengthens teachers' ability to engage and support diverse learners.

Automated grading systems, plagiarism detection, and AI-powered chatbots reduce repetitive administrative work, freeing teachers to dedicate more time to lesson planning, mentoring, and student engagement [4, 12]. Gamification elements and adaptive feedback further optimize classroom processes, while generative AI supports project-based learning with visualization, simulation, and prototyping tools that foster creativity and problem-solving [9, 10]. AI also contributes to professional development by offering instructional insights, encouraging reflective practice, and enhancing teaching competence [7]. Through data-driven analytics, teachers can monitor learning progress, predict disengagement, and intervene early to prevent dropouts [6, 10]. Personalized content generation and curriculum adaptation allow educators to design inclusive learning environments that accommodate diverse student needs [5, 8]. Finally, AI-driven accessibility tools, including real-time translation and speech recognition, strengthen equity in multilingual and diverse classrooms, ensuring that teachers can reach all learners effectively [2, 8].

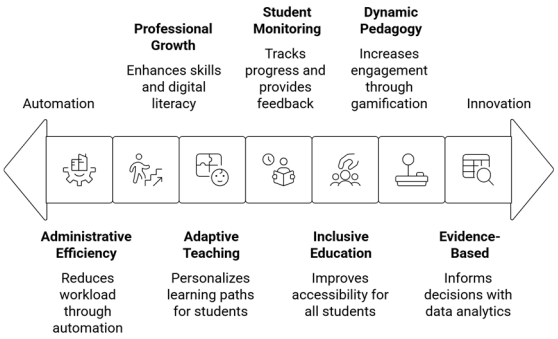

Figure 3: Benefits of AI for Teachers and Instructors

4.4 Challenges of AI for Inclusive Education

While AI offers major benefits, its integration also raises challenges across technological, pedagogical, ethical, and socio-cultural dimensions. If unaddressed, these risks could widen the digital divide and undermine inclusivity.

Technological barriers include limited infrastructure, weak accessibility features, high costs, and poor compatibility with learning systems [5, 6]. Pedagogical issues involve insufficient teacher training, risks of bias, neglect of neurodiverse learners, and over-reliance that may weaken critical thinking [9]. Ethical concerns stem from massive data collection, questions of ownership and security, and opaque algorithms that erode trust [11]. Culturally, AI may reinforce Western-centric perspectives and reduce human interaction, leading to isolation [10].

These findings highlight that AI can transform education only when paired with inclusive design, robust infrastructure, training, and ethical safeguards. Figure 4 summarizes the main challenges of AI integration in inclusive education across technological, pedagogical, ethical, and socio-cultural dimensions.

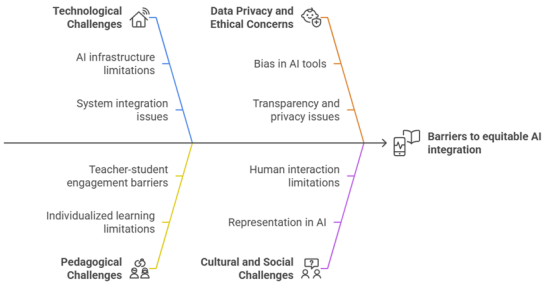

Figure 4: Challenges of AI for inclusive education

5 Discussion

The results confirm that artificial intelligence has substantial potential to advance inclusivity, personalization, and efficiency in education, yet they also expose critical challenges that require careful management. AI technologies align with inclusive digital education and international policy frameworks [1, 2]. By offering accessibility features like captioning, speech-to-text, and adaptive content, AI reduces barriers for students with disabilities [5, 8]. These tools reflect UNESCO and EU priorities on equity [2, 1] and extend digital inclusion beyond connectivity toward adaptability, personalization, and cultural responsiveness

[5, 6]. AI enhances personalization, engagement, and learning outcomes, complementing constructivist and connectivist pedagogies [5, 9]. Gamification and real-time feedback foster motivation [10], while adaptive tools address gaps for students with special educational needs [8]. For teachers, AI improves efficiency, curriculum design, and professional growth, aligning with EU priorities on digital literacy and training [7]. By reducing administrative tasks, AI enables more student-centered teaching, supporting claims that it should serve as a partner rather than a replacement [4].

This study has several limitations. First, as it relies on literature and secondary data, some findings may already be outdated given the rapid evolution of AI [5, 6]. The classification of tools into student-, teacher-, and institution-focused groups [4] also oversimplifies, since many serve multiple roles. Moreover, no primary empirical validation (e.g., classroom trials or large-scale surveys) was conducted, so results should be seen as indicative rather than conclusive [5, 9]. Finally, the reliance on English-language sources may introduce cultural bias and limit global representation [10].

The findings highlight key implications. Governance frameworks must enforce ethical standards, transparency, and privacy compliance such as GDPR [14]. Teacher empowerment through professional development and AI literacy is equally vital [7]. Inclusive design should guide technological adoption, as emphasized in international inclusion frameworks [2, 6]. Finally, institutions must continuously evaluate tools in response to AI's rapid evolution [5].

6 Conclusion

This study reviewed the role of AI in education, focusing on its potential to enhance inclusivity, learning outcomes, and teaching practices. A literature review and tool analysis revealed clear benefits but also significant challenges. AI improves accessibility, personalization, and engagement through adaptive platforms, tutoring systems, and assistive technologies [5]. Teachers benefit from automated grading, lesson planning, and content generation, while institutions gain tools for data-driven decisions and inclusion strategies [6]. At the same time, infrastructural barriers, costs, and limited interoperability restrict adoption. Teachers need continuous training, and ethical concerns (e.g., bias, privacy, transparency) pose risks to equity and trust. Beyond highlighting opportunities and risks, the findings underline the importance of embedding AI into broader pedagogical and institutional frameworks. Inclusive design principles, such as those promoted by UNESCO and the EU, must guide AI adoption to ensure that technology strengthens rather than undermines equity [1, 2]. Teacher professional development and AI literacy are equally critical, as educators play a central role in mediating how these technologies are used in practice [7].

Future priorities include empirical validation of AI's classroom impact to move beyond secondary evidence, alongside continuous teacher training in AI literacy. Policies should ensure ethical governance and transparency so that AI complements rather than replaces human teaching. When responsibly designed and supported, AI can help build a more inclusive, adaptive, and equitable education system.

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Perspectives on AI in Higher Education: Survey Insights from Teachers and Institutional Management

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Abstract

Artificial Intelligence (AI) is reshaping higher education by enabling personalized learning, improved accessibility, and inclusive teaching. This study presents survey results from higher education teachers, researchers, and administrators across European institutions, focusing on perceptions of AI in inclusive digital education. Respondents emphasized benefits such as stronger student engagement, personalized support, accessibility for learners with disabilities, and efficiency in lesson planning. AI was also recognized for fostering cultural and linguistic diversity. At the same time, concerns were raised about infrastructural gaps, limited training, over-reliance, and ethical risks related to bias, privacy, and academic integrity. The study concludes that AI can complement human-led teaching if supported by governance, teacher training, and inclusive design, with priorities including AI literacy, ethical safeguards, and equitable infrastructure.

Keywords

artificial intelligence; inclusive digital education; accessibility; higher education; teacher training; ethical AI

1 Introduction

Artificial Intelligence (AI) is increasingly regarded as a transformative force in education, providing tools for personalization, adaptive learning, and inclusive pedagogy [1]. At the same time, inclusive digital education has become a priority for higher education institutions (HEIs) and policymakers, ensuring equitable participation of students with diverse needs, including those with special educational needs and disabilities (SEND) [2]. This urgency is reflected in frameworks such as the UN Convention on the Rights of Persons with Disabilities, which guarantees inclusive, quality education [3], and UNESCO's definition of inclusion as reducing barriers and increasing participation [4].

Although AI shows strong potential for accessibility, adaptive learning, and assistive technologies, concerns persist around bias, privacy, and equitable access [5]. To address these issues, this study conducted a structured survey to capture stakeholder perspectives on AI in inclusive education, focusing on three dimensions: (i) benefits for students, (ii) benefits for teachers, and (iii) systemic challenges in technology, pedagogy, ethics, and culture. The objectives were to evaluate perceived benefits, identify risks, and propose evidence-based recommendations for responsible adoption.

The article is structured as follows: Section 2 reviews the theoretical background; Section 3 outlines the methodology; Section 4 presents survey results; Section 5 discusses implications; and Section 6 concludes with recommendations.

2 Theoretical Backgrounds

Inclusive digital education is based on the principle that all learners, regardless of physical, cognitive, or socio-emotional differences, should have equitable opportunities to participate. Guillemot, Lacroix, and Nocus describe digital inclusion as enabling students with disabilities to study alongside peers [1]. A milestone was the UN Convention on the Rights of Persons with Disabilities, which guarantees inclusive, quality education [3]. UNESCO defines inclusion as addressing learner diversity by reducing barriers and increasing participation [4].

Effective inclusion requires more than classroom placement. Slee stresses the need for structural reforms in curricula and pedagogy [6], while Reder [7] emphasizes access to devices, content, and digital literacy. The FCC and NDIA outline five essentials: affordable broadband, appropriate devices, digital literacy, support, and accessible applications [8]. Achieving digital equity demands systemic investment to remove barriers for disadvantaged groups [9].

Students with special educational needs and disabilities (SEND) often require adapted environments. UNESCO defines these learners as needing support to achieve their potential [4]. SEND categories include cognitive and learning disabilities, sensory and physical impairments, social and emotional needs, and communication difficulties [10]. The European Agency stresses flexible frameworks to ensure participation [11].

To implement inclusivity, Universal Design for Learning (UDL) provides three principles: multiple means of representation, action and expression, and engagement [12]. UDL encourages proactive design of flexible environments, improving outcomes for SEND and all students [13, 14].

AI intersects with these frameworks through adaptive and accessible tools such as tutoring systems, text-to-speech,

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captioning, and adaptive assessments [15]. It also supports teachers by personalizing content and automating tasks, though challenges remain in bias, data representation, and privacy [16, 17]. In this study, inclusive digital education, SEND, accessibility, and UDL form the theoretical lens for interpreting survey results and debating AI's role in equity.

3 Methods

This study used a quantitative survey to explore how higher education stakeholders perceive the benefits and challenges of artificial intelligence (AI) in inclusive digital education. The goal was to gather insights from teachers, researchers, and managers on AI adoption, its potential for inclusivity, and barriers to responsible use.

3.1 Survey instrument

The questionnaire was collaboratively developed by the AI-ENABLE project team, building on established frameworks of inclusive education and AI in educational practice. It consisted of four sections:

1. *Background* information – including gender, country, institutional affiliation, role, discipline, and years of teaching or research experience.
2. *Awareness* and use of AI tools – measuring familiarity with AI applications, types of tools used, and frequency of use.
3. *Perceived* benefits of AI – covering aspects such as accessibility, personalization, student engagement, collaboration, and teacher support.
4. *Perceived* challenges of AI – addressing technological, pedagogical, ethical, and cultural barriers.

Questions combined multiple-choice formats, Likert-scale ratings (1 = strongly disagree to 5 = strongly agree), and open-ended prompts to allow elaboration of personal experiences.

3.2 Participants

A purposive sampling strategy was applied to recruit respondents from higher education institutions participating in the AI-ENABLE project network. A total of 200 valid responses were collected. The sample comprised 109 female, 90 male, and 1 non-disclosed respondent. Participants often reported multiple roles: researchers (n = 162), teachers (n = 125), management/administrators (n = 60), and other roles (n = 39). Responses were distributed across institutions in several European countries, with the largest share from Ukraine (n = 97), followed by Spain (n = 31), Slovenia (n = 19), and Türkiye (n = 19). Academic disciplines ranged from humanities and social sciences to STEM fields, ensuring a diverse coverage of higher education contexts.

3.3 Data collection

The survey was administered online through a secure platform to maximize accessibility across devices. Participation was voluntary and anonymous. Respondents were informed about the study's purpose, and consent was obtained prior to completion. Data collection was carried out between March and June 2024.

3.4 Data analysis

The analysis proceeded in two stages. First, descriptive statistics were applied to summarize demographic information, AI adoption patterns, and the distribution of perceived benefits and challenges. Second, cross-tabulations and mean comparisons were performed to explore differences between subgroups (e.g., by role or country). In addition, open-ended responses were examined using qualitative thematic coding, allowing identification of recurring themes such as creativity support, ethical concerns, and institutional readiness.

This mixed quantitative–qualitative approach ensured both breadth and depth: statistical analysis enabled systematic comparisons, while qualitative insights enriched interpretation by capturing nuanced perspectives. The methodology thus provides a robust foundation for understanding how AI is currently perceived as both an enabler and a challenge in inclusive digital education.

4 Results

The survey provides detailed insights into how higher education teachers, researchers, and management staff perceive the integration of artificial intelligence (AI) in inclusive education. The findings are presented in terms of participant characteristics, patterns of AI adoption, perceived benefits for teaching and learning, inclusivity-related outcomes, and the main barriers that limit effective use.

4.1 Sample characteristics

A total of 200 respondents participated in the survey, comprising 109 females, 90 males, and one who preferred not to disclose gender. Most participants held more than one role, with 162 identifying as researchers, 125 as teachers, 60 as members of management, and 39 as other professionals. The largest institutional share came from a single university in Ukraine (n = 73), while additional responses were collected from a wide range of European higher education institutions.

Country-level data were reported by 166 participants. The majority came from Ukraine (97), followed by Spain (31), Slovenia (19), and Türkiye (19). Disciplines represented a broad spectrum of humanities, social sciences, and STEM, including fields such as philology, media studies, business, and design. Respondents also varied considerably in terms of teaching experience, with both early-career and senior professionals represented.

4.2 AI adoption, frequency, and tools

AI has already found broad uptake among academics. Of the 200 respondents, 138 reported using AI in their professional work, while 61 stated they do not, and one was unsure. Frequency of use was high: 49 respondents used AI daily, 81 several times a week, and 32 several times a month. Only a minority reported rare or no use.

General-purpose generative AI tools dominated, with ChatGPT cited by 165 participants. Other tools were used at lower levels, including Gemini (17), Copilot (5), Perplexity (4), Bard (4), Canva (4), GitHub Copilot (2), Wolfram Alpha (2), DALL·E (2), and Smodin (1). The most common academic applications included designing class materials (120), checking

knowledge (116), designing tests (105), conducting research for classes (74), scaffolding learning (62), and creating presentations (60). Specialized uses also appeared in domains such as nursing (50), programming (33), creative writing (31), and design (28)..

4.3 Perceived benefits for teaching

Educators consistently emphasized that AI supports teaching efficiency and quality. Respondents highlighted its usefulness in saving time through automated grading and plagiarism detection, enriching lesson planning by providing instant suggestions, and supporting curriculum development through the generation of teaching resources. Many also valued AI's ability to help create more diverse and inclusive materials, enabling them to better address student heterogeneity and accessibility needs.

4.4 Perceived benefits for students

Teachers generally agreed that AI enhances student learning through personalization, engagement, and improved outcomes. Respondents stressed that AI helps create more interactive and motivating environments via gamified exercises, quizzes, and simulations. Collaboration was another benefit, with AI tools enabling group work and interactive learning.

AI also supported study and research by helping students brainstorm, structure assignments, and synthesize large volumes of information. In addition, educators pointed to benefits for language practice and creative tasks, such as essay writing or script development. Overall, the consensus was that AI enables students to work more autonomously, while also complementing traditional teaching practices.

4.5 Benefits for inclusive education

Survey results confirmed that AI can act as a catalyst for inclusivity. Respondents highlighted four areas in particular: (i) accessibility, through tools such as text-to-speech, captioning, and alternative content formats; (ii) personalization, by adapting resources to specific learner needs; (iii) alternative communication, particularly for students with disabilities; and (iv) cultural and linguistic inclusivity, by enabling translation and adaptation of materials to diverse contexts. These findings indicate strong recognition of AI's role in supporting equity within higher education.

4.6 Challenges and barriers

Alongside optimism, participants expressed substantial concerns. Accessibility and personalization remain limited, as current tools often lack integration with assistive technologies and struggle to accommodate diverse disability profiles. Technical and financial barriers—such as high costs, interoperability problems, and infrastructure inequalities—were also widely noted.

Pedagogical risks emerged as another significant theme. Respondents expressed concern about student over-reliance on AI, erosion of critical thinking skills, and the potential for academic dishonesty. Ethical and privacy risks were frequently cited, with educators emphasizing the sensitivity of student data, risks of bias from non-representative training datasets, and the opacity of AI decision-making. Finally, some raised cultural concerns, warning that current tools may privilege Western perspectives and reduce meaningful human interaction in classrooms.

4.7 Training, resources, and governance

Across the sample, there was a strong call for systematic teacher training and AI literacy programs. Respondents emphasized that educators require not only basic familiarity with AI but also advanced training and ongoing professional development. Institutional support in the form of modern infrastructure, secure digital services, clear ethical guidelines, and transparent governance frameworks was likewise identified as essential for successful integration.

4.8 Student use and encouragement

Teachers reported that students are already using AI for tasks such as report writing, presentations, laboratory work, and creative assignments. Many educators encouraged this use, noting benefits such as time-saving, better organization, enhanced digital competence, and preparation for employment. Others, however, expressed reservations, particularly regarding plagiarism, uneven skill development, and the risk of over-reliance on AI-generated outputs.

5 Discussion

The survey findings provide an important snapshot of how higher education teachers, researchers, and management staff perceive the role of AI in inclusive education. Taken together, the results confirm both optimism about AI's potential to enhance teaching and learning and persistent concerns about infrastructure, ethics, and pedagogy.

5.1 AI as a supportive layer in academic practice

The high uptake of AI—particularly ChatGPT—demonstrates that generative AI has already become embedded in routine academic workflows. Teachers use it extensively for designing materials, preparing tests, and checking knowledge, while students rely on it for writing assignments, presentations, and laboratory work. This suggests that AI is increasingly perceived not as a novel experiment but as a practical tool that supports everyday academic practice. Importantly, respondents emphasized that AI should serve as a complement to human-led teaching rather than a substitute, aligning with human-centered and inclusive pedagogical principles.

5.2 Benefits for students and inclusivity

Respondents widely agreed that AI enhances student learning by providing personalized feedback, creating interactive experiences, and supporting research activities. Many highlighted its contribution to accessibility through captioning, text-to-speech, and adaptive content, which directly benefit students with disabilities. The ability of AI to adapt materials to different languages and cultural contexts was also seen as a strong enabler of inclusivity, allowing diverse student groups to participate more fully in learning. These findings underscore

AI's potential to bridge gaps in higher education, particularly for learners who might otherwise face systemic barriers.

5.3 Challenges and risks identified by educators

Despite this optimism, the survey also revealed widespread caution. Technical and financial barriers—such as high costs, infrastructure inequalities, and limited integration with assistive technologies—remain major obstacles. Pedagogical concerns were equally strong: respondents pointed to risks of over-reliance, reduced critical thinking, and academic dishonesty. Ethical challenges were identified as particularly pressing, with educators worried about student data protection, bias in training datasets, and opaque AI decision-making. Cultural issues, including the dominance of Western-centric perspectives and the potential reduction of meaningful teacher–student interaction, further complicate adoption. These concerns highlight that AI's benefits cannot be realized without systematic attention to governance, training, and inclusivity.

5.4 Implications for policy and practice

The findings suggest several directions for higher education institutions and policymakers. First, teacher training and AI literacy are critical to equip educators with the skills needed for responsible adoption. Second, institutional and national policy frameworks must provide clear guidance on ethics, privacy, and accountability. Third, targeted investment in infrastructure, assistive technology, and technical support is needed to avoid widening digital divides. Finally, inclusive design should remain central: AI tools must be evaluated not only for efficiency but also for their ability to promote equity, accessibility, and cultural diversity.

In summary, the survey shows that while AI is already reshaping higher education practice, its role as a driver of inclusive digital education will depend on deliberate strategies that combine technological innovation with pedagogical responsibility. Only by addressing the challenges identified by educators can AI become a sustainable enabler of equity in learning.

6 Conclusion

This study explored the perceptions of higher education teachers, researchers, and management regarding the role of artificial intelligence (AI) in inclusive digital education. Based on a cross-institutional survey, the findings highlight that AI tools are already widely used in academic practice, with general-purpose generative systems such as ChatGPT serving as the most common entry point. Educators acknowledged clear benefits for teaching and learning, including support for lesson planning, time savings, and enhanced student engagement. Students were seen to benefit through personalized learning, interactive materials, and accessibility features that reduce barriers for those with special educational needs and disabilities (SEND).

At the same time, the results underline significant challenges. Respondents emphasized technological and infrastructural barriers, the need for continuous teacher training, and ethical risks related to privacy, bias, and academic integrity. Concerns about cultural representation and the potential erosion of critical thinking further illustrate the complex environment in which AI adoption occurs. These limitations highlight that AI's transformative potential will only be realized if equity, inclusivity, and human-centered pedagogy remain at the forefront of its integration.

Looking ahead, three priorities emerge: (i) investment in AI literacy and professional development for educators, (ii) establishment of clear institutional and policy frameworks addressing ethics, transparency, and privacy, and (iii) targeted support for infrastructure and inclusive design practices to ensure equitable access. By addressing these priorities, higher education institutions can leverage AI not simply as a technological innovation but as a catalyst for building more adaptive, accessible, and inclusive learning environments.

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Mathematics and Critical Thinking in the AI ERA: Rethinking Classroom Practices

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Abstract

In an educational context, increasingly shaped by Artificial Intelligence (AI), mathematics plays a strategic role in fostering critical thinking and problem-solving within an inclusive framework. Moving beyond traditional approaches centered on formulas and mechanical procedures is, therefore, a pedagogical priority. This study implemented and analyzed two didactic proposals integrating AI tools into 120-minute problem-solving sessions with higher education students. The first session emphasized guided exploration of an AI tool, focusing on question formulation, answer analysis, and strategic use of keywords. The second involved group work with mental calculation supported by AI, where the assessment considered strategy, interpretation, and collaboration. Findings highlight increased student autonomy, improved problem-solving skills, and deeper critical engagement with AI in mathematical reasoning.

Keywords

Artificial Intelligence, Critical Thinking, Inclusive Education

1 Introduction

The COVID pandemic accelerated the digital transformation of higher education, highlighting the role of emerging technologies in teaching and learning. Among these, artificial intelligence (AI) has gained relevance for its potential to personalize learning, support assessment, and foster student autonomy, while also contributing to inclusive practices [17, 5]. However, many teachers face difficulties in adopting such tools due to limited training and the absence of clear competency frameworks [11].

In mathematics education, AI represents a strategic opportunity to enhance learning experiences [4]. Tools, such as ChatGPT and Microsoft Copilot, can operate as virtual tutors, offering explanations, feedback, and adaptive guidance that reinforce understanding of abstract concepts. More broadly, AI can support the development of higher-order skills, critical thinking, argumentation, and decision-making, considered central to 21st-century mathematics education [9].

This study examines the integration of ChatGPT and Copilot into statistical problem-solving tasks, with a focus on their impact on student autonomy, hypothesis formulation, and critical thinking in higher education contexts, aiming for total inclusiveness.

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2 Artificial Intelligence and Critical Thinking: Risks, Challenges, and Educational Implications

AI has emerged as a transformative tool with the potential to amplify cognition, personalize learning, and support decision-making [13]. Its integration in education benefits students and institutions, while fostering inclusion [18]. Yet its ubiquity raises concerns for critical thinking, a skill requiring interpretation and reflection [6]. Nevertheless, over-reliance on AI risks leads to the blind acceptance of answers, weakening autonomy and reasoning [1]. Trust in virtual assistants or predictive systems may foster passivity, while deepfakes further blur reality, spreading disinformation and eroding trust [7].

Educating people to use AI critically and ethically is urgent. AI literacy must promote questioning, awareness of bias, and reliance on diverse sources [8]. In education, AI should stimulate reasoning, not replace it. Tools such as ChatGPT and Copilot can act as cognitive mediators, enabling hypothesis testing, comparison of strategies, and feedback [15]. Combining human and AI assessments strengthens evaluation of critical thinking [19], aligned with critical mathematical literacy [16].

AI is built by humans, with subjectivity influencing data, algorithms, and applications [12]. Thus, responsibility remains central. Preparing students requires cultivating ethical and critical interaction with intelligent systems, ensuring AI becomes a collaborator rather than a substitute in developing autonomous, creative citizens [13].

3 Methodology

This study adopts a qualitative, descriptive, and exploratory approach to examine teaching and learning in mathematics education supported by AI tools. As Bogdan and Biklen [3] note, qualitative research focuses on meanings participants attribute to their experiences in natural contexts.

3.1 Description of Pedagogical Practice

This proposal was designed for two 120-minute sessions in a computer room with internet access. Its main objective was to foster understanding and application of hypothesis testing through an interactive, AI-mediated approach. The first session introduced the fundamentals of statistical inference. Students worked in small groups, beginning with an activity to explore their preconceptions, followed by a teacher-led discussion of core concepts:

null and alternative hypotheses (H_0, H_1), type I and II errors, significance level, test statistic, and p-value. ChatGPT and Microsoft Copilot supported this stage by reformulating textbook concepts, generating examples (including intentionally incorrect ones), and illustrating AI's role in interpreting statistical decisions. Students were encouraged to ask questions such as: (1) How do I know if I reject H_0? (2) What does a p-value of 0.03 mean? (3) Can the sample mean be used to reject H_0?

The first session introduced the statistical language of hypothesis testing and encouraged critical reflection on AI-generated answers. The second focused on applying this knowledge collaboratively, with groups analyzing data sets and addressing inferential questions such as:

- *Do school students sleep less than 7 hours a night on average?*
- *Is there evidence that the proportion of users satisfied with AI exceeds 60%?*

Based on the data provided, the groups had to: (i) formulate the null hypothesis (H_0) and the alternative hypothesis (H_1), (ii) define the appropriate significance level (e.g. 0.05), (iii) calculate or interpret the test statistic and p-value, (iv) make a reasoned inferential decision, (v) use ChatGPT or Copilot to confirm the reasoning and explore alternative explanations or validate the conclusions generated with AI support.

Throughout the process, the teacher took on the role of facilitator, circulating among the groups, promoting debate, answering conceptual questions, and encouraging comparison between their own resolution and the resolution proposed by the AI.

3.2 Practice Evaluation

The assessment was formative, guided by explicit criteria, which valued: (a) the correct formulation of hypotheses, (b) the appropriate interpretation of the p-value, (c) the apparent justification of the statistical decision made, (d) the critical and conscious use of AI tools (avoiding automatic or uncritical responses), (e) the clarity and rigor in communicating the results.

To organize the teaching practice, the teacher distributes three problem situations to the groups to work on the topic of Hypothesis Testing. The three problem situations include simulated data and clear questions, ready to be used either on paper or using ChatGPT and Copilot. The first problem situation deals with students' hours of sleep:

- *The aim is to find out whether students at a school sleep, on average, less than 7 hours a night. A random sample of 20 students was taken.*
- *Based on this data supplied, is there statistical evidence that students sleep less than 7 hours a night?*

Instructions given by the teacher: (1) formulate the hypotheses H_0 and H_1; (2) consider the significance level $\alpha = 0.05$; (3) use AI to calculate the p-value or compare it with the critical value; (4) decide whether or not to reject H_0; (5) justify your decision with the support of AI (you can ask ChatGPT or Copilot to run the t-test for this sample and interpret the result).

For the second Problem-situation (satisfaction with an AI app), the following statement was given:

- *"A company wants to know if more than 60% of users are satisfied with its new AI application."*

Instructions given by the teacher were the same as the previous ones.

For the third problem situation, the aim is for students to recognize that this is a hypothesis test for the difference between two means, for which the following statement is provided:

- *"Two groups of students used different methods to study statistics. Group A used only textbooks; Group B used AI as support (ChatGPT/Copilot). After a test, the results (out of 20 points)."*

The data to consider when solving the problem was given to the students, and the students were asked to search for:

- *Is there a significant difference between the means of the two groups?*

Instructions given by the teacher were the same as the previous ones.

3.3 Pedagogical Approach to the First Problem Situation - Students' Sleeping Hours

In this phase, the teacher contextualizes the first Problem Situation and addresses the students by stating:

- *Let's explore whether the students at our school sleep less than 7 hours a night.*

To do this, they should review the following key concepts: the difference between H_0 and H_1, the meaning of the p-value, the significance level (α), and whether the test is one-sided ($\mu < 7$). During the resolution, the teacher moves around the classroom and interacts with the students, actively mediating and making some observations:

- *Have you formulated the hypotheses?*
- *Why is this a one-sided test and not a two-sided test?*
- *Does the p-value you considered make sense in light of the sample mean?*

The teacher began by encouraging students to share strategies freely, fostering collaboration. Discussion then shifted to traditional resources for solving statistical problems. Though initially shy, students soon interacted, and one group presented its solution on the board. The teacher promoted debate by questioning other groups, leading to disagreements about the meaning of the p-value. Inviting an alternative answer, the teacher compared strategies until the class identified the most statistically sound result, highlighting the value of critical analysis. Finally, the teacher gave a guided talk on digital resources, introducing AI and its applications in research and problem-solving.

3.3.1 A practical introduction to the use of AI. The teacher presented two AI tools, ChatGPT and Microsoft Copilot, and explained their potential applications in pedagogy. The teacher demonstrated how to formulate transparent and objective questions, how to interpret and evaluate the answers provided by AI, and how they can support mathematical and statistical reasoning. The teacher conducted a practical example that helped students better understand how the technology works, promoting a critical, ethical, and responsible attitude in its use. The importance of using appropriate keywords when formulating AI questions was also stressed. The teacher also pointed out that vague or poorly structured questions can generate inaccurate or decontextualized answers. For example, instead of asking "lower mean" or "statistical test", it would be more effective and specific to ask:

- *Can you do a t-test to see if the sample mean is less than 7?*

The teacher also warned of the risks of excessively long and confusing questions, which make it difficult for the AI to understand. The teacher used the following inappropriate wording as an example:

- *"We have a set of data and we want to know if the mean can be considered statistically different from the mean of another school because the students sleep little, and we want to know if this is relevant and what to do with the data..."*

This intervention aimed to help students reflect on clarity and precision in mathematical communication, as well as to utilize AI tools as a support for critical thinking, rather than as a substitute for autonomous reasoning. The students are given some guiding questions to think about, about what to ask the AI:

- *Does AI understand everything at once, or should we divide our question into clear and objective parts?*
- *In statistical terms, how can we make our question clearer?*
- *How does AI identify keywords such as "p-value", "mean", "significance" or H_0?*

It is explained to the students that the keywords serve as clues for the AI, allowing the tool to select the appropriate statistical method (t-test, z-test, p-value, etc.) and correctly interpret the desired outcome. The lesson continues with some questions for the students, which serve to direct what they want to get from the AI:

- *Do we want to know if there are significant differences?*
- *Is the mean higher or lower than a certain specified value?*
- *Is the proportion different?*

After the theoretical explanation and the initial example, the teacher returned to the first Problem Situation, illustrating it with the statement:

- *I want to know if the students' mean number of hours of sleep is less than 7.*

In this context, he reminded students of the importance of using relevant keywords, such as "t-test", 'mean', "less than 7", and "p-value". The teacher then challenged the students to consider the most effective way to ask AI questions, supporting them in formulating more transparent and more precise questions. Examples of guiding questions included, *"what is the parameter we are testing?"*, *"what is the null hypothesis (H_0) and the alternative hypothesis (H_1)?"*, *"what is the mean value taking into account H_0?"*, *"What is the significance level (α)?"*, and *"what type of test is most appropriate (t, z, one-sided, two-sided)?"*. To support the organization of thought, the teacher also explained how to divide the questions progressively and gave examples of how to do implement it: *"What is the mean of the sample?"*, *"What is the value of the mean that we are going to test?"*, *"What is the sample size?"*, *"What is the alternative hypothesis?"*. Finally, the teacher presented a well-structured instruction:

- *Run a one-sided t-test on this data to see if the mean is less than 7. Consider $\alpha = 0.05$.*

3.3.2 Group Work and Interactions with AI. Each group selected a problem and, based on prior examples, formulated questions for the AI to obtain rigorous statistical answers. With the teacher's support and real-time projection, they saw how small changes in wording—such as shifting from one- to two-sided tests—could alter conclusions. While groups worked, the teacher circulated, reviewing hypotheses (H_0, H_1), checking test choices (t, z, one-/two-sided), guiding clearer questions for the AI, and ensuring correct interpretation of p-values.

3.3.3 Mediation of Difficulties and Collective Discussion. One of the groups showed additional difficulties, prompting the teacher to intervene, asking:

- *Is your alternative hypothesis consistent with the problem question?*
- *Does the p-value you obtained indicate evidence against H_0? Why?*

After completing the tasks, the class held a collective discussion based on the projected answers. To encourage reflection, the teacher asked questions such as:

- *What was the result of your sample? Was the mean less than 7?*
- *What was the value of the t-statistic and the p-value?*
- *What decision did you make? Did you reject H_0 or not?*
- *Do you think AI helped to better interpret the problem? Why?*

The teacher then projected an answer generated by the AI, previously selected as clear (or confusing), asking the students to assess its validity. One of the groups compared the AI answer with their own, concluding that they preferred their resolution because it was simpler and they understood the reasoning better. The teacher took the opportunity to emphasize that AI does not replace human statistical reasoning, but only supports it. To deepen the assessment of statistical understanding, the teacher issued a provocative challenge:

- *If the AI told you not to reject H_0 with a p-value of 0.02, what would you say?*

The group answered correctly, "if the p-value is 0.02 and the significance level is 0.05, then as $0.02 < 0.05$, we must reject H_0. There is sufficient evidence against H_0." The teacher continued to stimulate critical thinking with new questions:

- *What if the significance level was 1%?*
- *What if the sample had 50 students?*

The answers given by the group revealed a solid understanding: "If $\alpha = 0.01$, then $0.02 > 0.01$, so we don't reject H_0"; "with 50 students, the test would be more accurate. With more data, it becomes easier to determine if there is a real difference in sleeping hours."

3.3.4 Discussion on statistical errors and AI limitations. To assess understanding of type I and II errors, the teacher made the following comment:

- *In the problem situation of hours of sleep, if H_0 is true but the p-value is 0.03 and we reject H_0 with $\alpha = 0.05$, what kind of mistake have we made?*

Responses generated by AI for each group:

- Group I: Type II error, because we rejected H_0 even though it was true (they used ChatGPT).
- Group II: It could be a type I or II error, depending on the interpretation (they used ChatGPT).
- Group III: Type I error, because we rejected H_0 when it is true (they used Microsoft Copilot).

The teacher projected the three answers and asked the groups to evaluate them. Group III acknowledged that only their answer was correct. Group II insisted that theirs also made sense, but eventually recognized that the AI shouldn't give contradictory answers. Group I remained undecided. The teacher took the opportunity to explain that sometimes AI can present "hallucinations" or incorrect answers. The teacher again reminded the students that a Type I error consists of rejecting H_0 when

it is true and that a Type II error corresponds to not rejecting H_0 when it is false. Finally, it reinforced the importance of critical thinking, emphasizing that students with essential thinking skills can explain their reasoning, explore multiple resolution strategies, and critique fallacious arguments [10].

3.4 Assessment and Reflection on Learning with AI Support

The aim of learning assessment in this pedagogical practice was not only to verify the acquisition of statistical content, but above all to gauge the development of critical thinking and intellectual autonomy among students when interacting with artificial intelligence tools. To this end, a descriptive evaluation summary was drawn up, focusing on four key dimensions of the work carried out by the students in the context of solving statistical inference problems:

A - *Formulating statistical hypotheses - Aims to assess the ability to distinguish and correctly state the null hypothesis (H_0) and alternative hypothesis (H_1), as well as the choice of the appropriate statistical test.*

B - *Interpretation of Results - Observes the understanding of the p-value, significance level, and type I and II errors, as well as the coherent justification of the decisions made.*

C - *Use of Artificial Intelligence - Analyzes how students used ChatGPT and Copilot as tools for reasoning and supporting statistical thinking, distinguishing between passive and critical use.*

D - *Collaboration - Considers students' involvement in group discussions, their ability to explain mathematical strategies, and debate the answers generated using AI.*

This synthesis has been structured into three performance levels: beginner, intermediate, and advanced, allowing for continuous and reflective formative assessment. This approach aims to promote an assessment culture that is more in line with the cognitive demands of the digital age, where in-depth understanding and the ability to question are more valued than simply reproducing procedures.

4 Final Considerations

Students developed greater autonomy in problem solving, improved mathematical reasoning, and deepened critical awareness of AI. They enhanced question formulation and strategy selection, promoting more meaningful learning approaches aligned with AI use in class. These findings agree with Zhou et al. [20], who showed that generative AI fosters self-regulation and strengthens critical thinking. They also support Trikoili et al. [19], who advocate combining human and AI assessment. The practice highlights AI's transformative role in promoting critical thinking, as argued in [14], though requiring careful attention to ethical and technical challenges. Properly integrated, AI enables more personalized learning, benefiting teachers and students alike [2].

Using tools like ChatGPT and Microsoft Copilot in statistical inference, students rigorously formulated hypotheses, interpreted evidence, and critically reflected on AI's role. Autonomy, clarity of statements, and detection of AI errors improved—key indicators of critical thinking. This underlines the need for teacher training in pedagogical AI use, not as substitutes for thought but as mediators of mathematical dialogue and statistical literacy. Teachers should integrate self-regulation strategies to maximize AI's impact (Satone et al., 2025). Further research and curricular references are recommended to embed critical thinking as a transversal competence in mathematics teaching.

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Good Practices of AI Use: Case Studies from Türkiye

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Abstract

This paper presents three AI-supported good practices developed in Türkiye as part of the AI-Enable Erasmus+ project illustrating how artificial intelligence can support inclusive education in higher education. The practices were created during exploration workshops at Istanbul University-Cerrahpaşa with the involvement of academic staff and students. They focus on diverse areas, including academic writing support, inclusive language teaching materials, and accessible video content. The cases demonstrate that low-cost, open-access AI tools can be effectively used in pedagogical contexts to enhance digital creativity and address diverse learner needs. Participants reported increased confidence, engagement, and awareness of inclusive practices. However, challenges such as internet access, language limitations of tools, copyright concerns, and the need for ethical guidance were also noted. Overall, the findings show that the meaningful use of AI in inclusive education depends not only on technology itself but also on pedagogical design, ethical implementation, and institutional support.

Keywords

AI-Enable Project, Artificial Intelligence, Inclusive Education, Good Practices, Higher Education

1 Introduction

The integration of Artificial Intelligence (AI) into higher education offers new opportunities for inclusive, personalized, and student-centered learning. Adaptive learning platforms and intelligent tutoring systems enable students to receive individualized instruction and feedback [1]. Educators can create more flexible and inclusive learning environments that respond to diverse learner needs [2]. While the impact of AI on education remains a subject of ongoing debate, its potential to promote inclusion and improve educational outcomes is increasingly recognized [3].

In this context, the growing use of AI tools such as ChatGPT, Gemini, Napkin, and Canva highlights the importance of shaping education policies that prepare individuals for the future, developing flexible and accessible learning systems, and establishing guidelines for the ethical use of AI [4]. As part of the Erasmus+ supported AI-Enable Project, a framework, guidelines, and good practice examples have been developed to guide AI integration in higher education. This paper presents selected good practices from Türkiye to demonstrate how AI technologies can contribute to inclusive education through concrete, context-sensitive examples.

Inclusive education in higher education requires not only access to digital tools but also pedagogically grounded, ethically responsible, and learner-sensitive practices. However, without addressing challenges such as limited infrastructure and lack of teacher training, these practices cannot be effectively implemented [5]. The AI-Enable Project brought together universities from Slovenia, Spain, Portugal, and Türkiye to identify and document inclusive, AI-supported teaching practices. Through exploration workshops with academic staff, students, and researchers, ten good practices aligned with pedagogical value, scalability, and inclusive AI principles were developed.

This paper focuses on three selected examples from Türkiye, ranging from academic writing support to multimodal material design. These cases illustrate how AI tools can enhance inclusion in Turkish higher education. Grounded in real educational challenges and tested in classroom contexts, the case studies offer insights into the transformative potential of AI when implemented thoughtfully and intentionally.

2 Methodology

This study aims to present good practice examples of inclusive artificial intelligence applications implemented in higher education institutions in Türkiye within the scope of the AI-Enable Project. The three good practices featured in this paper were developed during exploration workshops held at Istanbul University-Cerrahpaşa. These workshops brought together academic staff, undergraduate and graduate students, and researchers to collaboratively develop AI-supported solutions addressing educational challenges related to inclusion.

Each good practice was structured around the following components:

- The identified inclusion challenge
- The AI tool(s) used
- The target student group and level of education

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- The expected or observed outcomes
- Reflections on the strengths and limitations of the tools.

The selected practices were analyzed not only in terms of their technical application but also regarding pedagogical coherence, sensitivity to learner diversity, and ethical awareness. These examples offer insights into how inclusive, AI-supported educational practices can be meaningfully and sustainably integrated into higher education institutions in Türkiye.

These workshops were supported by Istanbul University-Cerrahpaşa through access to computer labs, stable internet infrastructure, and institutional encouragement of AI experimentation. While no formal training program was in place, instructors provided informal peer support and curated prompts. These grassroots support mechanisms were essential in facilitating meaningful experimentation with AI tools.

3 CASE STUDIES FROM TÜRKİYE

3.1 AI-Supported Inclusivity in Academic Writing

This practice implemented at Istanbul University-Cerrahpaşa, aimed to enhance equity in academic writing processes. In exploration workshops attended by graduate and doctoral students as well as academic staff, tools such as ChatGPT, Gemini, Scispace, Perplexity, and Consensus AI were used to support academic productivity. Participants utilized these tools for literature review, theoretical framework development, qualitative data analysis, and academic writing.

The initiative particularly aimed to alleviate barriers experienced by non-native English-speaking researchers, including language difficulties, time constraints, and limited access to academic resources. Through prepared prompt templates and sample contents, participants learned how to use AI tools ethically. At the end of the process, participants reported feeling more confident and productive; however, they also highlighted the need for more guidance on ethical use and sustainable access to AI tools.

3.2 Using AI Tools to Create Inclusive Worksheets and Audio Materials for Pre-Service Language Teachers

This good practice aimed to support English language teacher candidates in producing inclusive instructional materials for students with diverse learning styles. Participants created reading and grammar exercises aligned with CEFR levels using ChatGPT and Gemini and generated natural-sounding audio content with text-to-speech (TTS) tools such as Murf.ai, Play.ht, and ElevenLabs. Canva and Piktochart were actively used in the design of visual materials.

The resulting materials were diversified to address auditory, visual, and kinesthetic learning preferences. Accessibility was enhanced by providing audio content via QR codes. As a result of the practice, the teacher candidates gained valuable skills in using AI tools both creatively and pedagogically. Challenges included dependence on internet connectivity and limited experience in effective prompt engineering.

3.3 Using AI Video Tools to Create Inclusive Language Learning Materials

This practice conducted with pre-service English language teachers, focused on producing diverse and inclusive video content. Participants developed scenarios using ChatGPT and Gemini and transformed them into avatar-supported videos through tools such as Fliki, Pictory, and Synthesia. Audio components were created using Murf.ai and Play.ht, while Canva and Bing Image Creator were used for visual design.

The practice aimed to create accessible learning environments for students with learning differences such as dyslexia, attention deficit, and hearing impairment. Participants took active roles in planning, producing, and evaluating content through group work, which helped them enhance both their digital creativity and awareness of inclusivity. Feedback indicated that the activity strongly supported motivation and creativity but also revealed a need for further guidance on copyright issues and content verification.

4 CONCLUSION

The three good practices presented in this paper demonstrate how artificial intelligence can be meaningfully and creatively utilized to support inclusive education in higher education in Türkiye. Common features across the cases include the pedagogical integration of low-cost, open-access tools; the enhancement of digital creativity among both teachers and students; and a systematic sensitivity to diverse learner profiles.

These case studies highlight that AI tools are not merely technical solutions but pedagogical instruments that invite educators to rethink teaching and learning processes. Active participation by students and instructors enabled shared responsibility, critical reflection, and greater teacher autonomy. In this context, the AI-supported creation of learning materials not only enhanced accessibility but also increased learner engagement, motivation, and participation.

At the same time, the implementations revealed several challenges. Issues such as reliance on stable internet access, the linguistic limitations of AI tools, concerns over copyright and content accuracy underscored the need for institutional measures to ensure ethical and sustainable integration. Moreover, it became evident that teachers require more structured guidance, exemplary practices, and professional development opportunities to use AI effectively within pedagogical settings.

In conclusion, this study illustrates both the potential and the critical considerations of using AI to foster inclusive education, through three concrete examples from Türkiye. These practices may inspire not only local efforts but also broader initiatives across higher education contexts in Europe. These practices, while developed in a local university context, offer a scalable framework that can be adapted to different higher education institutions. Their emphasis on low-cost tools, participatory design, and contextual relevance makes them suitable for replication across diverse educational settings. For AI to play a meaningful role in inclusive education, it must be embedded in pedagogically sound, ethically grounded, and participatory approaches—beyond mere technological availability.

Further research is needed to evaluate the long-term impact of AI-supported inclusive practices on student outcomes.

Comparative studies across different universities or cultural contexts may offer additional insights into best practices for scaling and adapting these approaches. Developing institution-wide policies that ensure ethical use and sustainable infrastructure will also be essential in the coming years.

Acknowledgments

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Good Practices in AI Use: Case Studies from Spain

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Abstract

This paper presents the outcomes of the implementation of artificial intelligence (AI) tools during co-creation workshops conducted within the framework of the Erasmus+ project AI-ENABLE – Enhancing Inclusive Education in Higher Education Institutions with Artificial Intelligence. Two case studies - one from the Faculty of Social and Human Sciences and the other from the Faculty of Engineering, both from University of Deusto, Spain - are examined to illustrate how the integration of AI-driven tools can enhance inclusivity and transform traditional classroom environments. The findings underscore the need for future higher education practices to prioritize the long-term implications of AI, the development of comprehensive AI literacy programs, and the adoption of innovative pedagogical strategies aimed at fostering inclusive learning environments.

Keywords

AI tools, inclusive digital education, higher education, good practices, case study, personalized learning**.**

1 Introduction

Although the potential of artificial intelligence (AI) in education is broadly acknowledged [1, 2, 3], the study on its practical implementation and alignment with inclusive pedagogical practices remains underdeveloped. This paper addresses this gap by critically examining AI tools, assessing their applicability to inclusive education, and implementation it in the real higher education classroom setting. Furthermore, the study presents findings from institutional pilot projects conducted with co-creation workshop approach. By integrating these dimensions, the authors provide a comprehensive overview of AI-supported inclusive education and offer evidence-based recommendations for higher education institutions (HEIs), policymakers, and educators to promote the equitable and ethical integration of AI in teaching and learning.

The paper consists of four sections. Section 2 provides an overview of AI tools and their potential to enhance inclusive higher education. Section 3 outlines the structure, content, and outcomes of the co-creation workshop, which explored both the benefits and barriers to adopting AI in university classrooms. The implementation of AI tools is described in detail through two specific use cases. Finally, section 4 concludes with key insights regarding the implementation of AI-driven tools, based on the two use cases from the University of Deusto, Spain.

2 State of-the-art of Inclusive AI

Artificial intelligence (AI) tools in education have demonstrated considerable potential to enhance student involvement, streamline administrative processes, and enrich overall learning experiences. To explore the current landscape of educational AI applications, a comprehensive web-based review was conducted under the AI-ENABLE project's task *State of the art analysis of AI technologies and tools and their integration in education*. This review involved the identification, documentation, and classification of a wide range of AI tools relevant to educational settings. Each tool was analyzed according to the technology, potential application, and licensing model. The tools identified span various domains, including programming support, media processing, chatbot interactions, and research facilitation, with licensing options ranging from free access to subscription-based services. This mapping activity was completed in September 2024 [4]

The rapid and continuous development of AI technologies is the reason why the collection of outcomes presented in AI-ENABLE is not complete and could be already out of date. As such, it is imperative that educators and institutional stakeholders remain proactive in monitoring and evaluating emerging AI tools to ensure alignment with the evolving needs of modern, technology-enhanced education.

Inclusive education, as a foundational principle of equitable learning, ensures that all students, regardless of their abilities, backgrounds, or learning preferences, have access to meaningful and effective educational opportunities. AI-powered tools represent a transformative approach to inclusive pedagogy, enabling educators to create adaptive, accessible, and personalized learning environments. These tools support differentiated instruction, assistive learning technologies, and

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enhanced student engagement strategies, thereby fostering inclusive classroom practices.

Figure 1 illustrates the interconnection of various categories of AI tools and their contributions to inclusive course delivery. Below, selected examples of AI-driven tools that support inclusive education are presented.

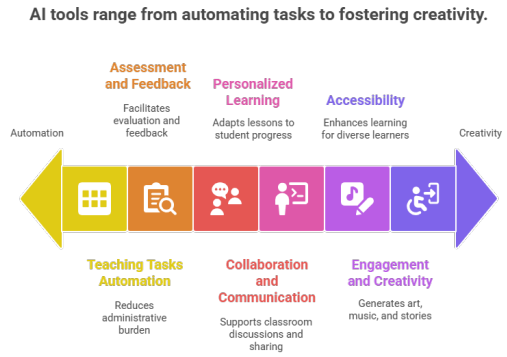

Figure 1: Using AI Tools for Inclusive Education (*created with Napkin.ai*)

2.1 Teaching Tasks Automation

AI tools help minimize administrative burdens and promote professional development for educators by supporting tasks such as grading, scheduling, and lesson planning (TeacherMatic, Teachology AI, TeacherDashboard.ai); proposing diverse and accessible materials (SALLEY, CourseGenie); offering inclusive best practices (Educator Lab, Almanack); providing AI-powered classroom management (AITeacha, Interflexion).

2.2 Assessment and Feedback

AI-powered assessment tools facilitate evaluation and feedback by designing quizzes from lessons or videos (Quizgecko, Yippity, Conker, Video2Quiz); creating customized tests and activities (MagicSchool, ClassPoint AI, TeacherToolsGPT); enhancing writing (Grammarly, QuillBot, Bard); summarizing research (PaperBrain, Scholarcy); ensure fair evaluation through detecting plagiarism and automating grading (Smodin, formative); tracking student performance and tailoring interventions (TeacherDashboard.ai).

2.3 Personalized Learning

AI-driven tutoring tools like ChatGPT, Claude AI, YouChat, and AcademicGPT offer continues personalized support, helping students grasp complex concepts at their own pace. Cognimates AI, Perplexity AI, and Ai Tutor self-direct students by guiding problem-solving. Carnegie Learning and Docebo platforms assess student progress and adapt lessons, while Moodle's AI plugin creates dynamic assessments. Flint, MyLessonPal, and CourseMind assist educators in managing personalized learning effectively.

2.4 Collaboration and Communication

AI supports communication and collaboration in the classroom by facilitating discussions & knowledge sharing (Claude AI, Socrates.ai); converting materials into flashcards and conversations (Jungle.ai, ChatPDF); assisting multilingual lessons (Polyglot Media); generating grasping presentation (Canva, MagicSlides, SlidesAI, Genially).

2.5 Accessibility

AI tools enhance accessibility for diverse learners by offering: text-to-speech, translation, and sign language interpretation (e.g., DeepL, Alexa/Siri, Google Assistant); AI-driven summarization and voice interaction for reading difficulties (e.g., Semantic Reader, TalkingPDF, AudioPen); text-to-audio conversion for visual impairments and dyslexia (Listening, Audioread, Amberscript); complex-to-simple texts for cognitive challenges (Diffit, Eduaide); lecture transcription for hearing impairments (Otter, Fireflies).

2.6 Engagement and Creativity

AI tools improve engagement and equip diverse learning styles through generating art and visualizing concepts (Midjourney, DALL-E, Canva, Napkin.ai, etc.); creating music or listening AI-generated explanations (MusicLM, Audiosonic); converting text to video for abstract topics (Fliki, HumanPal); AI-powered storytelling (StoryBooks); gamified interactive quests (Adventure AI, Gamify Learning, Kiwi Video).

Therefore, AI-powered tools are streamlining and transforming education by delivering personalized learning experiences, simplifying administrative tasks, and handling inclusivity. Through adaptive and emerging learning technologies, accessibility features, and dynamic content creation, these tools provide tailored support for diverse learners, helping to create an inclusive and effective educational environment.

3 Co-creation Workshop: Exploration of AI Tools for Pedagogical Innovation

A co-creation workshop including three sessions was implemented at the University of Deusto, Spain. The initial session introduced the AI-ENABLE project, outlining its goals, objectives, target audience, and overall structure. Participants engaged in a critical analysis of the benefits, challenges, and barriers associated with the integration of AI-driven applications in educational settings [5]. The second session focused on the principles of Universal Design for Learning (UDL) [6] and its application within engineering higher education. The AI-ENABLE scenarios illustrating the use of AI tools to support inclusive teaching practices in engineering classrooms were presented. Participants then began developing their own scenarios for integrating existing AI tools into their respective courses. Over the following weeks, these scenarios were implemented and tested in classroom environments. In the concluding session, educators met again to share, reflect upon, and discuss the outcomes of their designed scenarios.

3.1 Use Case 1: Community Service Study

This case was incorporated into a Community Service Study within the Social Work Degree program. 15 second-year students from diverse academic disciplines, including Psychology, Engineering, and Business, all of whom have chosen a community service pathway participated in the study. The implementation plan for integrating AI tools was designed to

address two primary objectives: (1) *student support*, by enhancing reading comprehension and providing tailored accommodations for a student with special needs; and (2) *community engagement*, by facilitating effective communication with diverse populations, including older adults, immigrants for whom Spanish is a second language, and individuals with intellectual disabilities or cerebral palsy.

In the "Social Engagement and Values" course (FAV, 2nd year) of the Social Work Degree, Grammarly for writing feedback, Napkin for visualizing content and ideas, Anki for creating the game-based learning approach, Ginger for sentence restructuring, and Voiceitt for supporting individuals with atypical speech were applied.

Napkin (https://www.napkin.ai/) enhances and adapts diagrams, visualizes teachers' notes and creates engaging class presentations. This tool allows for dynamic and intuitive diagramming, enabling instructors to refine complex concepts, tailor visual content to diverse learning needs, and foster deeper student understanding. Integrated into instructional practice, Napkin allows teachers to:

- Adapt diagrams to align with lesson goals and diverse learning styles.
- Visualize notes by converting content into clear, engaging formats that aid retention.
- Create presentations with accessible, interactive slides supporting varied learner needs.

Napkin improves the clarity and accessibility of educational materials, contributing to a more interactive and inclusive learning environment.

Voiceitt, (https://www.voiceitt.com/) is an inclusive voice AI tool designed to support both knowledge acquisition and the development of interpersonal competencies essential for meaningful and inclusive community engagement. The tool translates atypical speech into standard, intelligible speech, thereby enhancing communication accessibility.

Initially, Voiceitt was employed to process video testimonies from diverse community members, including older adults, individuals with cerebral palsy, and newcomers facing pronunciation challenges that contribute to language barriers. Subsequently, it was integrated into live conversations with these groups. These interactions offer students valuable insights into the lived experiences, perspectives, and specific needs of marginalized populations, thereby fostering empathy, awareness, and social sensitivity. This experiential learning activity equips students for effective engagement with similar communities throughout their academic and professional practice. Voiceitt contributes to the following learning outcomes:

- *Deeper understanding:* Community narratives offer practical insight into inclusion, accessibility, and communication.
- *Improved empathy and communication:* Exposure to authentic voices fosters respectful, effective interaction with diverse individuals.
- *Professional readiness:* Builds cultural competence and key skills for ethical, impactful community service.

Ginger (https://www.gingersoftware.com/) is an AI-driven writing assistant designed to correct grammar, enhance stylistic quality, and provide context-sensitive language refinements. It was implemented to support students in improving reading comprehension and to assist learners with dyslexia by simplifying complex language and elucidating challenging terminology. For example, Ginger deconstructs abstract vocabulary such as "commitment," which may be conceptually advanced or contextually nuanced for certain students.

The integration of Ginger into the educational process has facilitated comprehension of reading materials, understanding of abstract and sophisticated terms, and increased learner confidence in both reading and writing tasks. It was noted that by offering precise explanations and alternative phrasings, the tool has enhanced accessibility to academic texts, thereby promoting deeper cognitive engagement and critical thinking while mitigating frustration and supporting sustained interaction with course content.

Anki (https://apps.ankiweb.net/) is a flashcard-based learning tool that supports knowledge retention through repetition, expression, and practice. In the classroom, it effectively presents key terms and concepts using spaced, randomized repetition, engages students with interactive flashcards that reinforce understanding, supports language development by enhancing vocabulary through structured review and promotes systematic learning and reinforces core concepts in an accessible format.

Grammarly (https://www.grammarly.com/) supports a self-directed writing process by providing students with personalized, AI-driven feedback. Students begin by reviewing their own diary entries or notes and identifying areas for improvement. During class, they participate in peer review sessions, exchanging feedback to refine their ideas and strengthen arguments. After incorporating peer suggestions, students use Grammarly independently to polish their work -improving grammar, clarity, logical flow, and overall coherence.

This iterative process fosters continuous writing improvement. The final activity involves a structured key-sharing session, where students present their revised texts and reflect on their learning progress.

3.2 Use Case 2: Software Process and Quality

Engineering lectures traditionally depend on text-heavy slides, monochromatic diagrams, and code examples. The main objective of AI-driven tools adoption was to enhance the visual aspect of these lectures for Software Process and Quality subject. Many concepts within Agile methodologies and DevOps tools—requiring thorough understanding—are often represented through graphical elements such as boards and charts. Consequently, it is essential to employ tools that provide descriptive access to these visuals for learners who rely on reading/writing accommodations and for students with visual impairments. Additionally, efforts should be directed towards disrupting the predominance of textual content by integrating concise, synthesized charts that are also accessible through descriptive means for blind individuals. The AI tools selected to achieve the objectives were Microsoft Seeing AI, CLIP interrogator, Napkin.ai, GitHub copilot and ClickUP. The testing protocol included:

1) To explain a SCRUM's burndown chart, the CLIP Interrogator tool was used by importing the SCRUM's burndown chart into it. The resulting prompt — "a bar chart with the words sprint burndown chart, only with blue, rutkowski |, retaildesignblog.net, agile, unique features, desk fan, steps 50, oddly familiar, centered in image, wotc, very accurate coherent

image, uplifting mood, enterprise workflow engine, absolute chad, burn, ux" - failed to accurately capture the chart's essential information. This demonstrates the tool's limitations in interpreting data-driven visuals, requiring a more refined prompting strategy.

2) Importing the burndown chart into ChatGPT and using the prompt 'explain this burndown chart' produced sufficient and adequate results. Hence, ChatGPT provided clear and insightful feedback, beginning with the 'Key Takeaways':

a) *Consistent Work Done*: The team is reducing work at a steady rate (5 points per iteration).
b) *Remaining Work Trend*: The team appears slightly behind the ideal burndown line.
c) *Project Completion Prediction*: If the team continues at this pace, they may need extra time to complete all the planned work.
d) *Actionable Insights*: The team can assess whether they need to adjust workload distribution, increase velocity, or modify sprint goals.

3) ClickUp, proved to be a valuable tool in the classroom, particularly during lessons on Agile project planning. Collaborative work is a key component of engineering education, involving role definition, task planning, and progress tracking—areas where ClickUp was effectively utilized. Students shared their projects with the instructor, enabling real-time monitoring of their progress. This visibility helped identify groups facing difficulties, allowing for timely intervention and support. Additionally, the Trello-ClickUp integration streamlined workflow by automatically generating ClickUp tasks from new Trello cards, ensuring synchronization across multiple teams.

4) Napkin.ai was used to generate diagrams, graphs, and visual explanations to enhance the slides used in previous courses. For instance, Figure 2, generated for the SCRUM unit, provides a good slides' summary.

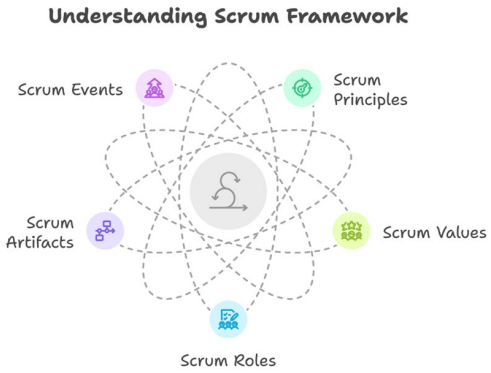

Figure 2: Using AI Tools for Inclusive Education (*created with Napkin.ai*)

5) Seeing AI: Talking Camera for the Blind was tested to help students with visual impairments receive descriptions of classroom activities and better understand the education charts through clear and detailed narration. This app is available on the App Store and Google Play. Furthermore, this tool can supplement traditional screen readers such as JAWS and/or Narrator.

6) Students integrated GitHub copilot into their learning programming workflow, thus receiving support for various coding activities.

As a summary, lecturers found these tools beneficial for ability to make learning more interactive, breaking the monotony of passive lectures. These brief interruptions help sustain attention, reinforce content, and keep students engaged. It is also important to show that generative AI can enhance learning without encouraging passivity.

3.3 The teacher's voice

The following testimonies reflect the overall positive experience provided by lecturers. *"I find beneficial" ... "their ability to foster presence, participation, and learning-driven empowerment… Spanish versions availability is a significant advantage"; "the available for each variety task allows students to choose the best fit for their individual needs and work/learning styles"; "the easy and intuitive usage of these tools"; "help many students grasp complex topics and conceptual relationships". "However, I have concerns regarding "AI tools, specifically regarding intellectual property rights, data privacy, and the implementation of subscription fee after an initial period of user engagement"; "that students rely too much on AI, substituting it for their own effort and hindering independent learning"; "data privacy is a concern for me. Where does the information go? It's quite sensitive. What about the rights to my information?"*

"At the beginning of the session, I was reluctant about using AI in the classroom. However, I have now changed my mind."

4 Conclusion

This paper presents two use cases implemented during co-creation workshops at the Faculty of Social and Human Sciences and the Faculty of Engineering at the University of Deusto, Spain. It highlights the transformative role of AI-driven technology in higher education, promoting inclusivity through personalization, accessibility, and ethical practices. During the AI-ENABLE workshop sessions, selected AI tools were tested and piloted in classrooms. As a result, educators reported significant benefits from AI integration; however, they also identified key challenges such as algorithmic bias, ethical concerns, and unequal access. These risks can be mitigated through AI literacy training, transparent policies, and continued human oversight in AI-assisted learning. Addressing these issues will require collaboration among educators, policymakers, technologists, and researchers.

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Digitalna vključenost v informacijski družbi

Digital Inclusion in Information Society

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