



A MOOC-INTEGRATED DESIGN THINKING MODEL FOR HEARING-IMPAIRED LEARNERS

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ABSTRACT

Aim/Purpose	This study aims to introduce an innovative approach to improving learning outcomes for hearing-impaired learners (HL) within inclusive education settings. By integrating design thinking principles into Massive Open Online Courses (MOOCs) specifically designed for HL, this research seeks to address their unique educational needs. The study examines the components of a design thinking model within MOOCs for HL and evaluates the effectiveness of the pilot course in enhancing their learning experience and achieving the required test scores.
Background	The persistent educational disparities faced by HL necessitate innovative solutions within inclusive education. By employing a design thinking approach, educational tools were developed specifically for these learners, with the empathy phase profoundly understanding and addressing their unique needs and desires. This study aims to bridge this gap by leveraging design thinking principles and MOOCs tailored for HL alongside instructional strategies and Universal Design for Learning (UDL) techniques.
Methodology	The study unfolds in three primary phases: Model Development, Model Assessment, and Model Piloting. In the Model Development phase, design thinking principles are integrated with Thai MOOC development, instructional strategies, and UDL techniques to create the initial model. The Model Assessment phase involves expert evaluations to validate and refine the model based on their feedback. Finally, in the Model Piloting phase, the refined model is tested with learners, and assessments are conducted to evaluate its practical applicability and effectiveness in a real-world setting.
Contribution	This research contributes significantly to reducing educational inequalities and advancing inclusive education. By introducing a model that integrates design

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	thinking principles into MOOCs tailored for HL, it promotes lifelong learning opportunities and aligns with broader societal efforts to address educational disparities.
Findings	Key findings from the study include the development of a comprehensive six-stage model and its essential co-components, which received high suitability ratings from expert evaluations. The model's application resulted in an impressive pass rate among learners, highlighting its effectiveness in enhancing learning outcomes. These results demonstrate the model's potential to impact inclusive education significantly by providing a scalable and effective framework for integrating design thinking into MOOC development. Furthermore, it creates courses that effectively meet the diverse needs of learners, ensuring accessibility and improved learning experiences for all.
Recommendations for Practitioners	Practitioners should adopt design thinking and UDL principles in MOOC development, ensuring courses are tailored to HL needs. Engage HL communities for relevant feedback and focus on accessibility with assistive technologies. Implement scalable solutions for broader impact and regularly assess course effectiveness to promote lifelong learning opportunities.
Recommendations for Researchers	Researchers should continue to explore and refine the developed model, considering its application across diverse educational contexts and populations. Collaboration with HL communities and stakeholders can provide valuable insights for enhancing the effectiveness of inclusive education interventions.
Impact on Society	The integration of design thinking principles into MOOCs tailored for HL has a profound impact on society by promoting equal educational opportunities and lifelong learning. By addressing educational disparities, this research contributes to creating a more inclusive and equitable society.
Future Research	Future research could focus on longitudinal studies to assess the long-term impact of the model for HL. Additionally, exploring innovative technologies and pedagogical approaches can enhance the effectiveness of inclusive education interventions. Collaborative research efforts across disciplines can advance the field of inclusive education and foster continuous improvement in learning outcomes for diverse populations.
Keywords	MOOC, design thinking, digital media, hearing-impaired learners

INTRODUCTION

Thailand 4.0, an economic strategy aimed at transforming Thailand into a high-income, innovation-driven economy, emphasizes sustainability and social equality (Wittayasin, 2018). Education plays a critical role in this transformation, significantly impacting social inequality and serving as a foundation for individual development and societal quality (Weerapan & Thinsandee, 2021), essential for achieving Thailand 4.0's goals. Therefore, access to education, particularly for individuals with disabilities, must be prioritized as it is fundamental to reducing inequality and promoting an inclusive society. In March 2023, Thailand had 2,180,178 individuals with disabilities and 405,920 hearing-impaired individuals. Among them, there were 4,543 hearing-impaired learners (Department of Empowerment of Persons with Disabilities, 2023). One problem is that their hearing impairments may hinder their access to online education and the ability to benefit from online learning resources like individuals free from disabilities (Meeanan, 2021). Hearing-impaired learners face significant challenges in online learning due to the lack of captioning, unclear audio, absence of translation and speech-to-text services, and inadequate visual materials. Addressing these issues is essential for

improving their education, highlighting the need for more accessible and effectively designed learning materials (Aljedaani et al., 2023). They continued to produce lower learning outcomes compared to their non-disabled peers, with a gap of up to 50% in academic achievements between the two groups of the same age range, as indicated by the results of learning measurement and evaluation in school (Thongprapan, 2018). Hence, there is a need for specific research to design and develop an online learning course tailored to hearing-impaired learners' needs. Highlighting the benefits of Massive Open Online Courses (MOOCs), these platforms offer affordable, location-independent education on a variety of topics from experts, supporting self-paced learning and continuous skill growth while connecting a global community through modern teaching methods. Their open and massive nature can help overcome inclusion barriers for learners worldwide, including hearing-impaired learners, other individuals with disabilities, the elderly, and foreign students. Accessibility requirements must consider the diverse needs, preferences, skills, and situations of learners and be integrated into the design and implementation of MOOCs' interfaces, content, and learning/assessment activities (Sanchez-Gordon & Luján-Mora, 2020). Therefore, MOOCs have the potential to enhance inclusive education greatly by providing accessible learning opportunities for a diverse range of learners. Proper implementation and consideration of accessibility needs, specifically tailored for hearing-impaired learners, are essential to ensure that these platforms can effectively support all students. Currently, extensive research is being conducted to create digital online lessons on MOOCs for hearing-impaired learners, such as the combination of MOOCs with sign language automatic translation technology (Sign Language MOOCs) for Deaf Learners (Escudeiro & Gouveia, 2023), and studies on developing video learning for hearing-impaired students through MOOCs (Ibrahim, 2020).

Furthermore, to provide education effectively and enhance the learning experience for hearing-impaired individuals, there is a need to formulate a model with specific guidelines for online course creation. Design thinking, a human-centered framework, can be instrumental in addressing this challenge. As a widely recognized framework for applying design principles to various challenges (Meinel et al., 2011; Sriwisathiyakun, 2023), design thinking emphasizes identifying and empathizing with the target audience, understanding their issues, and crafting solutions tailored to their needs. This approach helps establish practical learning guidelines and addresses the most pertinent educational needs among learners (Sriwisathiyakun, 2024). Therefore, integrating the concept of design thinking with other relevant concepts can facilitate the development of media innovation that genuinely addresses learners' needs and provides lifelong learning opportunities for this group of learners (Lugmayr et al., 2014). An exemplary application of this approach is seen in designing learning tools for hearing-impaired elementary students at SLB-B Santi Rama in Indonesia. By understanding their needs, defining goals, ideating with stakeholders, and prototyping an arcade game with word cards, significant improvements in language comprehension were achieved. This study demonstrates how design thinking can create educational tools effectively for hearing-impaired students (Suzianti & Atthousi, 2019).

Based on a review of the literature, it has been found that the concepts of MOOCs and design thinking are often used separately to enhance the educational outcomes of hearing-impaired learners. However, there is a lack of clarity regarding the integration of MOOCs, design thinking, and related learning theories into a cohesive model or framework. Developing an integrated model would provide a comprehensive blueprint for creating online courses specifically for hearing-impaired learners. This integrated approach would maximize the benefits and advantages of each concept, ultimately offering the greatest benefit to hearing-impaired learners. This study aims to construct a MOOC-integrated Design thinking model for developing educational digital media for hearing-impaired learners. The anticipated findings are expected to present a model optimized for the educational needs of hearing-impaired learners, enhancing their academic outcomes. Moreover, the proposed model will promote lifelong learning by providing hearing-impaired learners with access to knowledge anytime,

anywhere, thereby reducing inequality. The model also offers opportunities for both formal and informal education, reflecting the evolving nature of the education system in Thailand. The research questions are twofold:

- RQ1:** What constitutes a MOOC-integrated design thinking model for hearing-impaired learners?
- RQ2:** Does the implementation of this model in a MOOC-based course enhance learning and help learners achieve necessary test scores?

LITERATURE REVIEW

To address the research questions on a MOOC-integrated model for hearing-impaired learners, a systematic literature review has been conducted. This includes defining the scope, searching relevant studies using terms like “MOOC,” “design thinking,” “hearing-impaired learners,” and other terms relevant to the research questions, extracting data, synthesizing findings, and compiling the results in the following sequence.

DESIGN THINKING

Design thinking is a process used widely for developing innovative solutions based on a human-centered approach to design, which focuses on the individual as the center of the design process. This process was popularized by the Institute of Design at Stanford, also known as the Stanford D. School (Meinel et al., 2011).

Design thinking is a new designer’s approach that combines creativity and empathy to create innovative solutions (MJV Technology and Innovation, 2022). In practice, the design process involves a structured framework of actions to identify problems, collect data, generate possible solutions, refine ideas, and test those solutions. In education, design thinking can be applied flexibly as a framework for curriculum design, a roadmap for activities, or a guide for group projects (Teaching and Learning Lab, Harvard Graduate School of Education, n.d.).

Design thinking differs from other instructional design approaches in that it takes a human-centered design method, prioritizing the learner or user, considering them as a complete individual rather than a passive recipient of information. The use of empathic design in design thinking keeps the focus on the learner experience throughout the design process. This approach can be applied to creating instructional media to meet the needs of all learners, including those with specific requirements or who require additional support.

The application of design thinking has proven to be highly effective in developing educational tools and systems for hearing-impaired learners. Research conducted on a class assistance system for hearing- and speech-impaired individuals demonstrated enhanced learning satisfaction by following the five steps of design thinking (Lo et al., 2019). In Indonesia, a study addressing the lack of educational accommodations for hearing-impaired elementary students used design thinking to create an arcade game with word cards, significantly improving visual receptive and expressive language comprehension (Suzianti & Atthousi, 2019). Another study on virtual classroom design for deaf students highlighted the role of cloud computing and collaborative design thinking in creating effective learning environments (Maukar, 2021). These studies collectively demonstrate that design thinking can effectively address the unique needs of hearing-impaired learners, enhancing their learning outcomes and overall educational experience.

Design thinking is a non-linear, reproducible process based on the five-step model proposed by the Hasso Plattner Institute of Design at Stanford (2005). This model includes the following stages: (1) Understanding User Problems, (2) Interpreting and Defining Problems, (3) Brainstorming Creative Solutions, (4) Prototyping, and (5) Testing.

In this study, to create a model for innovative educational digital media development for hearing-impaired learners, design thinking components were gathered, selected, and adapted. The data used in the synthesis involved several design thinking models, including the fundamental design thinking process (Hasso Plattner Institute of Design at Stanford, 2005), the five-step instructional design thinking (Cypher Learning, n.d.), the implementation of design thinking in education (Harvard Graduate School of Education), the application of design thinking tools to solve complex problems (MJV Technology and Innovation, 2022), the Double Diamond design process (Ball, 2019), and the combination of design thinking with instructional design (Ní Shé et al., 2021). Components from the mentioned models were considered, and those deemed suitable for this model's development were used, as demonstrated in Table 1.

Table 1. Synthesis of components of design thinking

Methods	Meinel et al. (2011)	Cypher Learning (n.d.)	Teaching and Learning Lab, Harvard Graduate School of Education (n.d.)	MJV Technology and Innovation (2022)	Ball (2019)	Ní Shé et al. (2021)	Model components findings
Course Requirements						✓	Course Requirements
Empathy	✓	✓		✓		✓	Analysis with Empathy
Discover			✓		✓		
Analysis				✓			
Define	✓	✓			✓	✓	
Interpret			✓				
Synthesis				✓			
Ideate	✓	✓	✓	✓		✓	Ideate
Develop					✓		Prototype
Prototype	✓	✓	✓	✓		✓	
Test	✓	✓	✓	✓		✓	Evaluate
Implement				✓			Implement
Course Deliver					✓	✓	

MASSIVE OPEN ONLINE COURSE (MOOC)

The application of Massive Open Online Courses (MOOCs) has become increasingly significant in providing educational opportunities for hearing-impaired learners. Patiño-Toro et al. (2023) emphasize the necessity of designing MOOCs tailored for deaf or hard-of-hearing individuals, highlighting the importance of inclusive elements, varied methodologies, proper planning, and the use of appropriate tools. Their study outlines a methodology that ensures these courses meet the needs of this community effectively. Similarly, Mingsiritham and Chanyawudhiwan (2020) experimented with a MOOC prototype aimed at developing life skills in technology media for hearing-impaired students, finding significant improvements in academic achievement and high satisfaction levels among participants.

Escudeiro et al. (2022) present a pedagogical model integrating automatic translation technology between spoken and sign language within MOOCs, providing deaf students with didactic materials in their mother language, which has shown promising potential despite requiring further improvements. Additionally, Queirós et al. (2018) propose an inclusive MOOC model designed to support both deaf and blind learners by integrating tools for real-time translation between text, voice, and gestures, thus promoting social inclusion and equal opportunities in higher education. Collectively, these studies

demonstrate that when designed with inclusive strategies, MOOCs can significantly enhance educational accessibility and outcomes for hearing-impaired learners.

Thai MOOC is an educational platform in Thailand designed to offer free online courses to learners. The platform aims to provide accessible and high-quality education to a wide audience, regardless of their geographic location or educational background. The development of courses for use on the Thai MOOC platform followed a specific sequence of main steps: Proposing Courses, Developing Courses, Reviewing Courses, and Providing Online Instruction (including instructional management through the system, learner monitoring and support through the system, and conclusions of learning outcomes). The Developing Courses step involved four additional sub-steps: (1) target setting, which involves determining the courses to be taught and requesting the use of venues; (2) analysis, which includes course development and lesson structure; (3) designing online lessons, which involves developing a lesson plan; and (4) development of online courses involves creating lesson content and instructional media such as images, videos, and PowerPoint presentations and includes related links, learning activities, learning outcome assessments, course management through the online system, the addition of content, the creation of new learning activities, and the establishment of a system for scoring and assessing learner progress. Adherence to the established standards and guidelines was crucial in designing and developing instructional media for the Thai MOOC platform (Thai MOOC, 2017).

In the analysis of guidelines for the development of instructional media on MOOC platforms, several common steps were identified that could be integrated with those of Thai MOOC, with a particular emphasis on the technical specifications of individual MOOC providers that must be considered during the design and development process (Jdidou et al., 2016; Moy, 2020; Rollins, 2018). A synthesis of these findings is presented in Table 2.

Table 2. Synthesis of MOOC course development components

Methods	Thai MOOC (2017)	Rollins (2018)	Jdidou et al. (2016)	Moy (2020)	Model components findings
Defining Education Content/Target	✓	✓			Goal
Requirement Analysis	✓		✓		Analysis with empathy
Team Recruitment			✓		
Design	✓				Ideate
Conception			✓		
Development/Production/Filming and Postproduction	✓	✓		✓	Prototype
Content Development				✓	
Test/Revision			✓	✓	Evaluate
Standard Verification	✓				
Course Overview/MOOC reviewing/Final Review		✓	✓	✓	
Learning and Teaching with MOOCs/MOOCs Launching	✓		✓		Implement
Communication		✓			
Learners Engagement		✓			
MOOCs' Standards and Guidelines/Technical Integration/Platform Choice	✓	✓	✓		MOOC Platform (Learning Technology)

UNIVERSAL DESIGN FOR LEARNING (UDL)

Media and technology are essential for the instruction of hearing-impaired individuals, as they enable more effective teaching and learning. To accommodate the unique needs of this population, it is crucial to design media with these needs in mind. Universal Design for Learning (UDL) is a concept that involves creating a learning environment that is cost-effective, inclusive, and accessible to all learners, including hearing-impaired learners. Adopting UDL principles can help eliminate learning barriers for hearing-impaired learners and provide flexibility in educational management. This allows for a more responsive and inclusive learning environment where all learners can thrive. By designing flexible learning experiences with flexible tools, methodologies, and instructional media, teachers can meet the needs of individual hearing-impaired learners and ensure their success.

Dewi et al. (2019) conducted a meta-analysis of 12 studies, demonstrating that UDL principles significantly improve the quality of the learning process for diverse learners. They argue that UDL should be implemented in both usual and inclusive schools, providing effective teaching strategies for a wide range of student abilities. Luangrungruang and Kokaew (2018) applied UDL in an augmented reality (AR) education guidance system for hearing-impaired high school students, enabling them to understand IT content independently through smartphone applications featuring Thai sign language translations. This AR application enhanced student engagement and interest in higher education. Oreshkina and Safonova (2023) highlighted the role of UDL in inclusive engineering education programs, showing how it minimizes physical, organizational, and cognitive barriers to learning. Their study, conducted at a technical university, demonstrated the effectiveness of UDL principles in teaching STEM and socio-cultural disciplines, resulting in a multimodal educational environment that caters to the cognitive needs of both hearing-impaired and non-hearing-impaired students. Taken together, these studies emphasize the importance of UDL in creating inclusive educational environments that enhance learning opportunities and outcomes for hearing-impaired learners.

Furthermore, the National Deaf Center on Postsecondary Outcomes (2019), Brandt (2017), Burgstahler (2018), and Phillips (2021) highlight the importance of using UDL principles as a guide when designing and developing digital media for individuals with auditory or hearing disabilities. According to these sources, incorporating UDL into the design process is essential in creating inclusive and effective learning materials for hearing-impaired learners, as presented in Table 3.

Table 3. Synthesis of components of universal design for learning

Methods	The National Deaf Center on Postsecondary Outcomes (2019)	Brandt (2017)	Burgstahler (2018)	Phillips (2021)	Model components findings
Universal Design for Learning (UDL): Principles I, II, and III	✓	✓			Universal Design for Learning (UDL)
Universal Design: Sign Language Interpreter, Captioning and Transcription, Use Simple Plain Language			✓	✓	

UDL consists of three principles that should be considered when designing:

Principle I: Provision of multiple means of representation: The “What” of learning refers to the numerous ways information is presented to learners. Given that learners differ in how they understand and process data, it is important to provide multiple means of representation to support their learning. This includes using a variety of tools and strategies, such as images, captions, video captions, and sign language, to help learners understand the concepts being taught.

Principle II: Provision of multiple means of action and expression: The “How” of learning because learners differ in their understanding and access to the learning environment. Therefore, curricula should be designed to provide learners with flexibility and many ways to demonstrate their understanding and compliance with what has been learned, such as through multiple response methods and various modes of expression.

Principle III: Provision of multiple means of engagement: The “Why” of learning because learners differ in their motivation or level of interest in learning. Curricula should be designed to provide a variety of challenges and learning opportunities that are relevant to the learner and keep them engaged and motivated. Tools and strategies should also be implemented to foster meaningful relationships and connections between learners.

STUDIES ON THE DEVELOPMENT OF DIGITAL INSTRUCTIONAL MEDIA FOR HEARING-IMPAIRED LEARNERS

As Table 4 illustrates, Mingsiritham and Chanyawudhiwan (2017), Cooper Matthews (2016), Cruz (2013), and Somboon et al. (2015) have identified two key components to consider in constructing an educational digital media development model for learners with hearing impairments, which are as follows.

I. Guidelines for designing instructional media suitable for hearing-impaired learners

For the effective development of digital instructional media tailored for the hearing-impaired, it's essential to integrate multiple elements. These include a blend of text, visuals, and sign language to foster optimal communication and the use of multimedia, which pairs imagery with narrative text for enhanced comprehension. Video content, especially, should be supplemented with both closed captions and sign language interpretation. Mingsiritham and Chanyawudhiwan (2017) developed a smart book for hearing-impaired students, focusing on daily life communication scenarios. Their research found that incorporating text, pictures, and sign language significantly improves understanding and communication for hearing-impaired individuals. Cooper Matthews (2016) conducted an experimental study to evaluate the impact of multimedia on comprehension and cognitive load among deaf students. The study revealed that picture-plus-text and picture-plus-sign language formats significantly reduced cognitive load compared to text-only formats, though there was no significant difference in learning comprehension between the multimedia formats. Cruz (2013) explored instructional design strategies for deaf and hard-of-hearing learners in hybrid courses. The study highlighted the importance of accommodations such as closed-captioned videos, sign language interpreters, and accessible learning management systems in providing equal learning opportunities. Importantly, all these findings resonate with the principles of Universal Design for Learning (UDL), emphasizing the importance of diverse and inclusive instructional methods and materials. This ensures that all students, regardless of their hearing abilities, have equitable access to learning opportunities.

II. Stakeholder participation

Involving hearing-impaired learners in every stage of digital media development for learning is essential for creating effective and accessible educational tools. Cruz (2013) also highlights the importance of incorporating input from deaf learners in the instructional design process to create effective hybrid courses. The study gathered detailed feedback from these learners through various methods, emphasizing their participation in both the design and evaluation phases. This involvement ensures courses meet accessibility standards and provide equal learning opportunities, ultimately improving educational experiences for deaf learners. Similarly, Somboon et al. (2015) developed multimedia for teaching assistive technology terminologies in Thai sign language for hearing-impaired students. The research included selecting key terminologies, designing and producing multimedia, and evaluating its effectiveness. Hearing-impaired individuals participated in every stage, providing valuable feedback to ensure the content aligned with their needs and ways of thinking. This involvement was essential

for creating effective educational media, as it reflected their real experiences and preferences. The final multimedia package significantly improved learners' understanding, demonstrating the importance of user Participation in developing educational tools for hearing-impaired students.

Table 4. Synthesis of components of related research

Methods	Mingsiritham and Chanyawudhiwan (2017)	Cooper Matthews (2016)	Cruz (2013)	Somboon et al. (2015)	Model components findings
Including text, pictures, and sign language in media	✓	✓			Universal Design for Learning (UDL)
The use of video media with closed captions and a sign language			✓		
Taking UDL into account			✓		
Stakeholder participation			✓	✓	Participations

While the review of related research has not found adequate studies that integrate the concepts of design thinking, MOOCs, and UDL to leverage the advantages of each approach for enhancing the education of hearing-impaired learners, the researcher asserts that integrating these concepts would be beneficial to create a MOOC-integrated design thinking model for hearing-impaired learners. Based on the literature reviewed above, the researcher has categorized related aspects into two groups. Table 5 displays these categories as follows:

- I. *Stages* - This includes Goal, Analysis with Empathy, Ideate, Prototype, Evaluate, and Implement.
- II. *Key Elements to Consider (Co-Components)* - These are MOOC (Learning Technology), UDL, and Participation.

Table 5. Stage and co-component findings

Design thinking	MOOCs	UDL	Related research		Stages	Co-components findings
Course Requirements	Goal			=>	Goal	
Analysis with Empathy	Analysis with Empathy			=>	Analysis with Empathy	
Ideate	Ideate			=>	Ideate	
Prototype	Prototype			=>	Prototype	
Evaluate	Evaluate			=>	Evaluate	
Implement	Implement			=>	Implement	
	MOOC Platform (Learning Technology)			=>		MOOC (Learning Technology)
		Universal Design for Learning (UDL)	Universal Design for Learning (UDL)	=>		Universal Design for Learning (UDL)
			Participation	=>		Participation

RESEARCH METHODOLOGY

This research and development project aims to create a MOOC-integrated design thinking model for developing educational digital media tailored for hearing-impaired learners. The study is structured into three phases:

PHASE I: DEVELOPING THE MODEL

A prototype model was developed through the review of various research documents, both domestic and international. This model was then presented in a focus group discussion to a group of experts selected through purposive sampling. The inclusion criteria for these experts required a minimum of five years of relevant experience, and the group included two educational technology specialists, two hearing and deafness specialists, and one curriculum and instruction specialist. The focus group provided feedback on the prototype model, which was then revised based on their suggestions. The modified model was then assessed for quality by a group of experts in phase II.

PHASE II: ACCESSING THE MODEL

The Phase I model was evaluated for suitability by another five experts: two educational technology specialists, two hearing and deafness specialists, and one curriculum and instruction specialist. The experts assessed the model's suitability using a questionnaire that employed a five-level Likert scale (5 = Extremely high, 4 = high, 3 = medium, 2 = low, and 1 = lowest). The collected data from the questionnaire were analyzed using mean and standard deviation (SD). For responses on Likert scales, values were assigned based on calculated means: the assignments were - if the mean was in a range of [4.51 – 5.00] → 5, [3.51 – 4.50] → 4, [2.51 – 3.50] → 3, [1.51 – 2.50] → 2, or [1.00 – 1.50] → 1.

PHASE III: PILOTING THE MODEL

In this phase, the researcher is actively involved in creating pilot digital media content through the application of the MOOC-integrated design thinking Model. This pilot phase encompasses the development of two specialized courses: “Digital Storytelling Literacy” and “Utilizing Online Media as a Digital Citizenship” course, tailored specifically for hearing-impaired learners. Since these courses are hosted on the Thai MOOC platform, they were made freely available for student enrollment from anywhere. From December 2022 to August 2023, a total of 1,054 students completed all course-related activities. The assessment of student progress and achievement will be conducted through comprehensive examinations. Successful course completion requires students to achieve a cumulative score exceeding 70%, as per the established standards within the Thai MOOC framework.

To protect participants' rights, the researchers obtained approval from the chair of the human research ethics committee at Rangsit University, with certification number COA. No. RSUERB2022-099, granted on September 22, 2022. Following international research guidelines such as the Declaration of Helsinki, the Belmont Report, CIOMS Guidelines, and ICH-GCP, the study's objectives and data collection processes were explained to participants beforehand. Participants were assured of confidentiality regarding their identities and the research findings, which were meant solely for academic purposes.

RESULTS

DEVELOPING THE MODEL

A model prototype was formulated by examining numerous research papers. Subsequently, this prototype was introduced to a panel of specialists during a focus group discussion. Based on their insights, several refinements are proposed, as shown in Figure 1. First, it is important to define the learning outcomes in Stage 01's Goal clearly. Second, the model should explicitly address the needs of the hearing-impaired community by incorporating UDL principles and involving relevant stakeholders. Third, the Instructional strategies for hearing-impaired learners should be separated as another co-component, as it is essential to consider in Stages 02-03-04, which span from Analysis with Empathy to Prototype. Lastly, an instructional process should be added, encompassing a broad range of methods, procedures, and techniques teachers use to present subject content to learners and achieve effective results.

For example, an effective instructional strategy for hearing-impaired learners is to provide all teaching materials before the course begins. This approach reduces the cognitive load on learners in an online class, as it eliminates the need to take notes while also trying to follow along, which can be particularly challenging for those with hearing impairments. A strategy often includes several practices or techniques, such as those recommended by TTAC Online (2019), Deaf Unity (2020), ADCET (2021), York St John University (n.d.), and the AllPlay (n.d.) Program at Monash Education:

- Incorporating visual aids in lessons, such as video presentations, narrations, or sign language.
- Consistently checking learners' understanding before, throughout, and after lessons.
- Using straightforward language and maintaining a suitable speed when speaking or reading to ensure sign language interpreters grasp the entire message.
- Providing learners with a pause to understand the sign language fully before moving on to questions or a new topic.

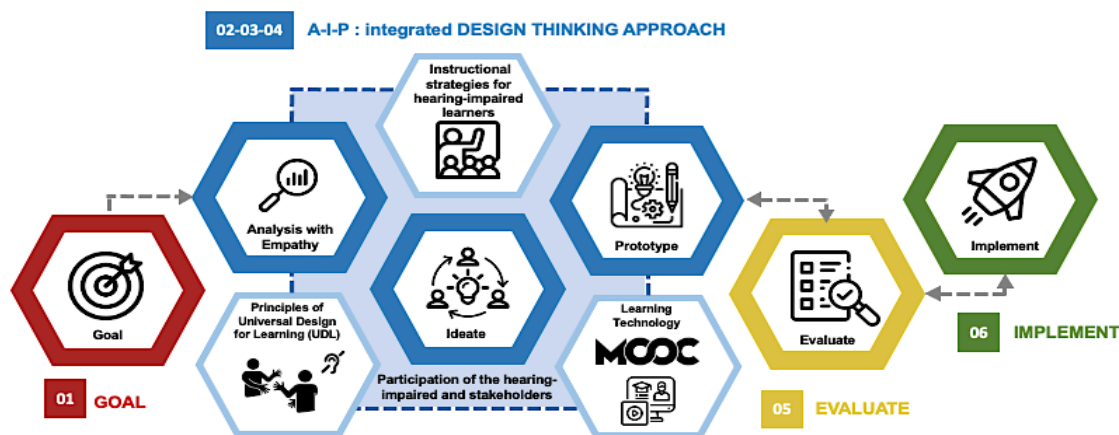


Figure 1. The MOOC-integrated design thinking model for hearing-impaired learners (Dhamanitayakul et al., 2023)

Table 6. Details of the six stages (Dhamanitayakul et al., 2023)

Stages	Actions (example)
01 Goal	Define the learning outcomes, identify the target learner group, outline the course requirements, develop the course syllabus, and prepare any additional necessary details.
02 Analysis with Empathy	Analyze and synthesize with empathy to recognize and understand the problems, thoughts, perceptions, emotions, feelings, and reasons behind the learners' actions. Consider developing a learner empathy map with research instruments such as observations, interviews, surveys, and stakeholder participation.
03 Ideate	Explore or invent ideas for creative solutions to problems and concepts to design media that respond to learner problems. Brainstorm about the unmet needs of the learners.
04 Prototype	Develop innovative digital media solutions starting from the prototype, emphasizing speed of development rather than aesthetics. Use the prototype to validate whether the concept can solve the analyzed learner problems by revisiting the Analyzing with Empathy and Ideation steps. Then, iteratively modify, add to, and validate the media until they meet the specified goals.
05 Evaluate	Conduct final testing before implementation and check standards for compatibility with related systems (such as Thai MOOC).
06 Implement	Deploy the media on the MOOC platform (Thai MOOC in this study), integrate it into lessons, and continuously monitor and evaluate the learners' progress against the learning outcomes.

Table 7. Details of the four co-components (Dhamanitayakul et al., 2023)

Co-components	Explanation
Participation of the Hearing-Impaired Learners and Stakeholders	The involvement of hearing-impaired individuals, hearing and deafness experts, and stakeholders.
Instructional Strategies for Hearing-Impaired Learners	The use of instructional strategies for hearing-impaired learners that focus on visual learning tools, assistive technologies, clear and visual-friendly communication, curriculum adaptation, and interactive, inclusive teaching methods. These approaches aim to accommodate their specific learning needs and integrate them effectively into the educational environment.
Principles of Universal Design for Learning (for Hearing-Impaired Learners)	The use of Universal Design for Learning principles for hearing-impaired learners involves presenting information in diverse ways, such as visual aids and sign language, providing varied expression methods, and ensuring accessible engagement to effectively accommodate their educational needs.
MOOC (Learning Technology)	The use of technical details, conditions, limitations, and standards as guidelines for the design and development of instructional media on the Thai MOOC platform.

To apply the model, it is essential to develop comprehensive documentation outlining the model’s stages and co-components as presented in Table 6 and Table 7. This includes detailing the activities required for each stage, the necessary tools, and the stakeholders involved. It is also important to ensure that all principles and conditions in the model are thoroughly considered and addressed.

ASSESSING THE MODEL

The MOOC-integrated design thinking model for hearing-impaired learners received exceptionally high ratings. According to Table 8, the experts assessed the model as being highly suitable overall, with an average score of 4.86. Additionally, the internal components were rated as extremely suitable, with a score of 4.80. This high level of suitability was consistent across the inputs (4.87), processes (4.87), and outputs (4.60) components. Overall, considering all six stages and four co-components, the experts concurred that the model was exceedingly appropriate, evidenced by an average suitability score of 4.94, for the development of digital media innovations to enhance learning among hearing-impaired learners.

Table 8. The Prototype model ratings (N=5)

Assessment issues	Model ratings		
	Mean	Standard deviation	Suitability
Part 1: The suitability of the model’s internal components			
1. The internal components of the model are suitable and consistent with fundamental theories, principles, and concepts.	5.00	0.00	Extremely high
2. The model includes components following the instructional design principles, design thinking principles, principles for developing online courses on MOOC platforms, and the needs and usage conditions of hearing-impaired learners in MOOCs.	4.40	0.55	High
3. The model’s components are coherent and interconnected, aligning with the Input-Process-Output (IPO) framework.	5.00	0.00	Extremely high
Total	4.80		Extremely high

Assessment issues	Model ratings		
	Mean	Standard deviation	Suitability
Part 2: The suitability of the model's inputs			
4. The development of digital media is suitable as it begins by setting goals and analyzing and interpreting problems.	4.80	0.45	Extremely high
5. The involvement of specialists and hearing-impaired learners in analyzing and interpreting problems for input and participating in the design and development (Ideate and Prototype) of digital media is suitable.	5.00	0.00	Extremely high
6. The requirements for universal design guidelines in designing media and MOOC's technical information to be used as input for design and development are suitable.	4.80	0.45	Extremely high
Total	4.87		Extremely high
Part 3: The suitability of the model's processes			
7. The model's development processes (Analysis with Empathy <-> Ideate <-> Prototype) can be iteratively implemented until a satisfactory solution is obtained to develop digital media specifically tailored to the needs of hearing-impaired individuals.	4.80	0.45	Extremely high
8. As detailed in the model, the proposed digital media development process is considered clear, appropriate, and consistent with the principles of design thinking and the development of online courses on MOOC platforms.	5.00	0.00	Extremely high
9. The requirement to use technical data and relevant standards specific to MOOCs in the design, development, and evaluation process is considered suitable.	4.80	0.45	Extremely high
Total	4.87		Extremely high
Part 4: The suitability of the model's outputs			
10. The requirement for a final test and an evaluation before implementation is appropriate. However, if the test results show that it still does not address the problem, it would be possible to go back and repeat the Analysis with Empathy, Ideate, and Prototype stages.	4.80	0.45	Extremely high
11. The model's stages, from the beginning to "Implementation," aim to integrate digital media into the MOOC platform can help reduce learning limitations, promote learning opportunities for individuals with hearing impairments, enhance digital literacy skills, and facilitate lifelong learning.	4.40	0.55	High
Total	4.60		Extremely high
Part 5: The suitability of the model's application for developing digital media to promote learning for hearing-impaired learners.			
Stage			
12. Goal: Defining learning outcomes, courses, and content scope on digital literacy for hearing-impaired learners.	4.80	0.45	Extremely high
13. Analysis with Empathy: An in-depth analysis and understanding of the problems faced by individuals with hearing impairments, by putting ourselves in their shoes (Empathy), through conducting surveys and in-depth interviews.	5.00	0.00	Extremely high

Assessment issues	Model ratings		
	Mean	Standard deviation	Suitability
14. Ideate: Brainstorming to design digital media and lessons that address the challenges faced by learners with hearing impairments.	4.80	0.45	Extremely high
15. Prototype: Development of innovative digital media solutions for learners with hearing impairments on Thai MOOC, starting from a basic prototype (focusing on rapid development rather than aesthetics) to serve as a tool for verifying whether the concept can solve the pre-analyzed problems of learners with hearing impairments. This step revisits the 'Analysis with Empathy' and 'Ideate' stages. Subsequent modifications and detail enhancements of the media, along with continuous validation, will be iteratively performed until the digital media is fully realized and meets the set objectives.	5.00	0.00	Extremely high
16. Evaluate: Evaluating media and content for quality and checking compliance with standards and compatibility with Thai MOOC before implementation.	5.00	0.00	Extremely high
17. Implement: Implementing by teaching courses on Thai MOOC.	5.00	0.00	Extremely high
Co-components that were required to be reviewed together during the Analysis with Empathy, Ideate, and Prototype stages			
18. Participation of the Hearing-Impaired Learners and Stakeholders: Involvement of hearing-impaired learners, experts in teaching the hearing-impaired learners, and stakeholders in the process.	4.80	0.45	Extremely high
19. Instructional Strategies for Hearing-Impaired Learners: The use of instructional strategies for hearing-impaired learners involves visual tools, assistive tech, clear communication, and inclusive teaching methods, aiming to effectively meet their needs and support educational integration.	5.00	0.00	Extremely high
20. Principles of Universal Design for Learning (for Hearing-Impaired Learners): The use of Universal Design for Learning for hearing-impaired learners, such as incorporating sign language and visual aids, ensures accessible and effective education.	5.00	0.00	Extremely high
21. MOOC (Learning Technology): Incorporating technical standards as guidelines for the design and development of instructional media on the Thai MOOC platform	5.00	0.00	Extremely high
Total	4.94		Extremely high
Conclusion			
22. In conclusion, the MOOC-integrated design thinking model for hearing-impaired learners is suitable for further research.	4.80	0.45	Extremely high
Average	4.86		Extremely high

PILOTING THE MODEL

To test the model developed in this study, two courses, “Digital Storytelling Literacy” and “Utilizing Online Media as Digital Citizenship,” were designed and developed using the MOOC-integrated design thinking model. This implementation was conducted within the framework of the Thai MOOC Platform to ensure streamlined and effective course delivery. Examples of the developed Thai MOOC courses and participants are depicted in Figures 2 and 3.

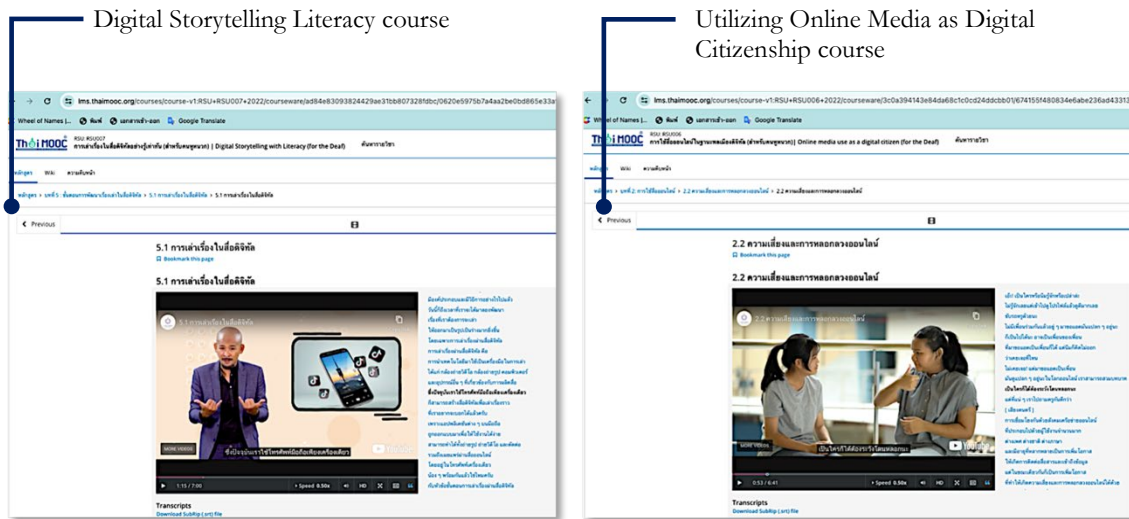


Figure 2. Screenshot of Digital Story-telling Literacy and Utilizing Online Media as Digital Citizenship courses for hearing-impaired learners on Thai MOOC

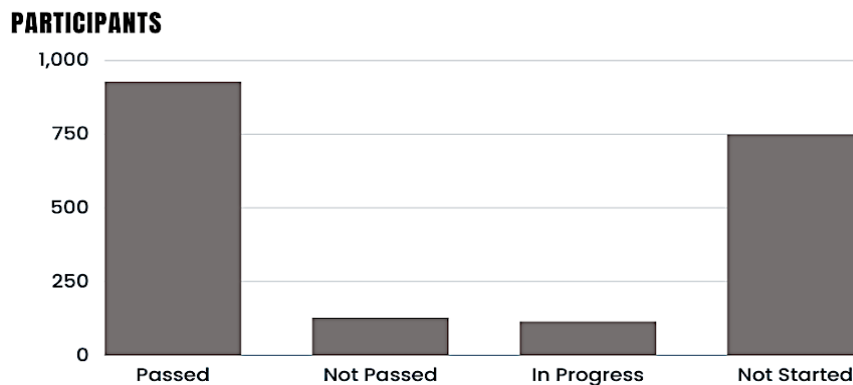


Figure 3. The information of participants in Digital Story-telling Literacy and Utilizing Online Media as Digital Citizenship courses for hearing-impaired learners on Thai MOOC

Referring to Figure 3, which illustrates the Thai MOOC system’s enrollment data from December 6, 2022, up to August 21, 2023, specifically for the courses “Digital Storytelling Literacy” and “Utilizing Online Media as Digital Citizenship,” there were 1,916 registrants in total. Out of this number, 1,054 have completed all course-related activities. Of these, 927 achieved the required examination standards, while 127 fell short. An additional 114 participants are currently engaged in the course but have not finalized all activities. Interestingly, 748 registrants have not initiated the course after enrollment.

DISCUSSION

To address Research Question 1, the researcher developed a MOOC-integrated design thinking model to create educational digital media for hearing-impaired learners, comprising six stages: (1) Goal, (2) Empathy Analysis, (3) Ideation, (4) Prototype Development, (5) Evaluation, and (6) Implementation. This model also included four co-components: (1) Participation of Hearing-Impaired and Stakeholders, (2) Instructional Strategies for Hearing-Impaired Learners, (3) Principles of Universal Design for Learning (UDL for Hearing-Impaired Learners), and (4) MOOC Learning Technology. The developed model effectively integrated various principles and concepts, such as design thinking, Thai MOOC development, instructional strategies, and UDL. Expert evaluations confirmed the model's suitability for creating MOOC-based lessons tailored to hearing-impaired learners.

Integrating educational concepts with MOOCs to enhance the learning of hearing-impaired learners aligns with the findings of Escudeiro et al. (2023), who found that while MOOCs are accessible, they often lack inclusivity for hearing-impaired learners. To address this, they developed an inclusive MOOC with a pedagogical model and technologies that enable deaf and blind individuals to access digital educational content. The evaluation showed positive potential but highlighted the need for further improvements. Moreover, this research aligns with Ballenger and Sinclair (2020), who emphasized combining design thinking and UDL to create inclusive and accessible courses, including MOOCs. They highlighted user-centric approaches and active engagement to ensure all students, regardless of ability, can participate. The Stanford design thinking model focuses on user needs, and using UDL guidelines as an evaluation framework enhances learner motivation, knowledge, and strategic thinking, ensuring equal opportunities for all students.

Additionally, to address Research Question 2, the researcher applied this model to develop pilot MOOC lessons and provided access to learners (both normal learners and hearing-impaired learners), resulting in a remarkable pass rate of 87.95%, according to the evaluation.

This finding aligns with recent studies indicating that each component of the MOOC-integrated design thinking model can significantly enhance the academic performance of hearing-impaired learners. Integrating a design thinking approach into the model has resulted in teaching materials that directly address the specific needs of hearing-impaired learners. This aligns with research from Indonesia and Taiwan, where employing a design thinking approach has led to the creation of effective learning aids. These resources not only enhance language comprehension among deaf students but also improve learning independence and confidence for those with hearing and speech challenges. This user-centered methodology proves vital in developing educational resources that meet specific learner needs and increase overall learning satisfaction (Lo et al., 2019; Suzianti & Atthousi, 2019).

Like using MOOCs as a foundation for developing a model, it also has an impact on elevating the learning outcomes of hearing-impaired learners. This aligns with Mingsiritham and Chanyawudhiwan (2020), who tested an online learning resource on MOOC for hearing-impaired students, revealing a significant improvement in their academic achievements and high satisfaction levels, particularly appreciating the up-to-date content and the freedom MOOCs offer. This indicates a positive impact of MOOCs on the educational experience of hearing-impaired students.

Furthermore, the inclusion of co-components related to the participation of hearing-impaired individuals and stakeholders aligns with the findings of Patiño-Toro et al. (2023), emphasizing stakeholder involvement in MOOC development to tailor content to diverse needs and enhance accessibility and learning quality through student-focused design and collaborative feedback-driven processes.

Additionally, another co-component, Instructional Strategies for Hearing-Impaired Learners, is in line with the research by Ezechinyere and Anyanwu (2021) from Akwa Ibom State, which underscores the significant impact of teachers' instructional strategies on the academic performance of students with hearing impairments in inclusive classrooms.

Finally, the incorporation of Principles of UDL for Hearing-Impaired Learners as a co-component helps develop suitable teaching materials, ultimately improving the learning outcomes of hearing-impaired learners. This is consistent with the findings of Luangrungruang and Kokaew (2018, 2022) and Oreshkina and Safonova (2023), who demonstrated the effectiveness of UDL in enhancing the education of hearing-impaired students. UDL, when integrated into augmented reality and e-learning approaches, empowers hearing-impaired individuals to grasp complex subjects such as information technology independently, resulting in improved learning outcomes. Furthermore, the successful application of UDL principles across various academic disciplines highlights the potential for inclusive and equitable education for all students, emphasizing the pivotal role of UDL in creating accessible and diverse learning environments.

CONCLUSIONS

This study has introduced an innovative approach to enhancing learning outcomes for hearing-impaired learners (HL) within inclusive education by integrating design thinking principles into Massive Open Online Courses (MOOCs) specifically tailored for HL. The research investigates the essential components of a MOOC-integrated design thinking model for hearing-impaired learners and examines the efficacy of the pilot course in improving their learning outcomes and achieving necessary test scores.

In conclusion, this study developed a comprehensive six-stage MOOC-integrated design thinking model, along with its essential co-components, tailored specifically for hearing-impaired learners. Besides the MOOC and design thinking principles, the model incorporates other crucial elements such as UDL, instructional strategies, and active participation in development to ensure the MOOC-based courses are well-suited for hearing-impaired learners. Expert evaluations validate the model's effectiveness, and the positive learning outcomes from the pilot course enhance confidence in its efficacy. This is consistent with both Thai and international research on the beneficial impact of design thinking on learning outcomes and satisfaction. This research contributes significantly to reducing educational inequalities, advancing inclusive education, promoting lifelong learning opportunities, and aligning with broader societal efforts to address educational disparities.

The MOOC-integrated design thinking model developed in this study serves as a solid foundation, offering a reliable and adaptable blueprint or framework for creating online lessons tailored to specific needs. The model's flexibility allows for adjustments to suit other disabled groups, aiming to bridge educational gaps. Further research applying and refining the model based on outcomes will further enhance its effectiveness and contribute to inclusive education.

Furthermore, future research could focus on longitudinal studies to assess the long-term impact of the model for HL. Exploring innovative technologies and pedagogical approaches can further enhance the effectiveness of inclusive education interventions. Collaborative, interdisciplinary research can advance inclusive education and enhance learning outcomes for diverse groups.

LIMITATION

The focus of this research was on developing the model. The pilot study on the MOOC platform demonstrated the model's applicability to a broad audience, including those without hearing impairments. However, future research will target specifically hearing-impaired learners to further evaluate their learning achievements. This will include comparing learning outcomes from lessons developed using the model with other teaching methods to establish the model's effectiveness.

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A MOOC-Integrated Design Thinking Model for Hearing Impaired Learners

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