# Technology-Enhanced Accessible Interactions for Visually Impaired Thai People

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**Abstract.** This research addresses the lack of an existing, comprehensive method to help developers evaluate and gather requirements for the evaluation and/or design of technological solutions for the visually impaired. This paper, utilizing interviews with experts and the visually impaired, focuses on using the "Technology Enhanced Accessible Interaction Framework Method".

**Keywords:** Accessible interaction · Visual impairment · Thailand

## 1 Introduction

The Technology Enhanced Interaction Framework (TEIF) Method was developed to technologically enhance accessible interactions between people, technology, and objects, particularly in face-to-face situations involving people with disabilities. It was successfully validated by three developer experts, three accessibility experts, and an HCI professor for use with hearing impaired people [1]. The TEIF Method supports other design methods by providing multiple-choice questions to help identify requirements, the answers to which help provide technological suggestions that support the design stage. This paper described how the TEIF Method has been extended for use with visually impaired people. Ten experts, 20 visual impaired students and 10 visual impaired adults were interviewed in order to create scenarios, and investigate problems of visual impairment problems and their subsequent technological solutions.

## 2 Literature Review About Visual Impaired Requirements

The Individuals with Disabilities Education Act (IDEA) defines the term "visual impairment" as impairment in vision that, even with correction, adversely affects a child's educational performance. The term includes both partial sight and blindness [2]. Nearly 11% of Thailand's registered disabled population in 1996 had a visual

Impairment, and the National Statistics Office 2007 data estimates that nearly two million women and men in Thailand, or approximately 3% of the population, or 2209,000 people had a registered visual impairment disability, [3].

To reduce discrimination in access requires accessible technology solutions, an accessible environment, accessible documents and accessibility awareness.


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### 2.1 How Can Blind People Get Information?

Golledge [4] analyzed the four senses involved in a navigation task:

1. Touch is a tactile perception ability which acquires information from objects pressed against the skin, using Mechanoreceptors. These utilize neural receptors to detect a pressure on human skin when it is touched e.g. pressure on hands, feet, follicle, tongue and body skin.
2. Sight is vision perception, which includes focusing, interpreting, and detecting visible light that bounces off and reflects from objects into the eyes. It provides information such as images, colours, brightness, and contrast.
3. Audition is sound perception, namely the ability to detect and interpret the vibration into various frequencies of noise in the inner ears. Hearing capability using both ears also provides the ability to echolocate, that is, detect orientation of the sound source. (Milne et al. [5]; Wallmeier and Wiegrebe [6]).
4. Olfaction is Odour perception, ability to smell objects in the environment, utilizing the Olfactory neural receptor.

Visual impairment obstruction detection at different levels is shown in Table 1. For example, visually impaired people use a white can to detect obstructions at ground level. They use guide dogs to avoid the obstruction and/or sighted people to avoid the obstruction.

**Table 1.** Shows the relationship between activities and internal perceptions (Watthanasak [7] via Williams et al. [8])

| Activities | Internal Perceptions | | | External Helpers | | |
|---|---|---|---|---|---|---|
| | Touch | Audition | Olfaction | White Cane | Guide Dog | Sighted People |
| Obstacle detection (ground level) | | | | ✓ | | ✓ |
| Obstacle detection (body level) | ✓ | | ✓ | ✓ | ✓ | ✓ |
| Obstacle detection (eye level) | | | ✓ | | | ✓ |
| Obstacle avoidance | | | | | ✓ | ✓ |
| Crossing the street with high traffic | | ✓ | | ✓ | ✓ | ✓ |
| Walking though a loud noise area (daytime) e.g., urban, shopping mall, construction area, etc | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Walking through a silent area (night time) e.g., inactive construction area | ✓ | | ✓ | ✓ | ✓ | ✓ |

## 2.2 Problem and Solutions of Visual Impairment

Problems and solutions experienced by the visually impaired and blind. People are shown in Table 2.

**Table 2.** Problems and solutions experienced by visually impaired and blind.

| Topics | Problem | Solutions | References |
|---|---|---|---|
| Unfamiliar places | Difficulties in navigating inside unfamiliar places which are usually large, complex, wide-open, full of crowds and noise, and have accessibility information. A guide dog sometimes is not allowed in some buildings, for example, hospital ICU | Sighted Guide<br>Guide Dog<br>Accessible Map (limited) | Williams et al. [8, 9] Guidedogs.org.au [10]; Guidedogs.org.uk [11] |
| Accessibility information | Difficulties in navigating inside the buildings due to lack of accessibility information such as tactile pavement, stair information, stairs, escalators, drop-offs, room number & name, etc. which are usually not provided | Sighted Guide<br>Accessible Map (limited) | Williams et al. [9]; Zeng [12] |
| Map for blind | Information provided in maps, both commercial or Public service, is limited and not enough for people with visual impairment. To provide more confidence in Navigation, objects and accessibility information should be integrated into the maps | Proposed Framework | Miao et al. [15]; Google [14]; Apple [16]; OpenStreetMap [17]; Kolbe et al. [18]; Li and Lee [19]; Lee et al. [20]; Ryu et al. [21] |
| Indoor navigation system | No matter what indoor positioning techniques have been used in the indoor navigation system, maps are the primary navigational tool, and these are normally proprietary and lack information required by blind | Proposed Framework | Indoors [22]; Wifarer [23] |
| Obstacle detection and avoidance | Difficulties in detecting and dodging obstacles installed or placed in the environment during the navigation | Echolocation Sensor: Ultrasound | Finkel [13]; Williams et al. [9] |
| Unpredictable obstacles | Difficulties in detecting or receiving information regarding unpredictable objects such as crowds, noise, etc | Sensor: Camera | Williams et al. [9] |
| Studying in class | Difficulty hearing recordings properly with background noise, difficulty in seeing/understanding what is | OrCam MyEye software, Assisted Vision Smart Glasses, | Quek and Olivereira [24] |

(*continued*)

**Table 2.** (*continued*)

| Topics | Problem | Solutions | References |
|---|---|---|---|
| | being written/drawn on board, difficulty in seeing/understand what is being pointed at | FingerReader software | |
| Visit museums | Difficulty in seeing text which explain exhibits, and in understanding exhibits which can not be touched or which move | Audio description, 3D tactile diagram | |
| Crossing roads | Difficulty crossing roads independently, and, and traveling independently in new environments | vibrating system at the traffic lights | |
| Shopping in grocery | Difficulty in identifying things like cans of soup, cereal boxes, cartons of milk, and other things by touch, and inability to see product detail | OrCam MyEye, braille labels, audio description, FingerReader | |

## 3 TEIF Interactions

Table 3 shows the five TEIF interactions while Fig. 1 shows the TEIF architecture. Someone pointing at something while referring to it as this, it is an example of Diexis.

**Table 3.** Interactions and Communication in the Technology Enhanced Interaction Framework

| Interaction | Explanation and example |
|---|---|
| People-People (P-P) | People communicate verbally (speak, listen, ask, answer) and non-verbally (lip-read, smile, touch, sign, gesture, nod). When communicating, people may refer (speak or point) to particular objects or technology – this is known as 'deixis' |
| People-Objects (P-O) | People interact with objects for two main objectives: controlling (e.g. touch, hold or move), and retrieving information (e.g. look, listen, read, in order to get information or construct personal understanding, and knowledge) |
| People-Technology (P-T) | People control technology, (e.g. hold, move, use, type, scan, make image, press, swipe,) transmit and store information (e.g. send, save, store, search, retrieve) |
| People-Technology-People (P-T-P) | People use technology to communicate/transmit information (e.g. send sms, mms, email, chat, instant message) other people |
| People-Technology-Objects (P-T-O) | People use technology (e.g. point, move, hold, scan QR codes, scan AR tag, use camera, use compass) to transmit, store, and retrieve information (send, save, store, search, retrieve) to, in, and from objects |

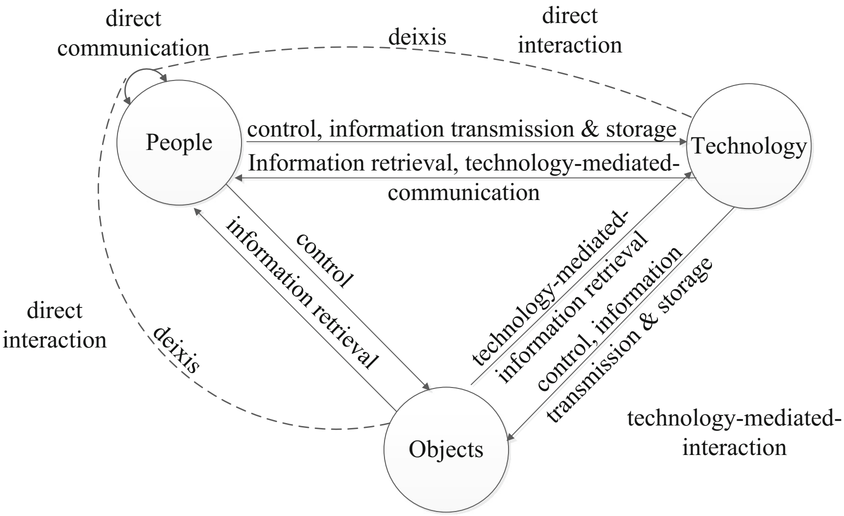


**Fig. 1.** The TEIF Architecture.

# 4 Developing TEIF for Blind

## 4.1 Interviews

The research analyses the information gathered from the experts and visually impaired people to develop requirement questions, five possible scenarios with actions, interaction issues, and possible technologies.

## 4.2 Transforming Requirements into Questions and Multiple Choices

The TEIF Method helps developers gather and evaluate requirements by using TEIF based multiple-choice questions. The questions help identify issues for which a technology solution is required.

In the following example, requirement questions □ means more than one answer can be chosen and ◯ means only one answer can be chosen. The example requirement questions which are shown below only include questions for which correct answers in the given scenario are provided.

1) What is the main purpose of the technology solution?
- ☐ a. improve communication and interaction
- ☐ b. make the service more interesting and exciting
- ☐ c. improve the service efficiency in terms of time and ease of use
- ☐ d. improve the storage and retrieval of information
- ☐ e. improve the service's more realiasm and authenticity,
- ☐ f. improve interaction accessibility.

2) Where and when does the scenario take place?
- ○ a. same time / same place
- ○ b. same time / different place
- ○ c. different time / same place
- ○ d. different time / different place

3) What main role do people have in the scenario?
- ☐ a. presenter – audience. Presenter gives information to the 'audience'- one or more persons- and controls the interaction. The audience can ask the presenter questions).
- ☐ b. peer -> peer. Any person can give information or ask questions to any other person and therefore no one person controls the interaction)
- ☐ c. no communication between people, only interaction with technology or objects
- ○ Number of presenters and audience members
- ○ a. one presenter – one audience member
- ○ b. one presenter – many audience members
- ○ c. many presenters – one audience member
- ○ d. many presenters – many audience members

4) Does the presenter have a disability?
- ○ a. Yes
- ○ b. No

5) What language does the presenter use?
- ☐ a. English
- ☐ b. Thai
- ☐ c. other language
- ☐ d. I do not know

6) What language does the audience use?
- ☐ a. English
- ☐ b. Thai
- ☐ c. other language
- ☐ d. I do not know

7) Does the audience have a disability?
- ○ a. Yes
- ○ b. No

8) What kind of disability do the audience members have?
- ☐ a. hearing impaired
- ☐ b. visually impaired
- ☐ c. physically impaired
- ☐ d. none

9) What level of visual impairment does the presenter have?
- ☐ a. blind
- ☐ b. some useful sight

☐ c. Unknown

10) What interaction types occur in the scenario?
☐ a. people to people
☐ b. people to objects
☐ c. people to technology
☐ d. people to technology to people
☐ e. people to technology to objects

11) What type of technology would be appropriate for the solution to the scenario?
○ a. online technology (Internet)
○ b. off-line technology
○ c. either
○ d. Unknown

12) What type of technology devices would be appropriate for the solution to the scenario?
○ a. mobile devices
○ b. non-mobile devices
○ c. either
○ d. Unknown

13) What media is used to provide information?
☐ a. Non-text image
☐ b. Printed text
☐ c. Handwritten text
☐ d. non accessible electronic files
☐ e. accessible electronic files e.g. pdf

14) Is live support available?
○ a. Yes
○ b. No

15) Is there “Deixis”?
○ a. Yes
○ b. No

16) Where does the situation take place?
○ a. indoors
○ b. outdoors
○ c. both
○ d. Unknown

17) What are the two main environmental considerations identified that impact the scenario?
○ a. noise (Background noise affects everyone’s ability to hear and understand what is said.)
○ b. room acoustics (surface (e.g. walls, windows, tile) and objects within every room interact to produce reverberation.)

- ○ c. distance (How far is the audience standing from the presenter? The further a student is from the presenter or sound source, the softer the sound they receive.)
- ○ d. visual access (How well can the audience see everything in different locations?)
- ○ e. lighting (Inadequate lighting or large banks of windows can be challenging for deaf or hard of hearing audience because they cannot see the speakers face well or an interpreter may be located in shadows)

18) Does the customer require a low cost solution?
- ○ a. Yes
- ○ b. No
- ○ c. Unstated

19) Should the technology solution work on a smart phone?
- ○ a. Yes
- ○ b. No
- ○ c. Unstated

### 4.3 Develop Scenario to Test Requirement Questions and Multiple Choices

In order to ensure that the TEIF has broad applicability,, five scenarios and technology solutions were considered during the development process: a blind person shops for groceries, crosses the road, finds rooms and buildings, studies at the University, and visits the Shadow Puppet Museum. The process illustrated TEIF suitability in these complex situations involving visual imparement, and addressed the specific aspects of these technologically- enhanced interactions.

Table 4 shows how the questions can be applied to the relationship between the multiple-choice requirement questions and answers for these five scenarios.

**Table 4.** How questions can be applied for five scenarios

| Requirement questions | Scenarios for blind person | | | | |
|---|---|---|---|---|---|
| | Grocery shopping | Crossing road | Finding rooms or buildings | Studying at University | Shadow Puppet Museum |
| (1) What is the main purpose of the technology solution? | a. Improve communication and interaction | f. Improve interaction accessible | f. Improve interaction | a. Improve communication and interaction | a. Improve communication and interaction |
| (2) Where and when does scenario take place? | a. Same time/same place | a. Same time/same place | a. Same time/same place | a. Same time/same place | a. Same time/same place |
| (3) Role of persons? | b. Peer - peer | c. No communication between people, only interaction with technology or objects | a. Presenter - audience | a. Presenter - audience | a. Presenter – audience |

(*continued*)

**Table 4.** (*continued*)

| Requirement questions | Scenarios for blind person | | | | |
|---|---|---|---|---|---|
| | Grocery shopping | Crossing road | Finding rooms or buildings | Studying at University | Shadow Puppet Museum |
| | | | | | c. interaction with technology or objects |
| (4) Number of presenters audience members present | b. One presenter – one audience member | a. One presenter – one audience member | a. One presenter – one audience member | b. One presenter – many audience members | b. One presenter – many audience members |
| (5) Does the presenter have a disability? | b. No | b. No doesn't have disability | b. No doesn't have disability | b. No | b. Doesn't have disability |
| (6) Presenter's language | b. Thai | b. Thai | b. Thai | b. Thai | b. Thai |
| (7) Audience Language? | b. Thai | b. Thai | b. Thai | b. Thai | b. Thai |
| (8) Audience diability status | a. Yes | a. Yes, user has disability | a. Audience has disability | a. Yes | a. Audience has disability |
| (9) Type of audience disability? | b. Visually impaired | b. Visually impaired | b. Visually impaired | b. Visually impaired | b. Visually impaired |
| (10) Level of presenters visual imparement | a. Blind | a. Blind | a. Blind | a. Blind | a. Blind |
| (11) Scenario interaction types | c. People to objects | b. People to objects<br>c. People to technology | a. People to people<br>b. People to objects<br>c. People to technology<br>d. People to technology to people | c. People to technology<br>d. People to technology to people | a. People to people<br>b. People to objects<br>c. People to technology<br>d. People to technology to people |
| (12) Appropriate technological solution | d. I do not know | d. I don't know | c. Either online or offline technology | c. Either | c. Either |
| (13) Appropriate type of technology | a. Mobile devices | d. I don't know | a. Mobile devices | a. Mobile devices | a. Mobile devices |

(*continued*)

**Table 4.** (*continued*)

| Requirement questions | Scenarios for blind person | | | | |
|---|---|---|---|---|---|
| | Grocery shopping | Crossing road | Finding rooms or buildings | Studying at University | Shadow Puppet Museum |
| (14) Media information source | a. Non-text image (touching can)<br>b. Printed text | d. Non accessible technology | b. Printed text | a. Non-text image<br>b. Printed text<br>c. Handwritten text<br>d. Non accessible electronic files | b. Printed text |
| (15) LIVE support available? | a. Yes | b. No | b. No | b. No | b. No |
| (16) "Deixis" Available? | a. Yes | b. No | a. Yes | a. Yes | a. Yes |
| (17) Situation location. | a. Indoors | c. Both | c. Both | a. Indoors | a. Indoors |
| (18) Two primary environmental influences | a. Noise<br>b. Room acoustic<br>c. Distance | a. Noise | a. Noise | a. Noise | a. Noise |
| (19) Customer requires low cost solution? | a. Yes | a. Yes | a. Yes, low cost solutions | c. Not mention | a. Yes, low cost solutions |
| (20) Solution smart phone compatibility | c. Not mention | c. Not mention | c. Yes, visitors' mobile devices | c. Not mention | c. Yes, visitors' mobile devices |

***Scenario 4: Problem of a blind students studying at the University***

Space limitations allow only one of the scenarios to be described in detail. "Golf" is the only blind student in the law faculty class. Golf normally sits in a front of the class as he wants to record the lectures. However, (1) there is a lot of noise as teachers do not use microphones and other students are also talking during the class. Therefore, the sound quality of the media file that he records is not so good. Golf uses Braille to take notes from the lecture sometimes but not so often because he is not very familiar with braille. During the class, the teacher speaks Thai, as all class members are Thais. (2) When the teacher writes notes on the blackboard, Golf does not know what the teacher writes. Golf sometimes asks a friend to read it for him. Also, (3) when the teacher refers to material by pointing at the board, Golf does not know what the teacher is pointing towards. Sometimes, (4) the teacher asks questions related to information on the board, but Golf is not able to answer as he does not understand the question as he cannot see the board. Sometimes (5) the teacher gives students a hard copy case study to read and analyse in class individually. Golf cannot read it so the teacher allows Golf to work in a pair. Golf mentions to the teacher that if she provides him a word file or information on the web then he will be able to read it, but the teacher tells him that she only has a .pdf file.

At the end of the class, (6) the teacher shows an important book that every student needs to read. Golf is not sure what is the book looks like, so he asks the teacher if he can touch the book and feel it's size and thickness. Despite not receiving any financial support from friends or the university, he normally incurs considerable personal expense by having friends or professionals type the books and convert them into text files. While expensive, this is required, as otherwise the lack of accessible materials would result in him failing the course. (7) Golf find it particularly difficult when pictures, graphs or multimedia are required.

In this scenario Golf requires on or offline problem-solving mobile devices that he can use in the class and at home. Following are potentially appropriate technologically-based adaptions, an analysis of which assists in the developer choosing practical solutions.

**Action 1:** Golf records teacher voice in the noisy environment
**Interaction issues:** (P-T-P) Golf unable to hear the recording properly with background noise
**Possible solutions:**

i. (P-T-P) Teacher uses microphone when talk to students that can reduce the noise.

**Action 2:** Teacher writes/draw on board
**Interaction issues:** (P-T-P) Golf unable to see/understand what is being written/drawn on board
**Possible solutions:**

i. (P-T-P) Teacher only uses pre-prepared accessible slides which Golf has access to before the lecture
ii. (P-P) Teacher or another student or helper read information aloud/explain it for Golf
iii. (P-T-P) Helper annotates drawing on screen with text information
iv. (P-T-P) Golf uses camera focused on board with Optical Character Recognition (OCR) and Screen Reading Technology (SRT) used to read text
v. (P-T-P) Teacher & Golf uses electronic whiteboard with OCR & SRT to read text
vi. (P-T-P) Golf uses pre-prepared tactile diagram
vii. (P-T-P) Golf uses electronic tactile display
viii. (P-T-P) Golf uses OrCam MyEye, an intuitive wearable device with a smart camera to read from any surface
ix. (P-T-P) Golf uses Assisted Vision Smart Glasses, a wearable device by the University of Oxford, could be used in this case
x. Digital Trends http://www.digitaltrends.com/mobile/blind-technologies)
xi. Hand Writing Recognition (HWR) & SRT

**Changes required:**

i. Teacher behavior
ii. Teacher or other students' behaviour or additional helper
iii. Technology with in class helper
iv. Technology
v. Technology
vi. Technology pre-prepared by helper
vii. Technology
viii. Technology
ix. Technology
x. Technology

**Action 3:** Teacher points to writing/drawing on board
**Interaction issues:** (P-T-P with diexis) Golf unable to see/understand what is being pointed at
**Possible solutions:**

i. (P-P) A teacher or another student or helper explains what the teacher is pointing at
ii. (P-T-P) A teacher provides pre-prepared tactile diagram with camera tracking of teacher's pointing and haptic glove (further development is required before this can be a feasible and affordable solution) **REF** Quek and Oliveira
iii. (P-T-P) A teacher uses Camera focused on board with OCR used to read text
iv. (P-T-P) A teacher uses an electronic tactile display with camera tracking of teacher's pointing and haptic glove (further development is required before this can be a feasible and affordable solution)
v. (P-T-P) A teacher uses an OrCam MyEye software which is an intuitive wearable device with a smart camera to read from any surface
vi. (P-T-P) Golf uses an Assisted Vision Smart Glasses, a wearable device by the University of Oxford, which could be used in this case

**Changes required:**

i. Teacher/other students: behaviour or additional helper
ii. Technology pre-prepared by helper
iii. Technology
iv. Technology
v. Technology
vi. Technology

**Action 4:** Teacher asks a question that related to the information on a board
**Interaction issues:** (P-T-P with diexis) Golf unable to see/understand what is referring to
**Possible solutions:**

i. (P-P) Teacher or another student or helper explains to what the teacher is referring.

ii. (P-T-P) Teacher provides pre-prepared tactile diagram with camera tracking of teacher's referring and haptic glove (further development is required before this can be a feasible and affordable solution)
iii. (P-T-P) Teacher uses camera focused on board with OCR used to read text.
iv. (P-T-P) Teacher uses an electronic tactile display with camera tracking of teacher's pointing and haptic glove (further development is required before this can be a feasible and affordable solution)
v. (P-T-P) Golf uses an OrCam MyEye software which is an intuitive wearable device with a smart camera to read from any surface
vi. (P-T-P) Golf uses an Assisted Vision Smart Glasses, a wearable device by the University of Oxford, could be used in this case.

**Changes required:**

i. Teacher/other students: behaviour or additional helper
ii. Technology pre-prepared by helper
iii. Technology
iv. Technology
v. Technology
vi. Technology

**Action 5:** Teacher gives a case study hard copy paper to Golf to read
**Interaction issues:** (P-T-P) Golf unable to see/understand what is being written
**Possible solutions:**

i. (P-P) Teacher or another student or helper reads it for Golf
ii. (P-T-P) Teacher uses a camera focused on board utilizing OCR for text recognition
iii. (P-T-P) Teacher uses an electronic tactile display with camera tracking of teacher's pointing and haptic glove (further development is required before this can be a feasible and affordable solution)
iv. (P-T-P) Golf uses an OrCam MyEye software which is an intuitive wearable device with a smart camera to read from any surface
v. (P-T-P) Golf uses the Assisted Vision Smart Glasses, a wearable device by the University of Oxford, could be used in this case
vi. vi. (P-T-P) Golf uses the MIT 'FingerReader' device software to read the book scanning text with a finger. **REF** Follmer et al. [25]

**Changes required:**

i. Teacher/other students: behaviour or additional helper
ii. Technology pre-prepared by helper
iii. Technology
iv. Technology
v. Technology
vi. Technology

**Action 6:** Teacher shows a book to students
**Interaction issues:** (P-T-P) Golf unable to see/understand what is being written
**Possible solutions:**

i. (P-P) Teacher or another student or helper reads it for Golf
ii. (P-T-P) Camera focused on board with OCR used to read text
iii. (P-T-P) Electronic tactile display with camera tracking of teacher's pointing and haptic glove (further development is required before this can be a feasible and affordable solution)
iv. (P-T-P) Use OrCam MyEye, an intuitive wearable device with a smart camera to read from any surface
v. (P-T-P) Assisted Vision Smart Glasses, a wearable device by the University of Oxford, could be used in this case
vi. (P-T-P) FingerReader is providing an ability to read the book by scanning text with a finger.

**Changes required:**

i. Teacher/other students: behaviour or additional helper
ii. Technology pre-prepared by helper
iii. Technology
iv. Technology
v. Technology
vi. Technology

**Action 7:** Teacher shows a graph/diagram to students
**Interaction issues:** (P-T-P) Golf unable to see/understand what is being written
**Possible solutions:**

i. (P-P) Teacher or another student or helper reads it for Golf
ii. (P-T-P) Electronic tactile display with camera tracks teacher's pointing and haptic glove (further development is required before this can be a feasible and affordable solution)
iii. (P-T-P) Electronic file that has alt tag with detailed explanation using an audible screen reader

**Changes required:**

i. Teacher/other students: behaviour or additional helper
ii. Technology pre-prepared by helper
iii. Technology

Table 5 shows a few of the suggested technologies which could be used to address these issues, and the tick or cross indicates whether it could address the requirements identified. Only the first 11 columns are shown due to space restrictions. Some of the technology suggestions are still at prototype stage and so further development would be required before considered practical and feasible.

**Table 5.** Technology suggestion table

| Technology description | 1a improve communication &interaction | 2a same time/same place | 3a presenter – audience | 4b one presenter – many audience members | 5b Presenter has no disability | 6b Thai | 7b Thai | 8a Audience have disability | 9b visually impaired | 10a blind | 11c P-T |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Microphone | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 2. Pre – prepared accessible slides | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 3. Camera focused on board with OCR/HWR to read text & SRT Enables text on a non-electronic board in class to be read by a screen reader | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 4. Electronic whiteboard with OCR/HWR to read text & SRT Enables text on an electronic board in class to be read by a screen reader | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 5. Pre-prepared paper tactile diagram Static 3D representation of a diagram that can be explored by touch by a blind person | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 6. Electronic tactile display | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 7. OrCam MyEye An intuitive wearable device with smart camera empowering the blind, visually impaired, or those with a reading disability or other conditions to read from any surface | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 8. Assisted Vision Smart Glasses A wearable device by the University of Oxford | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 9. "FingerReader", a device designed by MIT, providing an ability to read the book by scanning text with a finger | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 10. Diagram mediated text annotation Adds text to a diagram | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

(*continued*)

**Table 5.** (*continued*)

| Technology description | 1a improve communication &interaction | 2a same time/same place | 3a presenter – audience | 4b one presenter – many audience members | 5b Presenter has no disability | 6b Thai | 7b Thai | 8a Audience have disability | 9b visually impaired | 10a blind | 11c P-T |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 11. Optical Character Recognition (OCR) Converts a text image into text that can be read by a screen reader | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 12. Handwriting recognition (HWR) Converts a handwritten image into text that can be read by a screen reader | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 13. Screen Reading Technology (SRT) Automatically reads displayed text aloud and allows blind user to navigate screen | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 14. Camera and haptic glove tracking of teacher's pointing using tactile diagram/display Information regarding teachers's focus via electronic glove vibration | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | X |
| 15. Live electronic tactile display Dynamic 3D representation of a diagram that can be explored by touch by a blind person | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

## 5 Conclusion and Future Work

Interviews with experts and Thai visually impaired individuals permits extension of the TEIF Method, allowing developers to create technological solutions, thereby facilitating visually impaired individuals' interactions with people, technologies and objects. Planned future research will evaluate its use with developers and visually impaired students at Suratthani Rajabhat University, Surat Thani, Thailand.

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