A House of Quality (HOQ) matrix of assistive technology for deaf students at elementary school to enhance basic-level language competencies

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Abstract. Communication skill is a human basic ability to interact with one another. People usually have no difficulties in communication, yet not for deaf people. The basic communication ability of deaf people tends to be poor due to their hearing impairment. Thus, the technological role is an effective way to enhance communication skill for deaf people or so-called as assistive technology. This study generated a house of quality (HOQ) matrix which can be adopted to develop an assistive technology in the form of language instructional media. The HOQ matrix generated significantly contributes to translating from profound need analysis to assistive technology features to enhance communication ability through Indonesian language competencies for deaf students at elementary school. The user needs were formulized from a preliminary assessment at previous research which took twelve best deaf students from three special elementary schools in Special Region of Yogyakarta, Indonesia. This study has found that the priority of assistive technology development is visual and interactive media, either application or educational game, which comprises the vocabulary of concrete thematic nouns and non-affix transitive verbs and composing a simple sentence. Therefore, the HOQ generated is particularly noteworthy for Indonesian language major competencies by deaf students, which are: understanding reading text skill, writing, and speaking.

1. Introduction

Human esentially needs communication skill to socialize. Most of the people suppose that communication is commonly done in daily activities without any difficulties. However, it does not apply to disabled people especially deaf people who are part of the community. Deaf people with impaired hearing either partially or completely tends to have difficulty in communicating [1]; [2].

Communication ability experienced by deaf people can be assessed from achieved competencies for language subject. Wijayanti and Kurniawan [1] conducted a study to assess basic language ability for deaf students at elementary school in three special schools in Special Region of Yogyakarta, Indonesia. The study showed that their communication ability to achieve basic Indonesian language competencies were poor. Furthermore, some of the supporting factors that cause were imbalance ratio between teacher

and student, lack of competent human resources, conventional media and learning sources, lack of special education facilities, and negative public support ([1],[3],[4],[5], and [6]).

The use of technology to assist deaf students increasing their basic communication ability is one of the effective solutions. Technology advances which rapidly increase can be applied to improve the quality of life in various needs, one of which is instructional media in the education sector or so-called assistive technology [7];[2]. Table 1 shows an overview of technological roles in the education sector for disabled people from some researchers.

Table 1. An overview of educational-purposed technological application for disabled people expressed from research keywords

Authors	Involved technology/technological output	Category	Technological use
Abdallah and Fayyoumi [8]	Android-based mobile apps for deaf and dumb people to assist communication in the Arabic language	Mobile app	Assistance
Gerling et al [9]	Wheel chair-controlled motion-based video games	Game	Assistance
Merilampi et al [10]	Cognitive mobile games for memory-impaired older adults	Game	Rehabilitation
Colman et al [11]	Multi-player online video games for brain-injured people	Game	Rehabilitation
McNeill et al [12]	Game-based systems for motor function rehabilitation using virtual reality (VR) and video capture technology	Game	Rehabilitation
Karal et al [13]	Educational computer game to assist psychomotor ability for mentally disabled children	Game	Assistance
Standen et al [14]	Interactive computer game on cognition for people with learning disabilities	Game	Assistance
Williams et al [15]	Information and communications technology (ICT) for people with special education needs (a review)	-	Assistance
Coyle et al [16]	3D computer game for adolescent psychotheraphy	Game	Rehabilitation

Technology has been intensively developed to help disabled people in the form of either applications or interactive educational games. Coyle et al [16], moreover, explained that the advantages of interactive computer games in learning activity increases motivation, confidence, problem solving and discussion, and the ability to tell stories.

The significant role of technology contributes to transform special education for disabled people including deaf students who were previously conservative to be better and more effective. Deaf students rely on visuals to capture and respond messages to communicators [1]. The visual function accomodated through technological roles can assist deaf students to improve their communication skill. Abdallah and Fayyoumi [8] developed an assistive communication tool in the Arabic language for deaf and dumb people through an android-based application. The study enabled disabled people to interact with normal people through the assistive tool developed. In Indonesia, some assistive technologies developed to enhance communication ability of deaf students have also been carried out. Harnanto [17] designed an electronic sign language dictionary in Indonesian as a communication aid for deaf people. The application contained letters, numbers, days, months, money and evaluation page. Hakim et al [2] developed an android-based application for teaching and language training services which contained image and instructional video using Google Speech. Besides, Wirna et al [7] made a sentence corrector application on android-based for deaf people. The application also brought educational game that was able to compose sentence structure correctly.

The use of technology as an interactive, attractive, and effective learning has been developed to help deaf students enhancing their communication skill, particularly Indonesian language competence as the subject of this study. However, researchers who developed technology-based learning media have not conducted a profound needs analysis for users which are deaf students. The absence of the process resulted a process leap, and developed applications did not really work effectively in improving communication skills for deaf students because a needs statement might mostly be obtained from the reserchers' point of view. For instance, electronic sign language dictionary developed properly by Harnanto [17] has only accomodated limited vocabulary. On the other hand, Wijayanti and Kurniawan [1] stated that lack of vocabulary memorized by deaf students caused their poor communication ability. Hakim [2] has actually implemented a needs analysis in designing the application using a use case diagram. The needs analysis, however, has not been able to translate detailed needs in a specification context. Therefore, this study is going to formulate a comprehensive needs analysis using HOQ explaining deaf students' needs to enhance Indonesian language competencies at the basic level, and define a step-by-step instructional media recommended. The generated HOQ can be used as a reference to develop an effective technology-based visual-and-interactive instructional media for deaf students to enhance Indonesian language competencies at basic level.

2. Method

This study is going to generate a HOQ matrix which can be used as a guide to developing an assistive technology for deaf students at elementary school to improve their language ability. HOQ as a part of quality function deployment (QFD) is a well-known product development tool to translate the voice of customers into product specification through a relationship matrix [18];[19];[20]. HOQ is primarily applied to product development, but in today's application HOQ has been addressed to wide range applications such as for business process improvement, health care system, service industry, education, and others [21]. In this study, a HOQ matrix has three major parts, which are: a) user needs statement, b) relationship matrix which reveals user needs and metrics or so-called the needs-metrics matrix, and c) planning matrix/competitive analysis.

The user needs defined in this study means deaf students' needs at elementary school. The user needs data was obtained from user needs assessment which had been conducted at previous research by Wijayanti and Kurniawan [1]. Wijayanti and Kurniawan [1] successfully identified the needs assessment to improve the basic competence of Indonesian language subject which took twelve deaf students in three special elementary schools in Special Region of Yogyakarta, Indonesia. Relationship matrix explains assistive technology features or functions which meet user needs, in this case was needs of deaf students at elementary school to improve communication ability in Indonesian language learning. The last part is planning matrix which indicates a quantitative competitive analysis between assistive technology features developed at previous research and features which will be fulfilled in this study. A HOQ matrix being formulated in this study is notably aimed to a very specific subject which is Indonesian language and at a very basic competency which contains understanding and listening reading text, writing skill, and speaking skill; and therefore, it is strongly relevant to be implemented to deaf students at early-leveled communication learning.

3. Result and discussion

3.1 User needs statement

Wijayanti and Kurniawan [1] conducted a needs assessment study related to Indonesian language learning for deaf students at elementary school. The initial assessment shown from the study was that the communication ability of deaf students to attain basic Indonesian language competencies were poor. The Indonesian language competencies defined in the national curriuculum (curriculum of 2013) have not been achieved and shown by the actual language ability of deaf students. The weak ability of basic communication skill expressed from Indonesian language learning was indicated by the lack of

vocabulary and minimum Indonesian language competencies mastered which included understanding and listening reading text, writing skill, and speaking skill.

The result of the study indicated that the main cause for poor communication ability of deaf students was the lack of vocabulary memorized and grasped [1]. It affected difficulties in listening and reading the text and further affected writing skill even speaking skill. Mastering a range of vocabulary becomes essential to communicate. The lack of vocabulary mastered by deaf students made the communication process obstructed. An effective learning media which enables to enrich property of vocabulary to deaf students is visual and interactive learning using technological application. Deaf students rely on their sense of sight in capturing all the information presented; thus, technological role in displaying interactive visualization of vocabulary makes it easier for them to capture message and respond. Hence, the user needs statement defined from the study conducted by Wijayanti and Kurniawan [1] is technology-based visual-and-interactive instructional media to enrich vocabulary, to provide an understanding of vocabulary, and to teach composing a simple sentence.

3.2 The needs-metrics matrix
Metrics technically translate functions which should exist in the assistive technology from the user needs identified in the previous process as shown in Table 2. As stated above that there were three priorities to respond deaf student' needs due to poor basic language ability, which are: a) improvement in vocabulary property, b) improvement in simple sentence writing skill, and c) improvement in listening skill.

Improvement in vocabulary can be applied by adopting visual interactive media which are able to display the vocabulary of concrete thematic nouns. Concrete thematic nouns are crucial to meet the deaf students' needs in enriching vocabulary because covering basic communication ability. Besides, concrete thematic nouns are visually conceivable by deaf students with poor language ability and familiarly encountered in their daily life. Improvement in vocabulary can not only be applied by enriching conrete thematic nouns but also by visualizing transitive verbs. Transitive verbs are very easy to visualize and essentially found in frequent activities done by them. Therefore, concrete thematic nouns and non-affix transitive verbs are the first priority to overcome the lack of vocabulary of deaf students. These vocabulary are very close to their life and help them memorizing.

Secondly, improvement in simple sentence writing skill can be implemented by developing an application which provides a sentence composition menu for simple sentence comprising subject and predicate, a non-affix transitive verb. The menu will assist deaf students to compose a clause and understand the meaning through a simple sentence. At the higher level, a developed assistive technology can be added by affix verbs, composing either active or passive voice; however, it is acceptable to deaf students with sufficient language ability. At last, improvement in listening skill is achievable for deaf students who memorize and understand much vocabulary at their level, and are able to compose right simple sentences.

3.3 Planning matrix
In this study, a planning matrix describes competitiveness reflected by their features to meet user needs between opportunities and curent features on the assistive technology which have been developed by relevant studies. The result of competitive score as illustrated in Figure 1, furthermore, is become the input to prioritizing metrics.

Tabel 2. A Needs-Metrics matrix based on goals identified from deaf learners initial assessment

Goals	Needs	Metrics/Menu
Improvement in vocabulary properties	Visualized instructional media for nouns	Concrete thematic nouns
	Visualized and video-based media displaying action verbs	Non-affix transitive verbs/action verbs

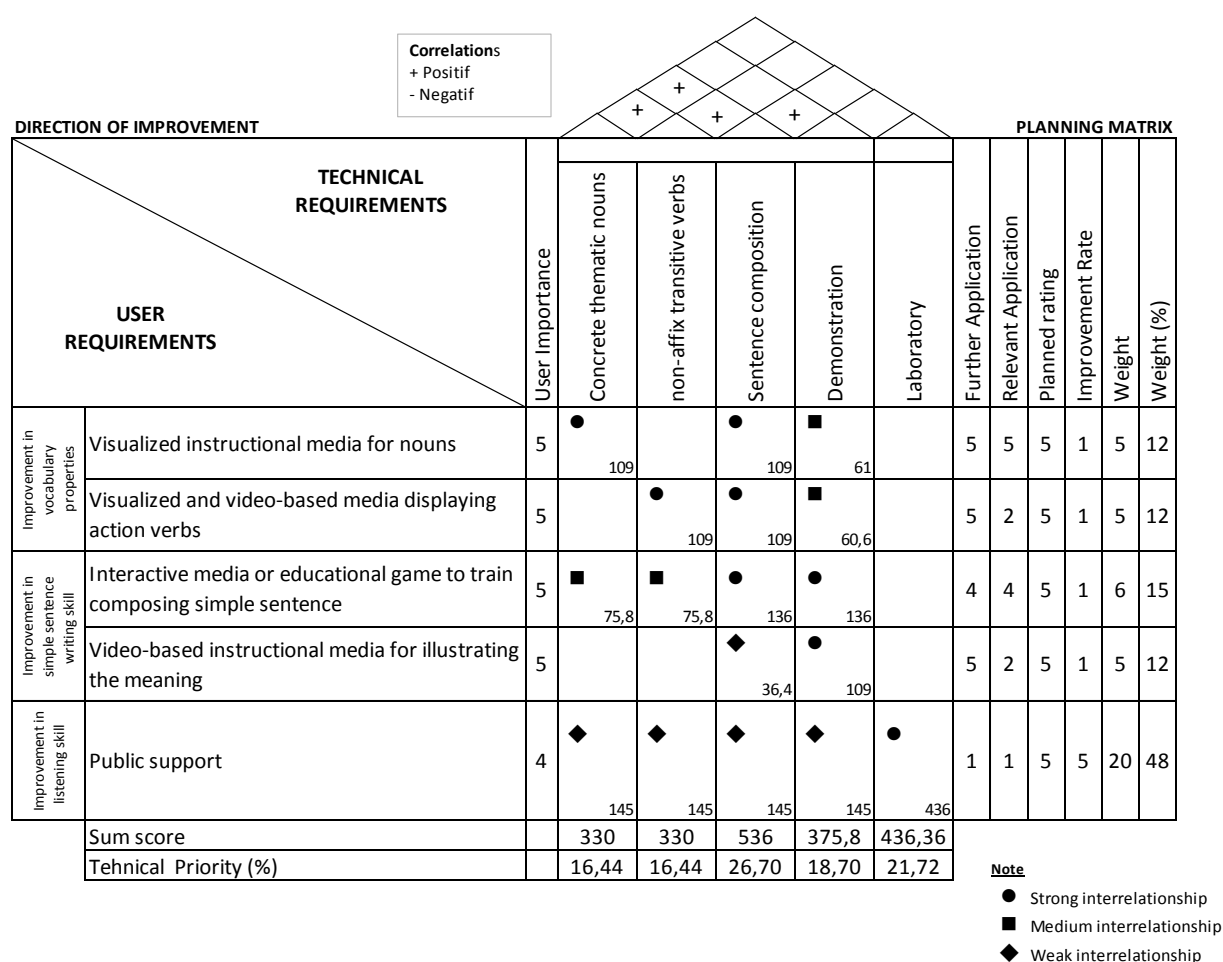| Improvement in simple sentence wiriting skill	Interactive media or educational game to train composing simple sentence	Sentence composition feature
	Video-based instructional media for illustrating the meaning	Composed sentence demonstration
Improvement in listening skill	Public support	Laboratory facilities

3.4 The HOQ Matrix

Figure 1. The HOQ matrix of assistive technology of basic-level Indonesian language learning for deaf students

A HOQ matrix generated in this study is going to provide an opportunity to apply the specific assistive technology. The assistive technology is relevant to have deaf students enhance their Indonesian language competencies from the early stage. The HOQ matrix translates deaf students' needs in Indonesian language learning into a set of specific metrics as depicted in Figure 1.

As stated above, there were three priority needs related to Indonesian language competencies which should be improved, which are: a) understanding/listening reading text, b) writing skill, and c) speaking skill. Accordingly, the HOQ matrix has met the poor communication ability of deaf students through an

assistive technology formulation which covers technical functions such as vocabulary enrichment, training to compose simple sentences, and understanding practice.

The major part of HOQ above is a relationship matrix which relates between user requirement, deaf students' needs, and metrics. A planning matrix is quantitatively calculated by comparing relevant assistive technology currently developed by Harnanto [17], Hakim et al [2], and Wirna et al [7]. Besides, the HOQ describes that metrics of concrete thematic nouns and action verbs positively correlate to the composition of simple sentences. Interestingly, public support has a high score of technical priority but weakly correlates to others.

Vocabulary enrichment features contain nouns and verbs. The follow up assistive technology development is going to expectedly accommodate the visual form of concrete thematic nouns and non-affix transitive verbs. Once deaf students have a good ability of vocabulary properties, it can be upgraded to composing simple sentences. The assistive technology should provide an interactive feature to practice a simple sentence composition from vocabulary given. The interactive feature means deaf learners are able to give feedback provided by assistive technology developed which is commonly in the form of educational games. Thus, this study has generated a HOQ matrix of assistive technology, either application or educational games, of Indonesian language learning which contain technical features to meet deaf learners needs at elementary school.

The HOQ as shown in Figure 1 describes two major levels of the learning process. Level 1 is vocabulary enrichment features. Some researchers or developers have developed visualized media which display vocabulary and the meaning at the various model. Thus, the model can be adopted and modified specifically into the scope of topics in Indonesian language learning such as conrete thematic nouns and transitive verbs. An application designed to enriching concrete thematic nouns such as vegetable topic or animals topic is going to be properly illustrated in order to deaf students have a good understanding about the concrete things. The application, nevertheless, is rather developed by illustrating video for action verbs. The common vocabulary memorized, at least nouns and verbs, are fundamental to compose simple sentences.

At level 2, deaf students are not only memorizing vocabulary but also practicing to compose a simple sentence with a simple structure such as subject and predicate. Subject belongs to concrete thematic nouns and predicates are transitive verbs. Furthermore, an assistive technology can also be developed to become more interactive by applying educational game in composing sentence. The sentence correctly structured is expectedly able to visualize animated video refers to the sentence. Therefore, an assistive technology developed using the HOQ generated by this study as a reference is powerful to help deaf students at the elementary level to enhance their basic communication ability through Indonesian language learning.

4. Conclusion

To conclude, this study has generated a HOQ matrix which recommends assistive technology features to effectively enhance communication skill for deaf students at elementary school. The second major finding was three priority features to improve early-leveled formal language lesson for deaf students. These are vocabulary stressing on concrete thematic nouns, vocabulary stressing on non-affix transitive verbs, and practice of simple sentences. Despite a qualitative approach conducted, this study offers a detailed formulation of assistive technology development for further work. The features in the assistive technology are specific and relevant to enhance poor communication ability through Indonesian language learning for basic-level deaf learners.

Finally, a number of limitations need to be considered. The current study has only proceeded a HOQ matrix which is strongly relevant at one level of language competencies. Besides, the scope of this study is limited to Indonesian language subject. Future research should, therefore, develop an assistive technology which is going to be applied into a prototype, assessed, and developed in other languages even bilingual.

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