E-Learning Model to Identify the Learning Styles of Hearing-Impaired Students

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Abstract: Deaf students apparently experience hardship in conventional learning; however, despite their inability to hear, nothing can stop them from reading. Although they perform impressively in memorizing the information, their literacy and reading capability still appear to be weak since they lack the chance to revise by listening and practicing repetitively. Currently, the teaching media for deaf students are quite rare and inadequate, forcing them to face difficulties in integrating new knowledge, even though most of the contents are in a form of written, printed, downloaded, or even accessible via an e-learning platform. However, it is crucial to bear in mind that each learner is different. There is evidence showing that some learners prefer particular methods of learning, also known as learning preferences or learning styles. Thus, the present study reports the sequence of learning styles obtained by using a modified VRK + TSL model that categorized students based on their learning styles. We also propose four different ways of teaching using content-adaptive learning styles, namely visual, reading/writing, kinesthetic, and Thai sign language. Based on personal preferences and the principle of universal design under synthesized learning, an e-learning model was developed to identify deaf learners’ learning styles. The objective is to provide e-learning to identify the learning styles of hearing-impaired students and to respond with up-to-date e-learning materials that can be used anywhere and at any time. These materials must support the education of deaf students. As a result, learners have increased efficiency and increased learning outcomes.

Keywords: e-learning; hearing-impaired; learning style; universal design

1. Introduction

It is difficult for students with hearing-impaired disabilities to learn language. Their first language is sign language since they cannot hear. This can cause problems for them in learning and in communicating with others, as they must put in more effort and have more patience than normal learners. Furthermore, deaf students require more attention, assistance, and suggestions to support them in learning. Therefore, providing education for this group is composed of preparing students and facilitating them to learn and acquire knowledge.

Impaired-learning students or deaf students are considered as a special needs population when they have to access learning resources, communications, and environments [1]. Their disability cannot be physically seen, so people are not aware of the obstacles the deaf are encountering as they look similar to others. It could be concluded that, as “the deaf solely rely on their vision to access information, which differs from normal people who can use both eyes and ears, so the optimum media for the deaf is the visual ones” [2]. Therefore, the instruction created for the deaf students should be delicately constructed in terms of the curriculum, teaching method, instructional media, assessment, and educational support [3].

Education for hearing-impaired students was established on 10 December 1951. At present, there are 21 schools for deaf students under the Special Education Bureau of Thailand, namely Setsatian School for the Deaf under the royal patronage of His Royal

In Thailand, the Department of Empowerment of Persons with Disability has stated in the legal guide for empowering and improving the life of persons with a disability (2009) that “disabled people’s right to access facility” refers to the ability to access and utilize the facility for disabled people, which is composed of the following three dimensions:

1. A universal and fair design whose principles are inclusive and idealistic;
2. The provision of assistive technology is the core of how to meet the special, personal, or group needs;
3. Reasonable accommodation between the two parties where both sides’ willingness to compromise is sufficient in whatever situations occur. The matter of providing reasonable accommodation is that the government must prioritize it by assigning related sectors, such as education and vocational agencies as well as social welfare to accommodate people with disabilities. Such accommodation should include the universal and fair design, and assistive technology and equipment considering equality and personal needs.

To construct a quality education for these people requires an integration of processes to fully develop learners’ potential, enabling them to be independent, autonomous learners with essential life skills. Traditional teaching methods are one of the reasons that these students can struggle. Students learn only through conventional methods, and they may find these boring and ineffective. Education and teaching styles have changed dramatically, and new forms of technology have been achieved. In addition, in today’s era, where working from home and online teaching have become the new normal all over the world, technology and teaching have become inseparable [4]. Applying technology to teaching and learning will help motivate students, especially when the components of the media consist of images, videos, animations, and sign language communication. E-learning is one way to assist this group of students when they are interested in learning a certain subject. At present, several techniques are applied to make the animations more appealing. Learners then easily acquire the knowledge, are attracted and not bored, and finally accomplish satisfying academic results. These methods could help them stay focused and allow them to autonomously practice, as well as enhance their confidence [5]. Furthermore, the deaf can autonomously and independently learn anywhere and anytime they want. This could be a guideline to develop media for other subjects effectively in the future, as learners are at the center of the learning process.

E-learning is a responsive learning medium as it is a study material that can be attended and reviewed at any time. It can allow students to spend more time on the material in order to gain a greater understanding. However, the current e-learning materials did not meet the needs of the learners or did not have enough material. Even though e-learning is designed to accommodate deaf students [6–8], there is no adaptive e-learning system that can indicate the learner’s learning style, although there are lessons that are built according to the learner’s learning style, which adds a special feature to e-learning. Therefore, adaptive e-learning teaching materials have been created that show the lesson pages according to the learner’s learning style.

This adaptive e-learning selects an appropriate learning style path based on the student’s background information to select the most appropriate learning style for the hearing-impaired student through the classification of the decision tree. Learners are taught lessons according to their preferences and aptitudes, as part of an e-learning system that reduces assessment of the learner’s learning style. The acquisition of technology-enabled teaching and learning has increased rapidly [9–13]. Increasing technological skills
in the teaching and learning processes is called Education 4.0. This automated e-learning system is also considered as an example of Education 4.0. The teaching and learning processes that support this technology are core concepts of Education 4.0. This type of technology-based teaching and learning experience provides students with opportunities for self-learning [14].

2. Literature Review

2.1. Universal Design (UD)

Universal design (UD) is the designation of products and environments for maximum use by everyone without modifications or specific designs [15]. ‘Universal’ means ‘everyone’ or ‘each person’. It is the concept of providing user-friendly products to different types of users without discrimination [16,17]. The UD view develops from the roots of the disability rights movement to an aging population, health and well-being, and social inclusion [18]. The scope of UD usage ranges from planners and designers to facility managers. In particular, it occurs in buildings, shopping malls, public facilities, the health sector, rehabilitation, and all types of disability-related groups [19–22].

In other words, universal design is dedicated to improving the quality of life through designing a better society regardless of age, gender, culture, ability, or disability [15]. Universal design facilitates everybody. No single person is targeted. Therefore, it is adopted in teaching and learning to diminish learning obstacles, make the teaching flexible, and to provide equal education for a wide range of people.

2.2. Universal Design for Learning (UDL)

The first principle underlying UDL is the belief that there are many ways to express knowledge during the learning process [23]. It involves designing teaching materials that allow diverse learners to access the content as much as possible [24]. Although UDL generally improves the learning process for all students, the impact may vary across different student groups and learning cycle [23].

In the field of special education, the universal design for learning has been adopted by applying technology to meet learners’ different desires. Its principle focuses on the concept that each learner is unique, with diverse needs. That is why universal design for learning adopted in special education should be able to create optimum learning environments that meet learners’ demands and encourage them to achieve their full potential in improving themselves. The universal design is an instant instructional media that teachers can promptly use with students.

The concept of universal learning was applied in the design of e-learning in this study, where different learning demands from each learner are considered and accomplished [25]. The solution to meet learners’ requirements was rooted in the concept of universal learning, as it was part of the lesson plan that assists teachers in constructing effective lessons for their classes [26]. The Table 1 shows that these procedures are consistent with the three UDL principles.

The application of universal design is categorized into three levels, as follows:

- 1st Level: Presentation Level

  Learning management based on universal design consists of various kinds of presentation, including the following:
  - Different patterns of information, such as images, audio, or concrete information;
  - Various languages and symbols;
  - Opportunities to revise lessons.

- 2nd Level: Communication Level

  In this level, learners are allowed to express in different ways, including the following:
  - Using their body;
  - Speaking;
  - Using executive function.
• 3rd Level: Participation Level

This level motivates learners using the following techniques:
- Providing freedom to choose;
- Encouraging an effort in performing;
- Encouraging self-regulation.

Table 1. The development of an e-learning model to identify the learning styles of hearing-impaired students.

<table>
<thead>
<tr>
<th>Universal Design Learning</th>
<th>Steps of Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Representation</td>
<td>- Design the content</td>
</tr>
<tr>
<td></td>
<td>- Make it applicable and suitable</td>
</tr>
<tr>
<td></td>
<td>- Use multimedia, such as websites, videos, images, and text</td>
</tr>
<tr>
<td></td>
<td>- Use sign language and symbols</td>
</tr>
<tr>
<td>Actions and expressions</td>
<td>- Adopt heuristic evaluation and examine satisfaction using questionnaires and suggestions</td>
</tr>
<tr>
<td>Participation</td>
<td>- Data is applied to construct an e-learning model that identifies deaf students’ learning styles through learning preferences and the principles of universal design</td>
</tr>
</tbody>
</table>

2.3. E-Learning

E-learning is defined as the sequence of lessons containing specific instructional content and activities in a standardized pattern embedded in electronic media. Inside it, there are objectives, lessons, learning activities, and achievement tests, as well as pre-tests and post-tests. Students can correct their information and monitor their learning outcome. Moreover, the interactions between teacher and students and vice versa can be conducted via chat boards or emails.

E-learning adopts electronic technology to create learning experiences [27,28]. E-learning can be considered as a well-designed learning guidance, putting the learning process as a center for everybody anywhere and at any time [29,30]. Currently, there are few teaching materials for deaf students. Most textbooks contain only texts and pictures that require sign language during the teaching process. If the instructors cannot convey meaning correctly and clearly, misunderstandings can occur. Developing an e-learning model can solve the problem systematically for the deaf students since the communication will become more accurate, precise, customizable, supportive of the deaf students’ lifestyles, and more effective for teaching and learning. Effective learning results can be facilitated by e-learning since the model itself is available everywhere and at any time [31,32].

E-learning and its technology can be an influential factor for learning among the group of people with disabilities due to their effective functions [33]. These special needs users gradually become comfortable with using computers, the Internet, TV and radio programs, and any type of education transmission [34]. An e-learning web application can be a significant tool to assist the learning process, since it includes all of the important one-stop resources [35].

The studies about special education have made us aware of the present context. The whole concept, the insufficient components among teachers, the system, and the learning methods were depicted, and new applicable learning models were sought [36]. Currently, teaching and learning methods are mostly engaged in the mainstream structure which most schools are utilizing [37–39]. The presence of e-learning will change the conventional surroundings into the accessible system provided for everyone, everywhere, and at any time.
E-learning has been playing an important role for disabled students, especially the deaf, since it is an effective tool that smartly functions, collects, and obtains information, and makes learning simpler and faster. Several countries have now paid attention to the deafs’ education equality. They help them reach the technology so that they can accomplish learning objectives and goals [40]. Consequently, e-learning has become an essential tool that facilitates everyone around the world. That is why the deaf are supposed to obtain the same rights, because they can fully benefit from the system where they can acquire knowledge and skills in a greater amount. In a conventional version, deaf students encounter some obstacles when they interact with interfaces which are not made for them. Thus, the need to construct an e-learning system specifically designed for them is apparent, since it can surely support their learning experience. The growth of e-learning usage has been obvious around the world, since it helps facilitate all related sectors in education [41]. Not only can common people take advantage of it, but deaf students will also have more options to assist in their learning [42].

2.4. Adaptive E-Learning (AEL)

Adaptive e-learning (AEL) was developed by Qazdar et al. in 2015 based on the concept that it was developed for each learner’s needs, preferences, and styles. Learners will enhance their proficiency as well as performance when they adjust to new learning experiences [43]. Several studies have insisted that adaptive e-learning, with its effective e-content suitable for different learners’ styles and preference, would improve their skills acquisition, experiences, and critical thinking skills [44–46]. The learning style of each learner is considered to be a crucial factor that impacts their learning performance; thus, it is normally seen as the root from which learning experiences stem [47–50].

Adaptive e-learning environments are designed by investigating student’s learning styles. Different learners show different learning preferences when they interact with the content provided for them, since plenty of investigations pointed out the congruence between e-learning and learning styles, which could be prompted during the learning process. As such, learning outcomes would finally be improved [51–53].

2.5. Learning Style

Learning style is defined as the way learners collect, manage, process, and make use of the knowledge or skills that they obtain, then bring it back and utilize it in the style which shows their techniques in communicating it [54–56]. Different students possess different learning styles. They recognize and store information in their mind and perform it later until they acquire the target experiences [57].

Learning style models are various, including the VARK model, one of the most famous models identifying learning styles. In this present study, we applied the model with deaf students who use sign language in communication in the form of a VRK + TSL learning model [58].

Common learners with visual ability learn with teaching materials and submit their assignments via different means, such as maps, graphs, images, or symbols, according to [59]. Literate students can utilize written learning materials, such as glossaries, handouts, textbooks, and lecture notes. Traditional learning and teaching are useful for those without disabilities [60]. However, deaf students conduct their learning activities through Thai sign language, TSL, during conversations, lectures, and discussions.

3. Materials and Methods

3.1. Research Design

This research is a quantitative study using an e-learning model to identify the learning styles of deaf students through learning preferences and the principles of universal design.
3.2. Sample

The sample group of this study is composed of the deaf students as participants, in Matthayom 1–3 (grade 7–9), from the two schools for the deaf in the northeast region, namely Khon Kaen School for the Deaf and Udon Thani School for the Deaf. Student data were collected in the first 1/65 semester of the school year for 4 weeks.

The sample group size was calculated by using Taro Yamane’s formula, as follows [61]:

\[ n = \frac{N}{1 + Ne^2} \]  

where \( n \) is the sample size;
- \( N \) is the population size;
- \( e \) is the level of precision that always sets the value of 0.05.

3.3. Decision Tree

During the late 1970s and early 1980s, J. Loss Quinlan, a specialist in the field of machine learning, developed the algorithm of the decision tree, also known as ID3 (Iterative Dichotomiser 3), which was previously adopted in the learning system by E.B. Hunt, J. Marin, and P.T. Stone. Later, Quinlan proposed C4.5 (developed from ID3), and this has become the standard for learning algorithm comparison [62]. The decision tree can be explained as the learning process occurring when classifying the data into classes using the attributes [63]. The data obtained by classification of the decision tree let us know which attribute determines the classification process, and to what extent each attribute is significant. Therefore, data classification can assist users in terms of data analysis and more precise solution making.

A decision tree is a decision-making diagram that extracts the model rules from the machine learning process [64]. It is a well-known mathematical model used for predicting and forecasting. The learning process in the decision tree is caused by teaching and learning with labels. Its structure looks similar to a flowchart, in which the non-leaf node refers to the attribute test. Each branch shows the test result. Furthermore, each terminal node will be labeled by its group names. The node located on the top, the root node, is able to be interpreted and presented. Basically, extracting rules from the machine learning model can be conducted by using the decision tree [64].

3.4. Paired Samples t-Test

The paired samples t-test compares the mean of two groups, two matching cases, or the mean of a single group by checking at two different points within the specified time. If the same group is retested in the same measurement, it is repeated measures t-test [65]. The design of the pre-test/post-test is an experimental example of a situation in which this technique is appropriately applied [66].

3.5. Difference Score

This method is obtained from the pre- and post-study measurement scores. It is a common basic method to develop scores with the concept that improvement scores are post-scores that change from pre-scores. This concept is widely applied because it is easy to calculate and convenient, without requiring advanced statistical knowledge. The development score is the post-score minus the pre-score, as follows.

This method may not be fair for people with high pre-scores, as the scores will be lower than people with low pre-scores, because it will be limited to a full score of only 10 points. This limitation is the ceiling effect.

3.6. Relative Gain

This method is obtained from the post-score and pre-score measurement scores. Relative gain score is calculated by the difference between the post-scores and the pre-scores,
with full score and pre-score difference. As a result, the ratio is multiplied by 100 to avoid decimal values [67]. The equation for calculating the relative gain score is as follows:

\[
\text{Relative Gain Score} = \frac{Y_2 - Y_1}{F - Y_1} \times 100
\]

where

- \( Y_2 \) = Score of post-evaluation;
- \( Y_1 \) = Score of pre-evaluation;
- \( F \) = full score of the evaluation.

This measurement can solve the ceiling effect problem for people who have high pre-scores, but the additional points are less for people who have pre-scores. It can also recognize people who score the same difference, but the pre-scores are not the same. People with high pre-scores received a higher relative score than people with low pre-scores.

### 3.7. Instruments and Procedure

According to the findings from the study titled "Adaptive Fleming-Type Learning Style Classifications to Deaf Students Behavior" [58], it was found that the most effective classification was the multi-layer perceptron. However, this type of classification still contained some limitations; that is, it cannot interpret the data as humans do, and cannot identify which variable or attribute most affects the prediction. On the other hand, the decision tree provides an interpretable explanation for humans [68,69], as shown in Figure 1. Thus, it was applied to predict the learning model for deaf students. The rules synthesized by the decision tree were applied for use in e-learning lessons.

![A decision tree obtained by classifying the VRK + TSL learning model.](image)

According to Table 2, the rules were obtained from the analysis using the decision tree. For example, for rule 1, if the students are between 12–13 years old and live in the area of the lower northeast region, namely the south, then they would demonstrate a K (kinesthetic) learning style. Additionally, for rule 2, if the students are between 12–13 years old and live in the area of the upper northeast region, namely the north, and are studying in Khon Kaen School for the Deaf, they would demonstrate the TSL (Thai sign language) learning style.

The e-learning model to identify deaf students’ learning styles through learning preferences and the principles of universal design in the computer, science, and technology department was conducted under the synthesized learning model consisting of the lessons, VRK + TSL learning activities, pre-test, achievement test, and post-test.
Table 2. An example of analysis using a decision tree technique.

<table>
<thead>
<tr>
<th>No.</th>
<th>Decision Tree Rules</th>
<th>Learning Style</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IF(Age = 12,13) and (Domicile = South)</td>
<td>K (Kinesthetic)</td>
</tr>
<tr>
<td>2</td>
<td>IF(Age = 12,13) and (Domicile = North) and (School = KKN)</td>
<td>TSL (Thai sign language)</td>
</tr>
<tr>
<td>3</td>
<td>IF(Age = 12,13) and (Domicile = North) and (School = UDN)</td>
<td>V (Visual)</td>
</tr>
<tr>
<td>4</td>
<td>IF(Age = 14,15) and (Level = M.2) and (School = UDN)</td>
<td>R (Reading)</td>
</tr>
<tr>
<td>5</td>
<td>IF(Age = 14,15) and (Level = M.2) and (School = KKN)</td>
<td>K (Kinesthetic)</td>
</tr>
</tbody>
</table>

The system checked the students’ data to determine whether or not they were in line with the rules obtained from the VRK + TSL learning model. Then, it presented the lesson matching with the students’ learning styles and the communication process for the deaf via the e-learning platform [70]. The content of VRK + TSL was divided into four types: namely visual, reading/writing, kinesthetic, and Thai sign language, as shown in Figure 2. Each step and learning content were matched with each student’s learning style, together with the sign language showing hand movements as well as facial expressions as a communication tool instead of verbal language [71]. The universal design was also applied.

![VRK+TSL Learning Style](image)

Figure 2. Dimensions and categories of VRK + TSL.

3.8. The Development of VRK + TSL Learning Model Based on ADDIE Concept

The ADDIE Model is made up of five significant activities, namely analyze, design, develop, implement, and evaluate [72,73]. This learning model is recognized as a well-known and widely accepted model and as an effective guidance in designing e-learning lessons. This model is flexible enough to adapt to different teaching environments and suitable for incorporating technology into teaching [74]. Its process shows inclusive steps within a closed system, and was considered from the evaluation at the final step before the data were examined, as shown in Figure 3.

The development of the VRK + TSL model based on ADDIE concept was divided into following steps:

1. Analysis (A)

The analysis and investigation of related data were illustrated below.

1.1 Data analysis: Data were collected from the teachers in the schools for the deaf in northeastern regions of Thailand, namely Khon Kaen, Udon Thani, Mukdahan, Surin,
Chaiyabhum, and Roi ET provinces. In this process, the optimum school subject was sought so that the outcome could be applied to other subjects as well as used in the competition in “Students Culture and Tradition” where they could express their different ideas and skills to reflect their academic achievement. The researcher analyzed and decided to develop a learning model for the computer subject, which is defined according to the curriculum used in Thailand and focuses on the usage of PowerPoint for teaching and learning, by following these steps:

1. Analysis (A)
   The examination and collection of subject-related documents, textbooks, and others;
   The analysis of behavioral objectives to guide the learning management and to evaluate the validity of the test;
   The analysis of learners who would employ the learning model, namely deaf students, Matthayom 1–3 who could understand sign language, from schools for the deaf in the Khon Kaen and Udon Thani provinces.

2. Design (D)
   To develop lessons and tests in each unit, the factors that should be considered are whether the multimedia contains the components that interact with the learners or not. Such components should be presented in the form of text, pictures, animations, and videos to motivate learners so that they are interested in following the content and accessing the learning component. The process of designing the VRK + TSL learning model was conducted. The interface was simplified for students, containing the main screen, the content screen, the objective screen, the subject screen, and the test screen.

   The steps that learners using the synthesized learning model should conduct are as follows. First, they must fill in their information. Then, the system checks their learning styles using the rules obtained from the analysis. That is, visual learners who enter the system for the first time will have to take a pre-test. Then, they study and conduct the post-test after the unit, and the system would be informed of the outcome.

3. Development (D)
   To develop the synthesized learning model, the steps are as follows:
   3.1 The preparation—at this phase, the learning was prepared following these steps:
      • The test was drafted into four-multiple choices based on the objectives;
      • The test was checked whether it related to its objectives by the experts;
      • The test was conducted with the students.

      3.1.2 In terms of the satisfaction questionnaires, the process is as follows:
      • The satisfaction questionnaire was developed as a five-point rating scale form employing Likert’s method [75,76].
      • The questionnaire was examined by the adviser to detect the errors and revise them.
3.2 The learning content of the e-learning model was developed under the concept of a VRK + TSL learning model analyzed by using data mining containing the following modules:

3.2.1 The first module was to classify students’ learning styles of VRK + TSL. It was conducted by comparing students’ data with the rules obtained from data classification to divide them into four groups, namely visual, reading/writing, kinesthetic, and Thai sign language. Thai sign language Learning style were incorporated into a Thai sign language video together with e-learning. Under the supervision of the National Electronics and Computer Technology Center (NECTEC), a QR code was embedded in the documents to connect with the sign language video.

3.2.2 The content was then developed into different topics and activities.

3.2.3 Teaching and learning process was also provided by presenting the content and activities during the lessons based on students’ learning styles.

3.3 The developed system was checked to consider its suitability and revised according to the adviser’s comments.

3.4 The developed system was rechecked by the experts according to the following steps:

3.4.1 The experts were selected to evaluate the developed system in terms of its technique, method, and content. The experts must be knowledgeable, with at least 5 years’ experience in teaching and learning, or with an academic achievement from a university. The three-participant sample was selected using the criteria;

3.4.2 The five-point rating scale questionnaires eliciting the experts’ opinion toward the techniques, method, and content were developed;

3.4.3 The questionnaires’ validity was assessed to find the congruence between the objectives and the content, as well as the process, by the three experts from a secondary school and university.

The questionnaires’ validity result was calculated to find the basic statistics of the content validity, the language suitability, and the question clarity by the three experts. The index of item—objective congruence, or IOC, was over 0.70, showing the congruence of the content. Some parts were revised according to the suggestions from the experts to be clearer and more comprehensible, but the original meanings still remained the same.

3.4.4 The developed system was tested by the experts and then they evaluated it using the questionnaires.

3.4.5 We revised the pilot results and had the adviser check before implementing the process.

4. Implementation (I)

The sample group, students in Grade 7–9 who could use sign language and who would employ the e-learning model for deaf students that identifies their learning styles through learning preferences and the principles of universal design, was determined at the computer laboratory of the school for the deaf in the Khon Kaen and Udon Thani provinces.

5. Evaluation (E)

The data collected from the use of the e-learning model for deaf students that identifies their learning styles through learning preferences and the principles of universal design were obtained by performing the steps illustrated below (Figure 4).

Before collecting the data, the researcher must undertake the training and obtain a certificate of Ethics for Human Research. For the data collection process, the researcher informed and asked for permission from the school before having students answer the questionnaires willingly. The details about the teaching and learning were provided for them. When they finished learning from the model, they evaluated their satisfaction, and the researcher concluded the study.

The use of e-learning lessons for students at deaf schools in the Udon Thani and Khon Kaen provinces according to the Thai sign language learning style and the scoring system summary is shown in Figure 5.
After students agree to voluntarily participate, they take a 10 questions pre-test that has been successfully assessed for conformance by experts. When e-learning is complete, there is a post-test with 10 original questions. After that, the system will evaluate the effectiveness and results of the pre-and post-learning of all students.

A test of e-learning materials was carried out by 50 deaf students in the Khon Kaen and Udon Thani provinces. Before starting to learn e-learning teaching materials, everyone starts by taking a pre-test. After that, when they have completed the study according to the specified content, everyone takes a post-test. From the data obtained in Table 3 from the pre- and post-study scores, the difference between the pre- and post-study scores and the relative gain Score indicates the learners’ developmental scores.
From Table 3, it was found that the students had higher average post-scores than pre-scores. The post-scores were 30.80 and the pre-scores were 76.40. It revealed that e-learning can, hypothetically, improve cognitive skills. It was revealed that the increase in different scores in the Thai sign language learning style was the highest at 78.00. Although the result of the kinesthetic learning model had an increase in the learning outcome value of the learning model that was not high, the relative gain score was at 66.92, which was the highest.

Kinesthetic learning affected students’ learning for better development. Students were able to see the learning process through demonstrations, which made them understand more. Another interesting learning model is the Thai sign language learning model that audiophile students use to communicate and study vocabulary in teaching materials. In-class lessons encouraged students to review and enhance their understanding of the lesson content clearly. Students could learn more new words about computer content. As a result, students showed a better understanding and learning when using this e-learning material.

From Table 3, pre-test and post-test data are graphed, as shown in Figure 6. The X-axis represents the number of students taking the test (50). The Y-axis represents the pre-test and post-test scores, with a maximum score of 100, to compare the pre-test and post-test differences and to observe the trend of post-test scores.

**Table 3.** The results for the pre-test score, post-test score, difference score, and relative gain score.

<table>
<thead>
<tr>
<th>Learning Style</th>
<th>Pre-Test Score</th>
<th>Post-Test Score</th>
<th>Difference Score</th>
<th>Relative Gain Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>35.00</td>
<td>76.67</td>
<td>76.67</td>
<td>53.87</td>
</tr>
<tr>
<td>R</td>
<td>22.86</td>
<td>72.50</td>
<td>72.50</td>
<td>54.81</td>
</tr>
<tr>
<td>K</td>
<td>29.03</td>
<td>77.10</td>
<td>48.06</td>
<td>66.92</td>
</tr>
<tr>
<td>TSL</td>
<td>38.00</td>
<td>76.40</td>
<td>45.60</td>
<td>62.80</td>
</tr>
<tr>
<td>Total</td>
<td>30.80</td>
<td>76.40</td>
<td>45.60</td>
<td>62.80</td>
</tr>
</tbody>
</table>

**Figure 5.** Test based on learning Thai sign language and the score criterion summary system.
Figure 6. Comparison between pre-test scores and post-test skill scores.

From Table 3, pre-test and post-test data are graphed as shown in Figure 7. The X-axis represents the number of students taking the test (50). The Y-axis represents the difference scores and relative gain scores, with a maximum score of 100, to compare the difference scores and relative gain scores. It revealed that even the same difference scores did not show that the relative gain scores were the same. For example, this was the case with the 12th student and the 15th student. To determine student development, relative gain scores must be considered, as they are measured by the initial pre-test and post-test scores. This solves the ceiling effect problem and makes it possible to know the order of the students who really developed.

Figure 7. Comparison between difference scores and relative gain scores.

From Figures 6 and 7, the difference in scores between pre-test and post-test was the difference scores on learning gain and relative gain scores. Overall, this describes the progression of learning with increased learning outcomes.
The comparison of pre- and post-learning achievements from e-learning lessons analyzed by a dependent sample t-test are summarized in Table 4.

Table 4. Comparison between learning achievement of pre- and post-learning students using e-learning.

<table>
<thead>
<tr>
<th>Testing</th>
<th>n</th>
<th>X</th>
<th>S.D.</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test</td>
<td>50</td>
<td>3.08</td>
<td>1.70</td>
<td>14.27</td>
</tr>
<tr>
<td>Post-test</td>
<td>50</td>
<td>7.64</td>
<td>1.69</td>
<td></td>
</tr>
</tbody>
</table>

Statistical significance level or at the 0.05 level.

The researchers needed to test that the results for the pre- and post-learning sessions of e-learning users were statistically different at the 0.05 level.

**Hypothesis:**

\[ H_0 : \mu_1 = \mu_2 \quad (3) \]
\[ H_1 : \mu_1 \neq \mu_2 \quad (4) \]

The calculated t-value of 14.27 is not equal to t from the table showing the critical value of the distribution (t) of 2.01. Consequently, it was accepted that the pre- and post-test results of students using e-learning materials differed statistically at the 0.05 level. It revealed that such e-learning materials had the effect of making students study more efficiently. Table 4 revealed that the mean of students studying e-learning lessons had a pre-score of 3.08 and a standard deviation of 1.70, and that the post-scores had a mean of 7.64 and a standard deviation of 1.69. Test scores that differed from e-learning between pre- and post-scores showed that post-scores were statistically significantly higher than pre-scores at the 0.05 level. It was based on the assumption that e-learning lessons affected better learning achievement.

Table 5 revealed that overall satisfaction with e-learning was at the highest level. When considering each aspect, students were most satisfied with the lesson design at 4.52, followed by evaluation at 4.51, and content at 4.48.

Table 5. Summary table of student satisfaction with e-learning.

<table>
<thead>
<tr>
<th>Topics</th>
<th>X</th>
<th>S.D.</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content</td>
<td>4.48</td>
<td>0.89</td>
<td>Good</td>
</tr>
<tr>
<td>Lesson design</td>
<td>4.52</td>
<td>0.84</td>
<td>Very Good</td>
</tr>
<tr>
<td>Evaluation aspect</td>
<td>4.51</td>
<td>0.87</td>
<td>Very Good</td>
</tr>
<tr>
<td>Total</td>
<td>4.51</td>
<td>0.86</td>
<td>Very Good</td>
</tr>
</tbody>
</table>

4. Discussion

The study was conducted, and the results were reported as follows. The content showed a positive correlation with adaptive students’ achievement and engagement based on their different learning styles, namely kinesthetic, visual, reading/writing, and Thai sign language. It could be assumed that a few factors have affected the findings. In other words, the designed adaptive content showed the capacity in providing an idealistic learning environment for learners and supporting them with adaptive content that suits their learning preferences. Its strength helps them learn and accomplish academic targets as well as to enjoy the learning process.

The whole research method can be demonstrated as follows:

1. To develop the e-learning system that identifies students’ learning styles through learning preferences and the principles of universal design, the researcher chose the computer subject for an experiment. This was to research e-learning design to accommodate deaf students. In [6–8], there is no analysis of adaptive e-learning. For this point, it is possible to indicate lessons and the learner’s learning style, which adds a specific feature to
e-learning. The model was analyzed, designed, developed, implemented, and evaluated. The developed version was then brought to the experts to try out, and they evaluated it with the questionnaire. The model was completely useful for the students since it could provide optimum teaching and learning suitable with their learning styles, enhancing the whole teaching and learning process.

2. To find the relative gain of the e-learning system that identifies students’ learning styles through learning preferences and the principles of universal design, data mining was conducted. The relative gain score is 66.92. The academic outcome reached the criteria, which could be explained as the learning activities met the learners’ demand and their personal learning styles. Furthermore, the nature of e-learning itself allows students to review and study as much as they want.

3. To compare the academic achievement before and after using the e-learning system that identifies students’ learning styles through learning preferences and the principles of universal design, the mean scores were examined. It was found that students achieved higher scores after using the model at the statistical significance of 0.05 because the developed model matched with their learning styles. Furthermore, learning activities during the course helped them to revise, and the test after each unit enhanced their potential.

4. To investigate student’s satisfaction with the e-learning system that identifies students’ learning styles through learning preferences and the principles of universal design, the developed model was employed with the students and their satisfaction was explored. Overall satisfaction with e-learning is at the highest level.

5. Conclusions

The present study has proposed the e-learning method and constructed an adaptive learning model with VRK + TSL based on the Fleming learning style. The target participants were the students who enrolled in a computer subject. The subject was categorized by using a decision tree classification algorithm based on their interests. Each student’s learning style was different. An optimum characteristic of an e-learning system is to be able to support the learners with what they need and prefer. To reach that step, an e-learning model should be extracted and utilized based on certain factors. The model is anticipated to design and provide materials that meet learners’ needs and styles. Four learning modes were embedded into the systems, i.e., visual, reading/writing, kinesthetic, and Thai sign language. Meanwhile, the model developed from various learning styles created engagement from learners. Students with unique learning styles tend to enjoy the learning process containing different teaching resources. Furthermore, the learning environment should also provide the optimum output to meet the needs of students. High-quality teaching resources and activities developed to match students’ learning styles stimulate them to perform better. The results showed that most of the students had an increase in relative gain, which also increased their academic performance as a result. However, the students had low scores on the pre-study test. Students can have a relative gain with full marks. When a student who takes a post-test test gets a full score on all of them, no matter how badly the student does in the pre-test, the score is not good. However, students can still have the best learning development. Students must diligently review the material from e-learning and be able to study the content. They can review lessons anytime, anywhere, and without any limitations, allowing them to complete the post-test with full marks and the highest scores.

In terms of research limitations, the characteristics of the target group could be more varied. In this present study, the participants consisted of a group of deaf students who use Thai sign language and came from different schools and locations, with different grades and ages. We, thus, anticipate that our contribution might inspire our fellows to utilize e-learning models that support different learning styles, using adaptive e-learning techniques and universal design.

Additionally, one common problem found among the deaf students using sign language is that there are some specific words used only in one certain school. To solve this
problem, some universal e-learning words were adopted from Educational Technology Substance Thai Sign Language Terminology affiliated with Ratchasuda College, Mahidol University. As such, e-learning vocabulary coordinately formulated was adopted into this study. To set up class activities based on the VRK + TSL learning model in another subject, instructors must select the activities in keeping with the subject’s objective, so they can enhance learners’ understanding and skills. This e-learning model can be further applied as a guideline for other courses or subjects and feasibly applied to other groups with disabilities, such as learners with speech or vision impairments or deaf students who use another sign language as their first language.

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**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** The participants’ datasets generated and analyzed during the current study are available on reasonable request from the corresponding author.

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**Conflicts of Interest:** The authors declare no conflict of interest.

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