Strategic study of visual, auditory, haptic information processing and identification of physics learning materials that require VAH-based learning media facilities

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Abstract. This study aims are to review cognitive theories derived from visual, auditory, and haptic (VAH) sensory and to identify physics learning materials that require digital/multimedia / video learning media that need to be enhanced with the haptic sensory facility. This study uses a quantitative method, especially content analysis. Literature used in this study were VAH information processing journals and books for cognitive reviews theory, and Hewitt’s Conceptual Physics for physics learning materials. The results of the study indicate that visual information pass through the sense of sight (eyes), auditory information pass through the sense of hearing (ears), and haptic information pass through senses of feeling (vibration, touch, palpation). This study also finds that some physics materials need to enhance with haptic sensory; namely support force, acceleration, friction, Newton’s Second Law of Motion, and Newton’s Third Law of Motion.

1. Introduction

In the era of the Industrial Revolution 4.0, the demands of digital-based learning are noticeably increasing. One part of digital-based learning is multimedia. Until now, multimedia tends to facilitate visual and auditory sensory only, whereas haptic sensory is less facilitated. Therefore, these three sensory needs to be facilitated by a new kind of multimedia. After that, that multimedia can be applied by the teacher to make meaningful learning in the classroom.

This research has two aims; to review cognitive theories derived from visual, auditory, and haptic (VAH) sensory; and to identify physics materials that require digital/multimedia / video learning media that need to be enhanced with the haptic sensory facility.

This research has broad benefits. First of all, this research contributes to learning media (multimedia learning) theory, learning styles theory, and haptic sensory theory. This research also will bring future learning media to public space. This research gives insight to teachers, so they can design effective learning media that improve students’ understanding of physics materials. Last but not least, the later researcher can continue this research by designing VAH-based learning media.

This research is based on three theories: triple coding learning media theory (VAH), VARK learning styles theory, and Mayer’s principles of multimedia learning.
1.1. Triple coding theory
Triple coding theory nickname is given by the author. This theory is a further development of dual coding theory. Dual coding theory was first coined by Allan Paivio. Paivio explains that the human learning process is pass through two systems: verbal and nonverbal [1]. Mayer interprets Paivio’s dual coding theory as two separate information processing channels, visual channel and auditory channel [2].

![Figure 1. Human learning process [1].](image1)

![Figure 2. Human learning process [2].](image2)

But now, the newest papers [3] submit a new instructional design with three separate information processing channels: visual channel, auditory channel, and haptic channel.

![Figure 3. Triple coding [3].](image3)
1.2. VAK / VARK Learning Styles Theory
VAK learning styles theory is based on the Barsch Learning Style Inventory. Barsch made this theory in 1991, and classify students’ learning styles into three groups: Visual, Auditory, and Kinesthetic. On the other side, VARK learning styles theory was developed by New Zealand education expert Neil Fleming. Fleming and Mills in his paper recount the use of modality preference questionnaires as catalysts, with the hope that students reflect on their sensory preferences and change their learning styles. Fleming classifies students’ learning styles into four groups: Visual, Aural, Read/Write, and Kinesthetic. Fleming’s and Barsch’s theory difference is Read/Write separation from Visual. By using the VARK learning styles theory, the teacher tries to adjust the learning material to the students’ learning style [4]. VAK (or VARK) modality preference is not fixed. Students should receive the learning which has all the modalities available. Students can and should develop their abilities to use the learning styles that are not their natural modes and preferences. Teachers should be focusing on learning materials’ best modalities, not students’ best modality.

1.3. Multimedia Learning Theory
Richard E. Mayer gives twelve principles of multimedia learning design and two boundary conditions for design principles [2]. The twelve principles are Coherence, Signaling, Redundancy, Spatial contiguity, Temporal contiguity, Segmenting, Pre-training, Modality, Multimedia, Personalization, Voice, and Embodiment. The two boundary conditions are individual differences condition and complexity and pacing conditions. Mayer’s dual coding mutually reinforcing combination of visual and audio, so that need to write while spelling in media [5].

2. Methodology
This study uses a qualitative methodology, specifically document/content analysis. According to Donald Ary and his teams, document/content analysis methodology has four characteristics and five possible objectives [6]. The key characteristics are: has its roots in communication studies, uses analysis of written or visual materials, describes the characteristics of the materials, and can be quantitative and qualitative. The possible objectives are: to identify bias, prejudice, or propaganda in textbooks; to analyze types of errors in students’ writings; to describe prevailing practices; to discover the level of difficulty of material in textbooks or other publications; and to discover the relative importance of, or interest in, certain topics.

Documents analyzed by the author are references about physics concepts and VAH information processing. The study was conducted by studying to determine the identification of the types and forms of VAH information processing and physics concepts that require the facilitation of VAH-based learning media. The physics materials are taken from Paul G. Hewitt’s book, Conceptual Physics [7]. Hewitt’s book is chosen by the author because that book has a comprehensive and conceptual approach, and also multimedia supported (that book has a dedicated Youtube channel, https://www.youtube.com/user/mellenstei).

3. Results and Discussions
This study results are analysis of VAH-based information processing and identification of physics materials that need VAH-based learning media facilitation.

3.1. Strategic Study about VAH Information Processing
The results of this strategic study were shown cohesively in Table 1. Table 1 shown about the processing of visual and auditory information has been widely discussed by previous researchers [2], but the processing of haptic information has not been widely discussed.
Table 1. Strategic Study about VAH Information Processing

| VAH Components | Information Processing Happen | Information Source(s) | Media which can facilitate information processing |
|----------------|--------------------------------|-----------------------|--------------------------------------------------|
| Visual         | Information entered into the eye, then processed in working memory [7]. | Images, writings, graphics | Videos, presentations on the projector, presentations on the whiteboard/blackboard |
| Auditory       | Information entered into the ear, then processed in working memory [8]. | Sounds | Voice recorder, videos |
| Haptic         | Manual interaction with the environment, include two things: the exploration of the environment to extract information and manipulate the environment [9]. | Vibration, touch, palpation | Utilities can give force feedback. |

Sigrist and teams conducted a theoretical review of the three components above [10]. According to the Sigrist group, haptic feedback is effective when carrying out easy motor tasks, whereas when carrying out more complex motor tasks, the effectiveness of haptic feedback still needs to be studied. According to the author, visual information processing only requires a sense of sight, and other senses (hearing, feeling) can be closed. Auditory information processing only requires a sense of hearing, and other senses (vision, feeling) can be closed. Nevertheless, haptic information processing only requires a sense of feel, and other senses (vision, hearing) can be closed.

3.2. Strategic Study about Identification of Physics Materials that Needs VAH-based Learning Media

The results of the strategic study about the identification of physics materials that can be learned through VAH-based information processing so that it requires VAH media from Conceptual Physics book [7] is shown cohesively in Table 2.

Table 2 explains about Chapter 1 material in Hewitt's book does not require haptic media, because the chapter only deals with science, physics as basic science, scientific measurement, and scientific methods. Chapter 2 material in Hewitt's book requires haptic media, especially the sub-chapter Support Force. Support force is the force acting on objects to support an object on its base. Support force can be felt but cannot be seen directly, nor can it be heard, therefore it is very difficult to learn. A tool that can provide force feedback is needed so that the support force can be felt and learned. Chapter 3 material in Hewitt's book requires haptic media, especially sub-chapter Acceleration. Acceleration is a change in speed, can be felt but is very difficult to see or hear, therefore it is necessary to use haptic media. A tool that can provide force feedback is needed so that acceleration can be felt and learned. Chapter 4 material in Hewitt's book heavily requires haptic media. Newton's Second Law of motion does require haptic media because acceleration is included in the law. This chapter also studies friction forces, which also cannot be seen but can be felt. A tool that can provide force feedback is needed so that acceleration, friction, and ultimately forces can be felt. Chapter 5 material in Hewitt's book requires haptic media. The essence of Newton’s Third Law of motion is action and reaction forces. The action forces are easy to understand because we do it, but the reaction forces are difficult to understand. We can’t see and hear reaction forces, although we can feel it. does require haptic media because acceleration is included in the law. A tool that can provide force feedback is needed so that the reaction force can be felt and learned.
Table 2. Identification of Physics Materials that Needs VAH-based Learning Media

| No | Sub-Chapter | Chapter Brief Summary | Learning Activities | V/A/H Media |
|----|-------------|-----------------------|--------------------|-------------|
|    |             |                       |                    |             |
|    | CHAPTER 1 About Science | | | |
|    | 1.1 Scientific Measurements | Scientific measurements done by scientists from ancient times until present days. | Observe measuring instruments in the laboratory. | V |
|    | | | Use measuring instruments in experiments. | V, A |
| | | | Watch the video "Eratosthenes and the round Earth" from Hewitt’s Youtube channel (https://www.youtube.com/watch?v=g3X82CaKJb8). | |
|    | CHAPTER 2 Newton’s First Law of Motion—Inertia | | | |
|    | 2.3 Newton’s First Law of Motion | Explanation of Newton’s First Law of Motion. | The teacher gives an explanation to students using whiteboard, blackboard, or projector. | V, A |
|    | 2.6 Support Force | Explanation of support force. | Students are asked to sit in a chair that can give force feedback when occupied. | V, H |
|    | CHAPTER 3 Linear Motion | | | |
|    | 3.4 Acceleration | Explanation of acceleration. | Students are asked to sit in a chair that can give force feedback when occupied. | V, H |
|    | CHAPTER 4 Newton’s Second Law of Motion | | | |
|    | 4.1 Force Causes Acceleration | Explanation of force causes acceleration. | Students are asked to sit in a chair that can give force feedback when occupied. | V, H |
|    | 4.2 Friction | Explanation of friction force. | Students are asked to sit in a chair that can give force feedback when occupied. | V, H |
|    | | | Students are asked to rub their skin with their hands or brush and feel the sensation experienced on the rubbed skin. | |
|    | 4.4 Newton’s Second Law of Motion | Explanation of Newton’s Second Law of Motion. | Watch the video from Hewitt’s channel (https://www.youtube.com/watch?v=tM9swQG3M1w). | V, H |
|    | | | Students are asked to sit in a chair that can give force feedback when occupied. | |
|    | 4.5 When Acceleration Is g—Free Fall | Explanation of free fall. | Students are asked to sit in a chair that can give acceleration worth g when occupied. | V, H |
|    | 4.6 When Acceleration Is Less Than g—Nonfree Fall | Explanation of motion in which acceleration is less than g. | Students are asked to sit in a chair that can give acceleration worth less than g when occupied. | V, H |
|    | CHAPTER 5 Newton’s Third Law of Motion | | | |
|    | 5.2 Newton’s Third Law | Explanation of | Watch the video from Hewitt’s channel | V, A |
Law of Motion
Newton’s Third Law of Motion. (https://www.youtube.com/watch?v=kQfM-q4xbfo).

5.3 Action and Reaction on Different Masses
Explanation of action and reaction on different masses.
Students are asked to sit in a chair that can give force feedback when occupied.

Chapter 1 material in Hewitt's book does not require haptic media, because the chapter only deals with science, physics as basic science, scientific measurement, and scientific methods.

Chapter 2 material in Hewitt's book requires haptic media, especially the sub-chapter Support Force. Support force is the force acting on objects to support an object on its base. Support force can be felt but cannot be seen directly, nor can it be heard, therefore it is very difficult to learn. A tool that can provide force feedback is needed so that the support force can be felt and learned.

Chapter 3 material in Hewitt's book requires haptic media, especially sub-chapter Acceleration. Acceleration is a change in speed, can be felt but is very difficult to see or hear, therefore it is necessary to use haptic media. A tool that can provide force feedback is needed so that acceleration can be felt and learned.

Chapter 4 material in Hewitt's book heavily requires haptic media. Newton's Second Law of motion does require haptic media because acceleration is included in the law. This chapter also studies friction forces, which also cannot be seen but can be felt. A tool that can provide force feedback is needed so that acceleration, friction, and ultimately forces can be felt.

Chapter 5 material in Hewitt’s book requires haptic media, especially in the core sub-chapter. The essence of Newton’s Third Law of motion is action and reaction forces. The action forces are easy to understand because we do it, but the reaction forces are difficult to understand. We can’t see and hear reaction forces, although we can feel it. does require haptic media because acceleration is included in the law. A tool that can provide force feedback is needed so that the reaction force can be felt and learned.

The authors have a design proposal for answer problems above this text, which is a chair or a floor. A haptic chair or haptic floor is designed in such a way that it can be controlled by students or teachers. The sketch is shown in Figure 4.

There are several studies that have tried using force feedback tools, and all studies conclude that students can learn the material more easily by force feedback [11].

**Figure 4.** Design proposal that can facilitate haptic sensory, either a chair or a floor.

Figure 4 shows two designs to facilitate the haptic sensory. The first design is a haptic chair that is a chair that can shake or sway if the material discussion requires shaking illustrations for each student.
who sits on it. While the second design is a floor that can sway which can cause all chairs located on the floor to vibrate. The first design requires a rocking machine for each seat, but the first design only requires a few floor-shaking machines. The first design advantage is that each chair can have shocks that can be adjusted according to the needs of the chair.

4. Conclusions and Suggestions
The study of visual, auditory, and haptic (VAH) cognitive theory states that visual information enters through the sense of sight (eyes), auditory information enters through the sense of hearing (ears), and haptic information enters through the senses of feeling (vibration, touch, palpation).

The study of Hewitt’s book review states that there are some materials that need to be enhanced using haptic sensory because it is very difficult to learn only with visual and auditory sensory only. These materials are normal force, acceleration, Newton's Second Law, friction force, and Newton’s Third Law.

For the next researchers, they can continue this research with further analysis and covering more materials, so this research will be more comprehensive than it is now. Next researchers can also try to implement our design proposal into the classroom.

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