Metadata of the chapter that will be visualized in SpringerLink

Book Title	Immersive Learning Research Network	
Series Title		
Chapter Title	Adaptive Hypermedia Driven Serious Game Design and Cognitive Style in School Settings: An Exploratory Study	
Copyright Year	2019	
Copyright HolderName	Springer Nature Switzerland AG	
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Keywords (separated by '-')	Serious games - Adaptive hypermedia - Cognitive styles - Holist-serialist

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Adaptive Hypermedia Driven Serious Game Design and Cognitive Style in School Settings: An Exploratory Study

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Abstract. The potential value of adaptive hypermedia and game based learning to education and training has long been recognised, numerous studies have been undertaken in both those areas investigating its potential to improve learner performance. In particular research has indicated that tailoring content to match the prior knowledge of the user has the power to increase the effectiveness of learning systems. Recent studies have begun to indicate that Adaptive Hypermedia Learning Systems (AHLS) based on cognitive styles have the power to improve learner performance. Recent examples of research exploring avenues for effectively incorporating serious games into AHLS indicated that integrating serious games into a personalized learning environment has the potential educational benefits of combining a personalized delivery with increased learner motivation. The exploratory study presented in this paper here developed an Adaptive Hypermedia Driven Serious Game (AHDSG) based around Pask's Holist-Serialist dimension of cognitive style. A prototype AHDSG was designed and developed to teach students about Sutton Hoo and archaeological methods. Sixty-six secondary school students participated in this study. Overall the findings of this study show that there was an improvement in performance among all participants. Although the participants that used the system which adapted to their preferred cognitive style achieved a higher mean gain score, the difference was not significant.

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1 Introduction

It has long been recognised that people learn and process information in different ways, however opinions regarding the validity of the numerous cognitive style theories vary greatly among academics in the field. Recent studies have begun to indicate that Adaptive Hypermedia Learning Systems (AHLS) based on cognitive styles have the power to improve learner performance [11]. An AHLS can be defined as an interactive training resource designed to personalise content and navigation based on the

© Springer Nature Switzerland AG 2019
D. Beck et al. (Eds.): iLRN 2019, CCIS 1044, pp. 1–14, 2019.
https://doi.org/10.1007/978-3-030-23089-0_11

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individual characteristics of each user. Many of these systems have been developed to tailor content to match the prior knowledge or cognitive style of the user.

Although there are various cognitive style models, Witkin's Field Independence/Dependence model is one of the most widely studied within the context of AHLSs [20]. Witkin defines field-independent learners as those that work within an internal frame of reference and are able to structure their own learning, whereas field-dependent learners rely on an external frame of reference and require guidance from the instructor. Conceptual links have been identified between the Field Independence/Dependence model and Pask's Holist-Serialist model [15], however relatively few studies have investigated the merits of the later in relation to AHLS [3]. A study investigating the effects of an AHLS based on Pask's Holist/Serialist model on postgraduate students indicated an increase in learner performance [11].

Recent research stresses the benefits of Games[1] and Simulations[2], so called Serious Games[3](SG) [23, 29], in increasing learner motivation through: (a) increasing learner engagement achieved by a combination of education and entertainment, introducing fun into the learning process [24]; and (b) the adaptation of the interactive learning experience responding to the evolution of learners' needs and requirements [25]. Adding fun into the learning process makes learning not only more enjoyable and compelling, but more effective as well [30]. A game that is motivating makes learners become personally involved with playing it in an emotional and cognitive way. By engaging in a dual level, learner attention and motivation is increased [31]. However, depending on the topic which is being covered Games and Simulations may be more or less suitable depending on the topic or the user's cognitive style.

This project aims to broaden current research by examining the capacity of Holist/Serialist based Adaptive Hypermedia Driven Serious Game (AHDSG) to improve the performance of learners in Key Stage Three (KS3).

Educators are encouraged to adapt their style of delivery to accommodate the varied cognitive styles of their students, logistically and technically this can be hard to achieve as teachers need the technical expertise to produce resources that meet the needs of all students. The ever-increasing use of hypermedia within educational environments affords an opportunity to meet the individual needs of each learner leveraging the power of AHDSG.

2 Background

2.1 Adaptive Hypermedia

Hypertext and Hypermedia. The meanings of the terms hypertext and hypermedia vary considerably within the research community, Wardip-Fruin argues that a historical

[1] We recognise games as recreational activities whose main objective is the entertainment.

[2] Simulations are about trying to recreate a situation that occurs in real life through a game.

[3] Serious Games are characterised as games/interactive gamified applications having other purposes besides the element of entertainment, such as education or training.

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approach can be employed to determine a common meaning. The terms hypertext and hypermedia were originally coined by Nelson in 1965 [13] and developed further in 1970 [14, 20]. Hypermedia take the form of branching presentations consisting of words and pictures, which the user can control and explore freely, whereas hypertext is a form of hypermedia which consists of discrete pieces of text that are connected by links [14].

The following section will discuss the limitations of ordinary hypermedia systems and how these may be addressed through the use of adaptive hypermedia systems.

Adaptive Hypermedia Systems. The non-sequential nature of standard hypermedia systems offers many advantages to the learner, allowing them to access and process the content in any order. On the other hand, they do have limitations; they are unable to cater for the diverse individual characteristics of the users, for instance goals, interests and knowledge [2]. Different users may require alternate navigational structures or alternate content. Adaptive hypermedia systems are designed to address this void by personalising the content and navigation based on the individual characteristics of each user.

Adaptive Hypermedia Driven Serious Games. The potential value of AH to education and training was quickly recognised, numerous studies have been undertaken investigating its potential benefits. For example, a range of studies have investigated the potential benefits of adapting learning experiences according to learning and cognitive styles [41]; focusing on factors such as learner performance, perceptions and satisfaction [21]. The Felder-Silverman learning style model [42] is most commonly applied to this field, however Truong [41] suggests that research focusing on different models is required. Cognitive styles, which are different to learning styles [18], have received less attention from researchers andit has been indicated that AHDSGs based on Pask's Holist/Serialist model of cognitive styles have the potential to increase learner performance [11]. Before investigating AHDSGs further it is necessary to gain an understanding of serious games (see Sect. 2.2) and cognitive styles (see Sect. 2.3).

2.2 Serious Games

Digital computer games have now been around for over three decades and the term games-based learning has been attributed to the use of computer games that are thought to have educational value, however there has been much debate surrounding this theory [32]. Research [27, 30, 33–35, 37, 38] indicated the educational benefits of serious games in assisting learning by providing an alternative way of presenting instructions and content on a supplementary level. Games and gamified environments can promote student motivation and interest in subject matter resulting in enhanced learning effectiveness. In recent years, a huge effort has been made towards the development of educational gaming experiences and the exploration of their advantages for learning by introducing a set of possible educational scenarios using leaderboards, badges, level-systems, geolocation services, achievements and rewards [39]. Wrzesien & Alcañiz

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Raya [28], conducted a thorough literature of serious games during the last decade and identified three main reasons for their growing use in education:

- they use actions rather than explanations and create personal motivation and satisfaction;
- they accommodate multiple learning styles and abilities;
- they foster decision-making and problem-solving activities in a virtual setting.

Mayo [26] discusses that SG are becoming a recognized venue of creative attempts to develop students' skills and attributes in both formal and informal educational settings due to the potential benefits of their use in educational contexts like: massive reach; experiential learning; enquiry-based learning; self-efficacy; goal setting; cooperation; continuous feedback; enhanced brain chemistry; time on task.

The successful use of SG for learning is based on:

- adopting gamified elements that support increased motivation and engagements which are usually considered prerequisites that lead to learning;
- accommodate multiple learning styles and abilities;
- adapt to users/learners learning and cognitive style.

The next section will discuss the two dimensions of cognitive style theories (verbalizer-visualiser and wholist-analytic) that can be potentially integrated in AHDSG.

2.3 Cognitive Styles

The terms learning style and cognitive style are perceived by many to have similar meanings and are therefore often used interchangeably. However, studies have shown that these terms should be treated as separate constructs [18]. Cognitive styles have been defined as individual different preferences of organising and processing information and experience whereas learning styles are individual skills and preferences that affect how students perceive, gather and process learning materials. Cognitive styles are generally seen as stable characteristics and learning styles are seen as variable, dependent on the environment [12]. Numerous theories relating to identification cognitive styles have been put forward, Riding and Cheema [17] found that they could be grouped under two dimensions; Verbaliser-Visualiser and Wholist-Analytic. This section will now provide an overview of each dimension:

Theories, which fall within the verbaliser-imager dimension are used to describe the different modes and methods of thought among individuals, placing them into one of two categories. Imagers (also known as visualisers) tend to think in the form of mental pictures whereas verbalisers are more inclined to think in the form of words [17]. Table 1 on the following page outlines the three main measures used to assess the verbaliser-visualiser dimension.

The wholist-analytic dimension of cognitive style has particular relevance to the learning preferences of individuals. Research has indicated that analytic students prefer to learn sequentially, building understanding in a logical and guided manner. However,

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Table 1. A summary of the theories grouped within the verbaliser-imager dimension by riding and Cheema (1991).

Individual difference questionnaire	Paivivo, 1971
Verbaliser-Visualiser	Richardson, 1977
Verbal-Imagery	Riding & Taylor, 1976

wholist learners need to start with an overview of a topic before drilling down to the fine details [17]. Table 2 outlines the five main theories grouped under the wholist-analytics umbrella:

Table 2. Summary of the main theories grouped within the wholist-analytic dimension by Riding and Cheema (1991).

Field dependence-Independence	Witkin, 1962
Impulsivity-Reflectivity	Kagan, 1965
Convergent-Divergent Thinking	Hudson, 1966
Leveller-Sharpener	Holzman & Klein, 1954
Holist-serialist	Pask, 1972

A number of studies have investigated the benefits of developing an AHDSG based around the Wholist-Analytic dimension of cognitive style, with particular focus being paid to Witkin's Field Independence/Dependence model. However, relatively few studies have investigated Pask's Holist/Serialist model [3]. Research has indicated that Holists and Serialists tend to approach hypermedia in different ways, for example Ford and Chen found that Holists preferred to navigate using the sitemap and spend more time studying the high-level content [9]. On the other hand, Serialists preferred to utilise the Back/Forward buttons in order to navigate and spend more time studying the deeper levels. Table 3 outlines the differences between the Holist and Serialist interfaces implemented in the Mampadi et al. study [11].

Table 3. The differences between the Holist and Serialist interfaces implemented in the Mampadi et al. study [11].

Adaptive hypermedia	Holist interface	Serialist interface
Direct Guidance	No guidance	Next/previous buttons
Link Hiding	Rich links	Disabled links
Adaptive Layout	Hierarchical map	Alphabetic index

Mampadi et al. [11], found that an AHLS based on the Holist-Serialist cognitive model has the potential to improve the performance and perceptions of students in higher education. This study aims to investigate whether similar affects are observed among learners in KS3 (aged 11–14) when using an AHDSG. The adaptive techniques employed by Mampadi et al. could be considered as coming under the category of *adaptive navigation support* [40].

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3 Hypothesis

It was the hypothesis of this case study that it would produce evidence to indicate that an AHDSG based on Pask's Holist-Serialist cognitive model might have the potential to improve the performance of learners in KS3.

In order to allow comparison, a serious game was designed and developed with three modes; ordinary, serialist and holist. The serialist and holist modes employs the following adaptive hypermedia techniques outlined by Mampadi et al. [10]:

- Direct guidance: This technique is usually implemented through the use of 'next' and 'previous' buttons. This suits the needs of Serialist learners, guiding them through the content;
- Link hiding: Serialists tend to prefer a linear navigation structure, often becoming disoriented when presented with too many navigation choices. This can be avoided by disabling the links within the body of the page;
- Adaptive layout: It has been found that Holists prefer to use a hierarchical map in order to understand the structure of the content, whereas Serialists favoured the use of the alphabetical index [11].

4 Material Preparation

4.1 Design of the Adaptive Hypermedia Driven Serious Game

The 'Discover Sutton Hoo' AHDSG was developed in order to evaluate the hypothesis. It serves as an introduction to the Anglo-Saxon period and general archaeological principles for learners in KS3. The narrative is based around Sutton Hoo, a site of great archaeological importance. An excavation carried out in 1939 uncovered an undisturbed ship burial containing a wealth of Anglo-Saxon artefacts. It is believed to be the burial of King Rædwald, the ruler of East Anglia during the 7th century.

During the development of the serious game it was decided to allow the users to take on the role of Basil Brown, the archaeologist that excavated the main ship burial during 1939. As Basil Brown the users excavate several selected representative artefacts which ensure coverage of key archaeological principles and facts regarding the Anglo Saxons. After each artefact has been selected the user is presented with a video which presents further information relating to the artefact. Knowledge and understanding are then developed and assessed using a range of interactive activities such as puzzles and quizzes.

The 'ordinary' mode of the AHDSG consists of all the features suitable for both Holist and Serialist learners. For example, it will contain both 'next' and 'previous' buttons and links within the body of the page. In the ordinary mode once the user has finished excavating the artefacts each one becomes a hyperlink which allows the user to find out more about it, this is shown in Fig. 1. In this mode the user can select each artefact in any sequence.

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Fig. 1. Excavated artefacts in ordinary mode

Figure 2 shows the excavated artefacts in the serialist mode, here the user is presented with a next button which guides the user through the videos and activities in a set sequence designed to scaffold the acquisition of knowledge and understanding.

Fig. 2. Excavated artefacts in serialist mode

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Finally, in the holist mode the user is presented with an index screen (as shown in Fig. 3) before uncovering the artefacts, this provides the user with an overview of all content. This enables the user to choose the sequence in which they wish to navigate through the product.

Fig. 3. Holist mode index screen

4.2 Study Preference Questionnaire

Ford (1985) developed the Study Preference Questionnaire (SPQ) for a study designed to investigate the impact of matching and mismatching holist and serialist learning materials to the cognitive styles of postgraduate students. The SPQ proved particularly effective as a cognitive style assessment tool and has therefore been utilised in several subsequent studies [4, 5, 9, 11].

In the questionnaire participants were asked to show their level of agreement with two statements. The level of agreement was measured on a five-point scale, point one indicating full agreement with the first statement and point five indicating full agreement with the second statement. In an evaluation of the questionnaire's performance Ford [6] highlighted five items, which proved particularly effective in the assessment of an individual's preferred cognitive style. For the purposes of this study these five items were adapted for use with KS3 students and presented in the form of an electronic questionnaire, which the students completed after the introduction to the topic, before using the AHDSG. The items in the questionnaire evaluate whether the learner prefers to:

- Focus on the most important parts of information or read through the information in order;

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- Learn about one topic or multiple topics at the same time;
- Look at the parts of a topic that interest them the most or learn each part in a logical order;
- Wait until they fully understand a topic before moving on or not;
- Read a book in order or skip about between sections.

4.3 Pre- and Post-Assessments

In order to assess the subject knowledge of each participant prior to using the system, an electronic, multiple-choice assessment based around the Anglo-Saxons was developed using Fronter [16], the participating school's virtual learning environment (VLE). At this point in KS3 it is anticipated that the students know that Anglo-Saxon were settlers in the Britain, however they would not have an understanding of their customs. A similar assessment was also developed in order to assess the amount of progress made by each student after using the system, a sample of the questions included in the post assessment can be seen in Fig. 4. This allowed the comparative effectiveness of the adaptive (holist and serialist) and ordinary hypermedia modes to be evaluated. Some students scored above 70% in the pre assessment, although this demonstrated a high level of prior knowledge it stills shows room for development, which can be evidenced through analysis of the gain scores. Therefore, it was decided that it would be valuable to include these participants in the study. The only exception is the six students that scored 100% in the pre assessment.

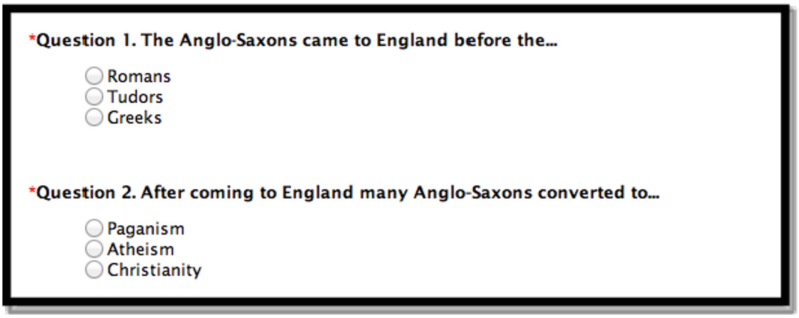

Fig. 4. Questions from the post assessment

5 Study

The study was conducted within a large UK secondary school. 66 Year 7 students (11–12 years old) participated in the experiment over a period of two days. The school provides all Year 7 students with one 50 min ICT lesson per week, therefore the participants already possessed the skills necessary to operate the AHDSG.

An ICT suite in the participating secondary school was chosen as the most suitable environment for this evaluation. The participants were already familiar and comfortable

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with this environment. The computers were laid out in a U around the edge of the room, with an interactive whiteboard (IWB) at the front for teacher demonstrations.

In order to evaluate the comparative effectiveness of the adaptive and ordinary modes the students were divided into two groups, Group A used the mode which matched their cognitive style, whereas every student in Group B used the ordinary mode. Three form groups were provided by the school for participation in the study during their normal ICT lessons, two of these forms groups formed Group A and the remaining group formed Group B. The participants from each group went through the same procedures, with the mode of the system being the only variable. Three 50 min sessions took place over the two days; each session consisted of one researcher and 20–23 students. Prior to the first session each of the research instruments were placed on the school's VLE (Fronter) in order to allow the results of each activity to be accurately recorded.

The following outlines the procedure that was followed during each session:

- The participants were informed that they were going to be using an educational program in order to learn about the Anglo-Saxons.
- The researcher used the IWB to introduce the pre-assessment. Next the participants were asked to take the pre-assessment to measure their level of knowledge before using the system. The students could only attempt each question once.
- The researcher introduced the SPQ and explained that it is designed to identify how the students prefer to use electronic learning material. The participants then completed the SPQ.
- Based on the result of the SPQ the participants in Group A were directed to use appropriate mode that have been designed for the Discover Sutton Hoo system. Students in Group B (both Holists and Serialists) were all directed to the ordinary mode. At this stage each participant was issued with a pair of headphones to facilitate full emersion within the system.
- Finally once the participants had completed all the activities in the Discover Sutton Hoo system they were directed to the post-assessment, which included questions designed to assess the current level of understanding.

6 Results and Discussion

6.1 Analysis

The results of the SPQ were used to categorise each participant as either a serialist or holist. Participants that received results of below 50% in the SPQ were categorised as holists and the participants that received results 50% or above were categorised as serialists. The gain score for each participant was calculated by subtracting the pre-assessment score from the post-assessment score, this measure was used as an indication of the progress made after using the AHDSG.

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This data was split to form four tables; Holists (Adaptive Hypermedia), Serialists (Adaptive Hypermedia), Holists (Ordinary Hypermedia), and Serialists (Ordinary Hypermedia). The mean pre-assessment, post-assessment and gain scores were calculated for each of the aforementioned tables, these can be seen in Table 4 below.

Table 4. The means of pre-assessment, post-assessment and gain scores

	Holist		Serialist	
	Ordinary	Adaptive	Ordinary	Adaptive
Pre-Assessment	60%	55%	67%	66%
Post-Assessment	80%	84%	82%	89%
Gain	33%	53%	22%	34%

6.2 Impact on Learner Performance

The performance of learners in both groups was analysed using the pre-assessment, post-assessment and gain scores. The mean scores for the holists and serialists in both groups are shown in Table 4 below:

Looking at Table 4 above it can be seen that the mean post-assessment and gain scores for the Holists in the adaptive hypermedia group are higher than the mean gain scores for the ordinary hypermedia group; this relationship is also illustrated in Fig. 5 below. The mean post-assessment and gain scores for the Serialists in the adaptive hypermedia group are also higher than the mean scores for the ordinary hypermedia group. There is a 20-percentage point difference in the mean gain scores of the ordinary and adaptive groups for the Holists and a 12-percentage point difference for the Serialists. The overall mean gain score, calculated by taking the mean pre and

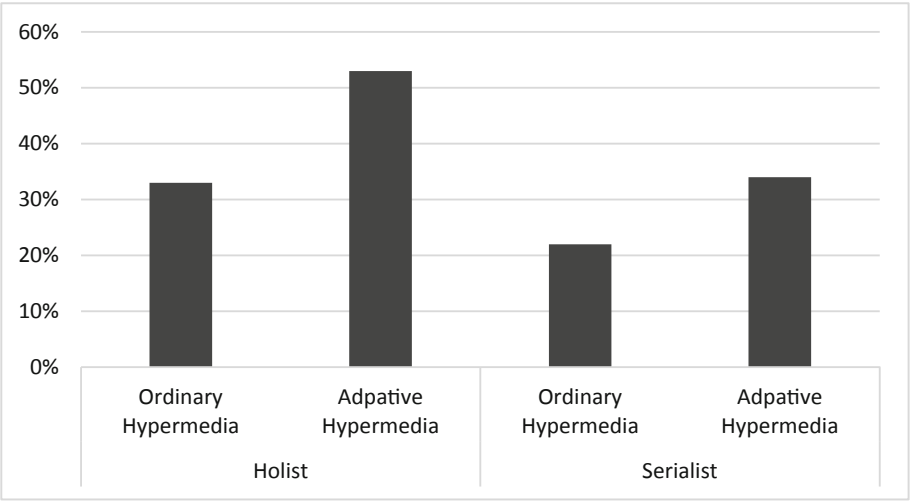

Fig. 5. A comparison of gain scores

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post-assessment scores for all participants and calculating the percentage change, is 36%. A related-samples Wilcoxon Signed Rank Test demonstrated that the effect size of the results for both groups combined is significant ($p < .001$). An independent-samples Mann-Whitney U test was employed to test the significance of the difference in results between the two groups. This demonstrated that the difference in the results was not significant (p.071).

Although the mean gain scores give some indication that matching the navigation system to the preferred cognitive styles of learners may have a positive impact on performance, this conclusion cannot be confirmed as the difference is not significant. However, the use of either type of system does seem to produce an increase in performance that is significant. These results could potentially be explained by the fact that the learners that used the non-adaptive version of the system were able to navigate the system in any manner and may have instinctively navigated in a way that matched their preferred cognitive style.

7 Conclusions

This study set out to examine whether AHDSGs based on Pask's Holist/Serialist model of cognitive style have the capacity to improve the performance of learners in KS3. An AHDSG designed to teach KS3 students about Anglo-Saxons and basic archaeological concepts was developed in order to evaluate this hypothesis. Analysis of previous studies relating to AHDSGs and cognitive style has shown that little attention has been paid to Pask's Holist/Serialist model and the main focus been on undergraduate and postgraduate students. This study aimed to shift the focus in order to investigate the impact on younger learners.

The results of this study have demonstrated that all participants made measurable progress after using the system, regardless of whether it was adapted to their preferred cognitive style. There was not a significant difference in performance between the participants that used the system that adapted to their preferred cognitive style and those that did not. This could be potentially be explained by the way in which the 'ordinary' version of the system enabled the learners to navigate in either a liner or non-linear manner; thus, potentially resulting in them navigating in accordance with their preferred cognitive style. This area could potentially be explored further by capturing and evaluating the navigation approaches employed by holists and serialists when using the 'ordinary' version of the system.

The focus of this exploratory study was limited to performance, however there is scope to evaluate other factors that have been examined in previous studies such as perceptions and satisfaction. Therefore, it is recommended that further research is needed to investigate the possible impact of AHDSGs on a range of factors in order to fully evaluate the potential benefits of these systems for young learners.

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