Migration Letters

Volume: 21, No: S8 (2024), pp. 703-712

ISSN: 1741-8984 (Print) ISSN: 1741-8992 (Online)

www.migrationletters.com

Effect Of Instructional Media On Extraneous Cognitive Load: A Study Of Elementary Level Students In Pakistan

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Abstract

The study was experimental in which the researchers used a quantitative approach to collect data. It investigated the effect of instructional material on the extraneous cognitive load of students in the subject of general science at the elementary level in a district of Punjab. The population of the study was 7th-grade students enrolled in high schools, from the school education department. The cognitive load test developed by Leppink, Paas, Van der Vleuten, & Van Merriënboer (2013) was adapted with the permission of the author and used as a pretest and post-test for measuring the Extraneous cognitive load of students. The validity and reliability of the instrument were confirmed. Three groups of participants were selected randomly. They were taught using PowerPoint slides, Textbooks, and Instructional videos. The data were analyzed using descriptive and inferential statistics. The study could be useful from a theoretical, managerial, and academic standpoint. According to the findings, the extraneous cognitive load of participants of groups using textbooks and videos was found higher than the participants taught using power points presentation as an instructional medium.

Keywords: *Media in education, Extraneous cognitive load, Textbook, instructional material, Elementary education.*

Introduction

Advancements in instructional technology have highlighted some limits of the human mind. Learning may be affected by instructional material (Ubimago, 2021)used in the teaching-learning process because of the load on the student's mind (working memory). Thus, the instructional material used in the classroom matters a lot, whether it will help elicit learners' activities and cognitive processes that may or may not lead to knowledge construction(Wambui, 2013). These understandings lead researchers to consider major features of human cognitive architecture as important factors (cognitive load) to assu[1]re the effectiveness of instructional material. Therefore, teachers should understand how to use instructional material in the classroom to manage the cognitive load of the students. Teaching learning is a very complex process, depending on several factors. One of them is instructional material. Instructional materials are the tools for transmitting or delivering messages, especially delivering content to the learners to achieve the learning objective. Media becomes one influential factor that may affect students' involvement, learning achievement, and cognitive load.

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Moreover, the content delivered by the teacher to students in the classroom will be more easily understandable. In addition, instructional materials are defined as physical tools used in conveying information, in the form of learning material to students(Ajoke, 2017). Instructional material is a tool to ease the teacher to transfer knowledge to achieve the learning objectives. Therefore, the media plays an important role in teaching and learning activities by facilitating both the teacher in delivering the material and students in understanding the content being delivered to reach the learning objectives.

In general, there are three main kinds of media, namely, the students themselves, realia, pictures, coursebook, board, overhead projector, flip charts, and computer-based presentation technology.

Printed media is one of the types of media that can be used in the teaching and learning process. Media have a lot of benefits on the teaching and learning process as long as it is properly designed, well-produced, and effectively used(Martin & Betrus, 2019). Effective media makes an easier way for teachers to transfer knowledge in an organized way and more systematically. Besides, it helps the teachers to save their time and energy. There are different benefits of using media in the teaching and learning process, are; saving time, increasing interest, holding attention, clarifying ideas, reinforcing a concept, adding tone, proving a point, and aiding memory.

The use of instructional material in the teaching and learning process can arouse new desires and interests, generate motivation stimulate learning activities, and even bring psychological influence on students (Dar et al., 2022). One way to increase students' attention and involvement in learning activities requires supporting tools in the form of visual aids because conceptual visualization is very helpful in concretizing abstract or theoretical concepts. It can be in the form of images, animations, simulations, and videos in learning. Accurately designed visualization of a concept can be used as a useful analogy to concrete abstract knowledge. All the ambiguities, clarity of concepts, and understanding can be achieved by using technology in the classroom. It can also enhance the interest of the learner in the topic. A teacher plays a vital role in our education system. Teachers are always striving to identify new ways of learning for students. It is important to note that computer technology has had a major influence on cognitive science theory. Using technology as instructional material in the form of projected material in the class is very important because it can either increase or reduce the cognitive load of the learner (Ayres & Paas, 2007). A teacher can help learners retain and retrieve information by properly managing the cognitive load imposed due to instructional material. The traditional lecture method is dominant in science classrooms. Most of the courses are text-based and are conceptualized as teacher-centered instead of learner-centered. An over-reliance on the textbook as a source of knowledge to be transmitted means that the extraneous cognitive load of learning science will be high.

Teaching General Science with instructional technology was found to be more effective and successful as compared to traditional teaching regarding retention of learning. The critical features of science texts are the multiple representations, such as text and visual elements, which assist in the representation of science concepts. Therefore, a teacher should control the extraneous cognitive load. This research study discussed the effects of both instructional materials on the cognitive load of students. The printed media used in this research was a textbook containing relevant images with different concepts while the digital one was the use of technology. Thus, more work is needed to be done to understand the extent to which instructional material affects the extraneous cognitive load of learners. Therefore, investigating the effect of instructional material from a cognitive load perspective was the focus of the proposed study. The elementary level is considered a fundamental step for creating and developing a basic understanding of science subjects that may help study science curricula in the form of physics, chemistry, and biology at the secondary level. Therefore, this study was proposed to investigate how different instructional materials affect learners' extraneous cognitive load in general science at the elementary level.

Review of the Literature

According to Coccia (2018), science being an organized social effort reveals the concerns as well as interests of society in addition to nations for achieving scientific discoveries to support humankind. This statement is further supported by Mosher (cited in Paas & van Merriënboer, 2020) within a more localized context, he acknowledged the significance of teaching science that assists students in the development of higher-order thinking skills, so that they may face the challenges of daily life. Higher order or critical thinking skills are of significant importance being twenty-first century skills. In the Pakistani context, different studies have been conducted to explore critical thinking through different aspects of their development and focus on the teaching-learning process as well as education policy documents. CT has been explored in the national context regarding science studies including Physics, Chemistry, and Biology curricula and teaching practices (Jamil, 2021; Jamil et al., 2024; Jamil & Rafiq, 2024; Jamil et al., 2023; Jamil & Muhammad, 2019; Jamil et al., 2021a, 2021b). Secondary school science teachers' perceptions and practices have been explored in different studies for the promotion of critical thinking (Jamil et al., 2023; Jamil et al., 2021b); analysis has been done for the policy documents regarding CT (Jamil & Muhammad, 2019); and assessing critical thinking skill development opportunities in textbooks. In another study effect of flipped science classrooms was explored on students' achievement in grade 7 (Saeed & Munir, 2023). Thus, the cognitive load imposed on learners due to instructional material in general science subjects was the focal point of the present research study. An individual can be subjected to intrinsic, extraneous, or germane cognitive load. An extraneous cognitive load is imposed by other factors that do not contribute to learning. Learning tasks are complex which is why this happens.

Cognitive load theory recommends instructional designers use instructional media according to the limited capacity of working memory, so that may not be overloaded to hamper the learning process (Oberauer, et al., 2018). This strategy is particularly useful in reducing the risk of overloading working memory and may help minimize the complexity of content material having high element interactivity (Ashman, et al., 2020; Paas & van Merriënboer, 2020).

Smith & Hill (2019) investigated the factors contributing to cognitive load measurement. They reported that content taught by using videos/animation as a medium of instruction overloads working memory capacity and learners put more mental effort into the processing of information than those taught by using text and images as a medium of instruction.

These researchers linked their work with the concept of cognitive load and recommended that the labels reduce the extraneous load related to the detail of the example by improving learning. In the present study, different instructional media were used to reveal the effect of instructional media on the extraneous cognitive load of students at the elementary level in general science. Information presented to learners creates an extraneous cognitive load, which is controlled by instructional designers (Weng, et al., 2018). Instructional media play a significant role in this load. Using a limited cognitive resource to process extraneous load reduces the number of resources available to process intrinsic load and germane load (i.e., learning). The materials should be designed such that they reduce extraneous loads, especially when intrinsic or germane loads are high (e.g., complicated problems). A great example of extraneous cognitive load is when there are two possible ways through which a student can describe a square, which is a figure, and it should be described through a figurative medium, thus reducing extraneous cognitive load. There is no doubt that an instructor can describe a square using a verbal medium, but it takes no more than a couple of seconds for a learner to understand what the instructor is trying to convey if they are shown a square rather than being told about one verbally. It is the efficiency of the visual medium that is preferred in this instance. Since the learner does not need to be overloaded with information that is not necessary, it is beneficial. Extraneous cognitive load is the term used to describe this unnecessary cognitive load (Paas, & van Merriënboer, 2020). There is a concept of extraneous cognitive load which was introduced by Chandler and Sweller in the 1970s. A major focus of this article was to provide the results of six experiments that were conducted to test this working memory load to report the findings.

The split attention effect was demonstrated by materials used in many of these tests. They discovered that the structure of educational resources either facilitated or hindered learning. They suggested that the instructional format's greater levels of cognitive load were the cause of performance discrepancies. This needless (artificially created) cognitive stress is known as "extraneous cognitive load" (Resti, & Rachmijati, 2020). The components of extraneous cognitive load can vary, including the interactive demands of instructional software and the clarity of texts (Saido, et al., 2018).

Research Objectives

The following research objectives were formulated for this research:

1. To Measure the level of extraneous cognitive load of students in the subject of General Science at the elementary level.
2. To investigate the effect of instructional media on the extraneous cognitive load of students in the subject of general science at the elementary level.

Research Question

The following research question was formulated for objective 1.

1. What is the level of extraneous cognitive load of students in general science subjects at the elementary level?

Research Hypothesis

The following hypothesis was formulated to achieve research objective 2.

$H0_1$: There is no significant effect of instructional media on the extraneous cognitive load of students in the subject of general science at the elementary level.

Research Methodology

This study was experimental, using a nested group design to investigate the effect of the instructional material on the extraneous cognitive load of students.

Participants

A school with a maximum strength of 7th-grade students was selected for the experiment. Participants were 195 elementary school students of the Punjab School Education Department enrolled in 7th grade of boys' high schools in a district of Punjab. Students were randomly assigned to three different groups. One group was taught using the textbook as a medium of instruction, the second group used PowerPoint slides, and group 3 was taught using videos as the medium of instruction.

Materials

The investigators used professionally produced videos with proper permission from the author (www.sabaqfoundation.com) about units 2,3 and 4 of the 7th-grade science textbook consisting of transportation in plants and animals, Reproduction in plants and animals, and Ecosystem and Habitat. Videos were presented using a projector and multimedia for the 6-week experiment. The videos were taken from Sabaq foundation.com with proper permission from the publisher.

The textbook group was taught from the Punjab textbook of 7th grade general science using traditional teaching methods while lesson plans for group 2 were presented through a PowerPoint presentation. Lesson plans were prepared using teacher guides from the directorate of staff development and validated through the expert opinion of the district QAED Academy for Educational Development.

Instrumentation

Students enrolled in the 7th grade were participants in the study. Their cognitive load was measured by the mean of the cognitive load test (Leppink, Paas & Van Merrienboer, 2013) before applying intervention. They filled out the pretest. Then students were randomly assigned to three different groups. Groups were taught the same content material using different instructional media. The experiment was conducted for 6 weeks and students were taught for 35 minutes per day and 5 days a week. They were post-tested to measure their extraneous cognitive load after every unit of 7th-grade content material used to experiment. As three units (unit 2, unit 3, and unit 4) were taught, three post-tests were conducted. The data was analyzed using descriptive and inferential statistics. The mean score of the extraneous cognitive load of each group was computed employing descriptive statistics for measuring Extraneous Cognitive load. The information was evenly dispersed. Furthermore, all the variables satisfied the linearity requirements. Analysis of data is given below.

Data Analysis

Table 1. The existing level of extraneous cognitive load of participants on pretest scores

Extraneous cognitive load				
	Desired range	Obtained range	F	%
Level1(Mild)	0---10	5---10	6	3
Level2 (Moderate)	11---20	11----20	51	26
Level3 (High)	21—30	21---29	138	71

Table 1 indicates the existing level of extraneous cognitive load of participants obtained on the pre-test. It showed that 71 %of participants fell in level 3, which is a high level of cognitive load, 26 % of participants obtained a moderate level, and 3 % of participants fell in the range of mild level of extraneous cognitive load.

Table 2: Descriptive statistics of extraneous, cognitive load scores of participants on pretest score.

Groups	N	Minimum	Maximum	Mean	Std. Dev
Group 1	65	5	29	21.90	5.72
Group 2	65	10	29	23.29	4.37
Group 3	65	7	28	21.56	4.02

Table 2 shows that the mean score value of the cognitive load of participants on the pretest was (M=21.90, n=65, SD=5.72), the mean score value of the cognitive load of participants of group 2 was (M=23.29, n=65, SD=4.37) and mean score value of the cognitive load of participants of group 3 was (M=21.56, n=65, SD=4.02). The descriptive statistics indicated that the means of groups were different. But to check whether the groups were equal, one-way ANOVA was used. The summary of ANOVA statistics is given in Table 3, below

Table 3: One-way ANOVA about the extraneous cognitive load of participants on pretest

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	108.35	2	54.17	2.39	.094
Within Groups	4352.83	192	22.67		
Total	4461.18	194			

Table 3 shows the difference in the cognitive load of participants on the pretest. A one-way analysis of variance is conducted. The difference is statistically not significant at p>.05; F (2,192) =.2.39 p=.094. Based on pretest scores, it is concluded that the participants of all groups were equal in extraneous cognitive load on the pretest.

Table 4: Descriptive statistics of extraneous, cognitive load scores of participants of different groups

Groups	N	Minimum	Maximum	Mean	Std. Deviation
Group 1	65	23.00	30.00	28.33	1.12
Group 2	65	2.00	23.33	12.85	4.69
Group 3	65	9.00	29.00	21.88	4.08

Table 4 shows that participants of groups using different instructional media, group 1 (Textbook), group 2 (PowerPoint slides), and Group 3 (Videos) have different mean score values of intrinsic cognitive load. Group 3 (videos) showed the highest mean score value (M=28.33, SD=1.12) of extraneous cognitive load. The descriptive statistics highlight that the mean of participants' extraneous cognitive load is different on post-tests 1, 2, &3. But to check the significance of the difference, one-way ANOVA is used. The summary of ANOVA statistics is given in Table 5.

Table 5: One-way ANOVA about the extraneous cognitive load of participants using different instructional media

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	7862.13	2	3931.07	295.95	.000
Within Groups	2550.25	192	13.28		
Total	10412.39	194			

Table 5 shows the difference in the extraneous cognitive load of participants. A one-way analysis of variance is conducted. The difference is statistically significant at p<.05; F (2,192) = 295.95, p= 0.00 P value is significant, which highlights to rejection of the null hypothesis, that there is no difference between groups. Therefore, it indicates that at least one of the groups is different from the others, To find which group is different. A post hoc Tukey test was conducted. The summary of the Post hoc Tukey analysis is given in Table 6.

Table 6: Post hoc Tukey Comparison of participants' extraneous cognitive load using different instructional media

groups	Comparison	Mean Diff	Std. Error	Sig.
Group1	Group 2	15.48*	.640	.000
	Group 3	6.45*	.640	.000
Group 2	Group 1	-15.19*	.640	.000
	Group 3	-9.03*	.640	.000
Group 3	Group 1	-6.45*	.640	.000
	Group 2	9.03*	.640	.000

Table 6 reveals the results of the Post hoc analysis. Comparison of each pair of groups (G1-G2, G1-G3, and G2- G3) indicated that all groups are significantly different from each other in extraneous cognitive load on post-tests 1, 2, & 3 at $p < 0.05$.

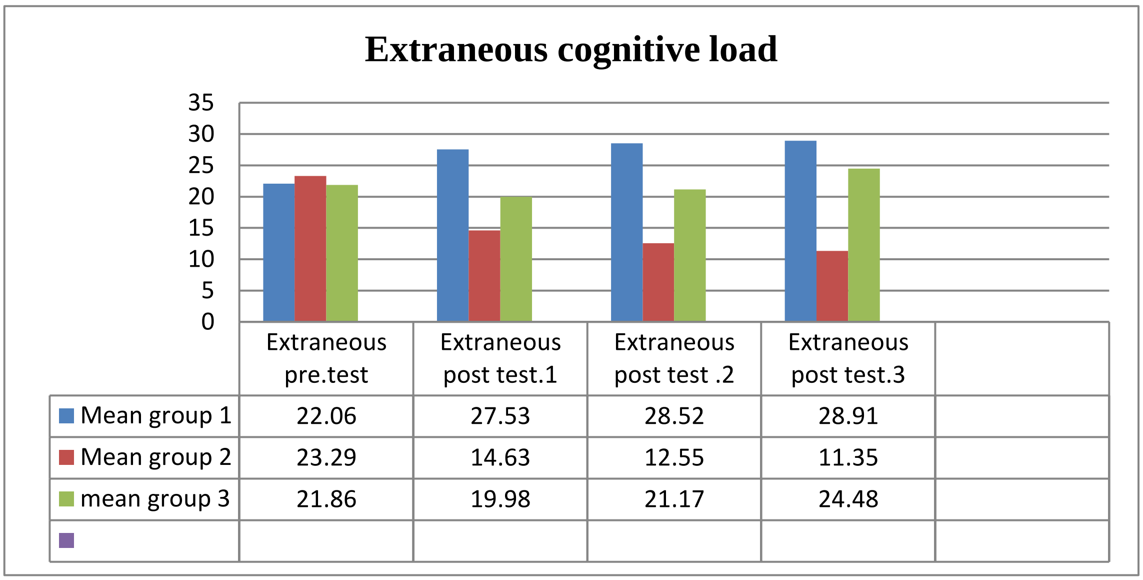

Figure 1: Comparison between an extraneous cognitive load of groups using different instructional media

Considering performance on the pre-test and post-test scores for the mean difference in the extraneous cognitive load of participants of groups using different instructional media (Textbook, PowerPoint slides, Videos). It is evident from Figure 1, that there was an increase in extraneous cognitive load from post-test1(M=27.53) to post-test 3 for group 1 participants (M=28.91), a decrease in extraneous cognitive load from post-test1 (M=14.63) to post-test 3 (M=11.35) for participants o group 2, and increase in extraneous cognitive load from post-test 1 (M=19.98) to post-test3 (M=24.48) as shown in figure1. It is concluded that participants of group 1(textbook) and group 3(Videos) exhibited more extraneous cognitive load than participants of group 2 (PowerPoint slides).

Findings

Participants indicated the highest percentage of extraneous cognitive load (71%) at level 3 (high level) (Table 1). It was found that cognitive load does not vary significantly among various groups on the pre-test, $p>.05$; $F(2,192)=2.39$, $p=.094$ indicating it is constant for all groups (Table .3). A difference in mean scores for the effect of different instructional media on extraneous cognitive load was examined by comparing the mean scores. The difference is statistically significant at the difference is statistically significant at $p<.05$; $F(2,192)=295.95$, $p=0.00$ (Table 5). In all the post-hoc comparisons conducted for participants' extraneous cognitive load, the researcher found that all the groups (G1-G2, G1-G3, & G2-G3) were statistically significantly different from each other at P 0.05 (Table 6).

Consequently, the null hypothesis stating that there is no significant effect of instructional media on the extraneous cognitive load of students in general science subjects at the elementary level was rejected.

Discussion

This study was quantitative and used an experimental research design to conduct the study. In the present study, we also studied the level of cognitive load that students have at present. Based on expert opinion and pilot testing, the rating scale proposed by Leppink et al., (2013) as a method for measuring the cognitive load of students was adapted. Public schools in the district of Punjab were the focus of the research study.

The results of the present study are supported by Leahy, et al., (2004) and by Aalioui et. al., (2022), who reported that learning tasks are characterized by intrinsic and extraneous cognitive load. Based on the cognitive load theory, extraneous cognitive load refers to irrelevant information that can impede learning. The result related to the Significant effect of instructional media on the extraneous cognitive load of participants of textbook using group is in line with the findings of (Akgün et al., 2016) as cited by Rachmijati & Cahyati, (2018) that textbooks contain material and exercises for students to be used by teachers for learning activities. A textbook contains both text and diagrams that needlessly repeat information, this repetition causes an unnecessary burden on working memory. Thereby increasing extraneous cognitive load. Based on the present research, there was evidence of an increase in the extraneous cognitive load of students using textbooks instructional material.

The results related to the decrease in extraneous cognitive load of group 2 (PowerPoint) in the present research study were found in conformity with the results of Aalioui et al. (2022) who revealed that extraneous cognitive load can be minimized by making complex content easier to learn using different instructional material. It will be easier for the students to understand the lesson if it is presented more skillfully, the teacher can teach the lesson by introducing simple components first and then slowly moving to difficult concepts.

The results related to the high extraneous cognitive load of using videos as an instructional medium are in line with the findings of Cahyati and co-authors as cited by Resti, & Rachmijati (2020) that young learners are interested in doing new things due to their curious nature. This curiosity helps them relate the perception of the taught content with the animation/object shown in the video. Students were keen to learn lessons using videos. The demerit of using videos as instructional material in the classroom is that students' attention is diverted to animation rather than focusing on the lessons. In such a situation, teachers need to manage the classroom setting and activities of pupils by engaging them in related content rather than focusing on a picture while watching the video.

Recommendations

1. The findings of the study may be shared with the Training Wing of the School Education Department and suggest to include topics in the professional development training

programs of teachers and heads so they may know the benefits of bringing innovation in teaching and the use of a variety of instructional material in the classroom along with teaching from the textbook.

2. Heads of institutions/ principals may need to be orientated about the results of the study. They will observe instructional material and may know whether teachers are using it appropriately in their classes, such as videos with suitable flow speed, slides having ideas, and content explained through bullets. Then they may nominate teachers for training related to the use of instructional technology and material in the classrooms.

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