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Effect of Printed and Digital Instructional Material on Germane Cognitive Load of Students in the Subject of General Science at the Elementary Level

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Abstract

The current study employed an experimental design with a quantitative approach to examine the impact of digital and printed instructional media on the germane cognitive load of elementary school students for the subject of General Science. The participants were 7th-grade students enrolled in high schools located in a district of Punjab. The digital instructional media utilized in the study included instructional videos and PowerPoint presentations, while textbooks were used as the printed instructional media. The researchers adopted the test developed by Leppink, Paas, Van der Vleuten, & Van Merriënboer after obtaining permission. The results revealed that the group exposed to instructional videos exhibited the lowest germane cognitive load, followed by the group that used textbooks. In contrast, the group that received instruction through PowerPoint presentations demonstrated the highest germane cognitive load. The observed differences in germane cognitive load across the three groups were found to be statistically significant.

Key Words: Germane Cognitive Load, Digital and Printed Instructional Material, PowerPoint Slides, Textbook, Instructional Videos

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Title

Effect of Printed and Digital Instructional Material on Germane Cognitive Load of Students in General Science Subject at the Elementary Level

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Contents

- Introduction
- Literature Review
- Research Methodology
- Research Question
- Conclusion
- References

Abstract

The current study employed an experimental design with a quantitative approach to examine the impact of digital and printed instructional media on the germane cognitive load of elementary school students for the subject of General Science. The participants were 7th-grade students enrolled in high schools located in a district of Punjab. The digital instructional media utilized in the study included instructional videos and PowerPoint presentations, while textbooks were used as the printed instructional media. The researchers adopted the test developed by Leppink, Paas, Van der Vleuten, & Van Merriënboer after obtaining permission. The results revealed that the group exposed to instructional videos exhibited the lowest germane cognitive load, followed by the group that used textbooks. In contrast, the group that received instruction through PowerPoint presentations demonstrated the highest germane cognitive load. The observed differences in germane cognitive load across the three groups were found to be statistically significant.

Keywords: Germane Cognitive Load, Digital and Printed Instructional material, PowerPoint Slides, Textbook, Instructional Videos

Introduction

Before modern education, knowledge and social skills were cultivated through interaction with people and the environment. By limiting novelty and change to established knowledge and skills, this approach limits the scope for innovation and change. The education system of today differs radically from this past approach. Now different instructional media is used in the teaching and learning processes. By developing engagement and facilitating the teaching-learning process, this instructional media plays a vital role in the teaching-learning process. In this process, students'

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engagement can be made possible through different interactive pedagogies for the development of critical thinking which is an important skill of the twenty-first century, also play a vital role in student engagement that is also useful in science subjects like physics, chemistry, biology and mathematics (Jamil, 2021; Jamil, et al., 2024a, 2024b, 2024c, 2024d, 2024e; Jamil & Muhammad, 2019; Jamil et al., 2020; Jamil et al., 2021a, 2021b). Improving the delivery of educational content and improving the learning process requires incorporating various tools, resources, and technologies. Instructional media have many factors that play a role in determining their effectiveness in teaching and learning. As a result, instructional media directly or indirectly affects all of these factors. The importance of taking these factors into account is crucial for educators to maximize the effectiveness of media integration and ensure optimal learning outcomes for their students (Ordu, 2021).

A teacher must have a thorough understanding of which instructional media works best for them to be able to effectively teach certain concepts in scientific disciplines to students. To ensure the effectiveness of instructional media that ensure cognitive load, researchers are taking key aspects of human cognitive design into account as important aspects i.e. cognitive load to ensure the effectiveness of the media. A study conducted by Bokosmaty et al. (2015) concerning instructional media and cognitive load has shown useful results when it comes to subjects such as math and science. Students have limited memory resources, and this is something that teachers must keep in mind to prepare them for learning.

To help teachers teach more effectively, it is essential to direct learners' attention to relevant information so that they will be able to teach effectively (Duran et al., 2022). To understand the effectiveness of instructional media on learners' cognitive load for General Science subjects, it was necessary to conduct the present study.

According to psychologists, cognitive load refers to any kind of mental effort. This type of mental effort is what is seen in the learning process. Cognitive Load Theory also talks about three different types of loads that contribute to this process. These three are intrinsic, extraneous, and germane (Anmarkrud et al., 2019; Emory, 2019). Intrinsic refers to how hard a task is mentally while extraneous can be any kind of information presented poorly and germane helps with schema making and other factors during memory processing. The theory shows that these three loads work together to make sure learning is efficient when it comes to cognitive performance.

Schemata encoding in long-term memory is about germane load (GL). Skilmowski & Xu, (2021), and Sweller et al., (2019) describe germane load as the cognitive resources used for producing and storing new knowledge.

Working memory buffer and schema development, as proposed by Baddeley (2000), would seem to correlate more closely with this hypothesis. When the germane load came into play in conjunction with the other cognitive load components, then any learning took place since the two other load components had an additive effect; thus, if the germane load was too much, due to the shortage of cognitive resources (Sweller et al., 2019). A study conducted by Sweller et al., (1998) suggested that there may be a connection between cognitive load and learning levels in some instructional formats. Enhanced germane load is one of the most important components of enhancing long-term memory as it is directly linked to how information is stored and therefore how learning occurs (Kaboli, et al., 2020).

Research Objectives

1. To find out the level of Germane cognitive load of elementary school students in General Science.
2. To compare the effectiveness of printed and digital instructional materials on students' Germane cognitive load in General Science.

The following research question and hypothesis were formulated on the basis of the above objectives.

Research Question

1. What is the level of germane cognitive load of students in the subject of General Science?

Research Hypothesis

$H0_1$: There is no significant effect of printed and Digital instructional material on the germane

cognitive load of students in the subject of General Science.

Research Methodology

The current study used an experimental design with a nested group structure. The purpose was to discover how the Printed (Textbook) and Digital (instructional video and PowerPoint slides) instructional material affected the Germane cognitive load in students. There were 195 elementary school students as participants who were enrolled in 7th grade in public schools. They were chosen on purpose so they could take part in the experiment in one school with seventh graders who all learned differently from each other. Each group had about 65 people randomly assigned, the traditional group was taught through the textbook, the second through slides of PowerPoint and the last group 3 was taught by Instructional videos. The instructional videos used in this study were professionally made by Sabaq Foundation publisher (www.sabaqfoundation.com). All units between two through four were covered which talked about the transportation of plants and animals, plants and animals' reproduction, and finally ecosystem with habitat. The first two groups that used textbooks or slides got their lesson plans traditionally, but Group 2 used PowerPoints for their presentation. The experiment lasted six weeks. After being pretested using mean scores on a cognitive load test for measuring germane Cognitive load, groups were taught using different instructional media until they had to take a posttest.

Data Analysis

The following tables describe data analysis.

Table 1

The existing level of germane cognitive load of the respondents for pretest scores

Germane Cognitive Load				
	Desired range	Obtained range	F	%
Level1 “Mild”	0---13.3	3—13	114	56.9
Level2 “Moderate”	13.4--26.6	14—26	67	36
Level3 “High”	26.7—40	28—37	14	7.1

Note. Rating is based on 11-point metrics (0=not at all to 10=extremely the case may be)

The above table describes the existent level of germane cognitive load of students based on pre-test scores. It describes that 56.9 % of students fall into a mild level of cognitive load. 36 % of students took a moderate level, while 7.1 % of students descended in the range of a high level of germane cognitive load.

Table 2

Germane cognitive load scores of the respondents for the pretest score

Groups	N	Minimum	Maximum	Mean	Std. Dev
Textbook	65	3.00	23.00	11.89	5.02
PowerPoint	65	5.00	27.00	11.83	4.48
Videos	65	4.00	27.00	11.07	4.69

The above table displays the mean score value of the test from three different groups. Group one with the (Textbook) had a mean value of 11.89, 65 students and a standard deviation of 5.02; group two with the (PowerPoint) had a mean value of 11.83, 65 students and a standard deviation of 4.48; group three with the (Videos) had a mean value of 11.07, 65 students and a standard deviation of 4.69. The descriptive statistics showed that there was a difference in means within each which is shown below in Table 3.

Table 3

Comparison of germane cognitive load of the respondents on the pretest

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	27.43	2	13.72	.612	.544
Within Groups	4306.45	192	22.43		
Total	4333.88	194			

Table 3 shows the difference in germane cognitive load scores on the pretest by all participants of all groups which is analyzed by using a one-way analysis of variance and found statistically insignificant at $p < .05$; $F(2,192) = .612$, $p = .544$. Therefore, based on pretest scores it was found equal from all those participants in all groups in terms of their germane cognitive load scores on test.

Table 4

Germane cognitive load scores of the respondents for the pretest

Groups	Total of Posttests	
	M	SD
Textbook	3.10	1.22
PowerPoint presentation	8.44	1.87
Instructional Videos	4.91	2.03

Rating is based on 11-point metric (0=not at all to 10=extremely the case may be)

Table 4 contains the statistics for groups that used different instructional media. It showed that the Germane cognitive load of groups is different on average. One-way ANOVA is used to test if this difference is significant or not. For more information, you may refer to Table 5.

Table 5

One-way ANOVA Analysis between groups

Germane Cognitive Load	Sum of Squares	df	Mean Square	F	Sig.
'Between Groups'	960.32	2	436.79	157.60	0.00
Within Groups	585.01	192	1.48		
Total	1545.32	194			

P<0.05

The significance of the difference was tested using a one-way analysis of variance with $p<.05$; $F(2,192) = 157.60$, $p=0.00$ as results for the Mean of Germane Cognitive Load of groups on posttest (Table 5). It means that there's a significant difference in germane cognitive load and we have to identify which group makes a significant difference. To do this, a post hoc analysis was conducted and a summary of it can be found in Table 6.

Table 6

Comparison between groups

Groups	Comparison	Mean Difference	Sig.
Textbook	PowerPoint presentation	-5.35*	.000
Textbook	Instructional Videos	-1.82*	.000
PowerPoint presentation	Instructional Videos	-3.52	.000

The above table describes the post-hoc analysis. To Compare each pair of Instructional media (Textbook –PowerPoint presentation, Textbook-Instructional Videos, PowerPoint presentation- Instructional

videos) indicated that students are meaningfully different in Mean of germane cognitive load at $p < 0.05$. The above table presents an analysis comparing the germane cognitive load experienced by participants across three different groups: Textbook, PowerPoint, and Instructional Videos.

The results indicate significant differences in germane cognitive load between the various groups. When comparing the Textbook group to the Powerpoint group, the mean difference in cognitive load is -5.35, with a significance level of .000 ($p<0.05$). This suggests that participants in the Textbook group experienced significantly lower germane cognitive load compared to those in the PowerPoint group.

In the same way, while comparing the Textbook group to the instructional videos group, the mean difference was 1.82, with a significance level of .000 ($p<0.05$). It indicates that participants in the Textbook group experienced significantly lower cognitive load as compared to those in the videos group. Moreover, while comparing the PowerPoint group to the Instructional Videos group then, the mean difference was -3.52, with a significance level of .000 ($p<0.05$). It implies that participants in the instructional videos group experienced significantly lower germane cognitive load compared to those in the PowerPoint group.

Overall, the analysis reveals that the videos group had the lowest germane cognitive load, followed by the Textbook group, and the PowerPoint group had the highest germane cognitive load. These differences in germane cognitive load across the three groups were found to be statistically significant. The null hypothesis was rejected.

Findings

Participants indicated the highest percentage (56.6%) at level 1(Mild level), indicating students find it easy to understand learning materials at a mild level. On the other hand, the cognitive load does not differ notably among different groups for the pre-test, $F(2,192) = .612$, $p = 0.544$, constant for all groups. There is also a difference regarding print and digital media mean scores on germane cognitive load were examined by comparing them significantly with $F(2,192) = 157.60$, ($p=0.00$) for the Mean of Germane Cognitive Load of groups on posttest. In all the post-hoc differences performed for respondents' germane cognitive load; investigators recovered that all the groups were significantly different from each other. Therefore, our results show that there are significant differences in germane cognitive loads between the various groups. When comparing the Textbook group to PowerPoint, we found that the mean difference is -5.35 with a significance level of .000 ($p<0.05$). In simple words, participants stated lower 'germane cognitive load' when they used Textbook than PowerPoint. This suggests that participants in the Textbook group experienced considerably low 'germane cognitive load' linked to those in the PowerPoint group.

Discussion

It was an experimental study. This study was conducted to study the current level of cognitive load in which students are currently involved. The result was associated with the positive effect of printed and digital material on the germane cognitive load of the respondents in various instructional media. Moreover, the findings of this research parallel the findings of Sweller (2019), who emphasizes that the provision of superfluous information can be a significant source of heightened cognitive load because it can impose a burden on the brain that has not been anticipated.

Moreover, Sweller provides insight into the idea that unnecessary details within educational materials like textbooks, can overwhelm learners' cognitive abilities. There is an association between the results of the present study, Akgün et al. (2016), and Sweller's theoretical perspective. Those results can be cited as well in Rachmijati and Cahyati (2018). It demonstrates the importance of designing instructional materials in a way that improves the germane cognitive load within an instructional situation. Among the findings of the present study is that the use of textbooks as an instructional device may decrease the germane cognitive load during the learning process (Sweller, 2019).

According to the study, PowerPoint presentations can also be beneficial as a medium of instruction since they induce a high degree of relevant cognitive load on students' working memory when used as a medium of instruction. Considering the alignment between research insights and practical applications of PowerPoint presentations (Sweller, 2019),

Sweller (2019) has argued that thoughtful visual integration into educational materials has become a crucial component of cognitive processes and educational outcomes. This aligns with Sweller's (2019) assertion. In the classroom, when animations were displayed on the screen in the form of videos, everyone was probably captivated by the use of instructional media in the form of videos themselves. Students focused more on the picture rather than on the content. The results of the present study supported the findings that young learners get easily bored and their attention is diverted as cited in (Resti, &Rachmijati, 2020).

Recommendations

Teachers are recommended to use PowerPoint presentations as an instructional medium. Teachers may design their lesson on PowerPoint by using Minimum text on presentation to essential points and using bullet points, keywords, or brief phrases instead of full sentences to prevent overwhelming the students with information. Teachers may prepare their presentations using the same fonts, colours, and formatting to create familiarity and reduce unnecessary cognitive effort. Teachers may incorporate interactive elements such as quizzes, polls, or discussions to engage learners actively, promoting deeper processing and reducing monotony. By applying these recommendations, Teachers can design PowerPoint presentations that optimize learning by managing cognitive load effectively, enhancing understanding, and promoting better retention of the material presented.

Every high school is equipped with computer labs. It is recommended that they may have multimedia that enables students in each class to practice and rehearse Microsoft PowerPoint in teacher guidance as it promotes effective learning by allowing students to engage with the software under supportive supervision, enhancing their understanding and retention of the material.

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