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Impact of a Digital Growth Mindset on Enhancing the Motivation and Performance of Chemistry Students: A Non-Cognitive Approach

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Abstract: The current study investigates the effects of a digital growth mindset on the motivation and success of chemistry students. The approach involves the use of technological tools that encourage students to face challenges and keep trying even when things become difficult. Students can achieve milestones by following this fruitful methodology. This study utilized a mixed-method design of an ordered–explanatory type, as identified in one of the categories of mixed-method approaches. The quantitative aspects of the research project were conducted using a matching-only pre-test–post-test control-group design. This was conducted because the study was carried out on secondary school students in Lahore, Pakistan, and the population included students up to the tenth grade. Only the experimental group participated in digital growth mindset activities. The control group was taught using traditional methods. The qualitative aspect of the study involved conducting focus group discussions with students in the experimental group. The results showed a significant improvement in motivation and chemistry achievement among the students in the experimental group, as evidenced by the higher mean scores from the pre-tests and the post-tests compared to the control group. The present research findings reveal that digital growth mindset interventions, when appropriately incorporated into chemistry curricula, possess the capacity to not only improve student engagement and subsequent performance but also to provide educators with valuable insights into instructional practices that are worth implementing in the digital era.

Keywords: growth mindset; fixed mindset; digital growth mindset; student motivation; chemistry achievement

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1. Introduction

Chemistry achievement has consistently been one of the primary goals of educators worldwide. Teachers can significantly enhance students' academic experiences by identifying the specific factors that contribute to chemistry achievement and implementing effective teaching methods. Traditionally, high-stakes testing has focused on cognitive skills associated with achievement, but it is crucial to consider other factors as well. However, this approach has automated students' class time and overlooks the development of non-cognitive skills such as mindset. A growing body of research has found that both cognitive and non-cognitive skills are correlated with academic achievement [1].

According to published report [2], the concepts of fixed and growth mindsets, people have different beliefs about whether basic personal traits like intelligence or ability can change which in turn results in distinct judgment and response patterns across tasks and situations [3]. Those with a fixed mindset believe that their intelligence, abilities, and other inherent attributes are static and cannot be significantly enhanced or altered over time. By contrast, those with a growth mindset view their intelligence, abilities, and other inherent attributes as malleable resources that can be improved or developed through learning and persistent effort [3].

As the name suggests, a digital growth mindset relates the idea of a growth mindset to the use of new technologies [4]. This concept emphasizes the belief that individuals can adapt to new technology and must continuously learn and grow in the digital age to remain competitive and successful. The basis for this idea is the belief that to keep up with the latest trends, technologies, and tools, one must utilize them effectively [5]. People with a digital growth mindset believe that they can develop their basic talents to adapt to new technologies and improve their ability to keep pace with technological changes through learning. By contrast, those with a digital fixed mindset believe that a person's level of technological expertise is unchangeable and cannot be improved [4]

According to [6] Digital literacy encompasses typing, image, audio, and text production, as well as design skills [7]. As digital technology has significantly impacted businesses, industries, and societies [8], it is crucial for individuals to develop digital literacy, which includes six modules; media, information, communication, technology, visual, and computer literacy [9]. A digital mindset is the belief that transitioning a product or process to a digital format can add value (in terms of cost, speed, quality, and functionality) to individuals and stakeholders [10]. Establishing a digital mindset can influence how one views academic achievement and lay the groundwork for digital transformation, leading to the development of new knowledge and skills [11,12].

Digital readiness has a multifaceted meaning. It can refer to the preparedness of individuals, institutions, and nations to embrace and utilize digital technology to reap the maximum benefits from it [13]. At the individual level, digital readiness encompasses both the attitudinal and operational components. Attitudinal digital readiness pertains to an individual's perspective on digital innovations and their implications. On the other hand, operational digital readiness is defined as "an individual's ability to leverage digital technology to create innovative applications, attain specific objectives, or adapt to the evolving digital landscape" [13].

While substantial evidence supports the positive effects of a growth mindset on enhancing students' motivation and chemistry achievement [1], the literature reveals a notable gap in understanding the specific impact of a digital growth mindset. A digital growth mindset refers to the application of growth mindset principles through digital platforms and technology-enhanced learning environments. Previous studies have predominantly focused on traditional instructional settings, with less attention paid to how digital interventions could potentially amplify these effects. Consequently, there is a dearth of empirical data exploring how digital tools and resources designed to foster a growth mindset directly influence students' motivation and academic performance in chemistry. This gap highlights the need for targeted research to ascertain the effectiveness of digital growth mindset interventions in educational settings. This study holds significance as it bridges a critical gap identified in the previous literature by examining the combined effect of a digital growth mindset on students' motivation and chemistry achievement. Given the increasing importance of educational technology in modern learning, understanding the potential of digital platforms in fostering a growth mindset is crucial. Through the implementation of digital strategies that encourage a growth mindset, this study aimed to provide empirical validation for the development of more effective educational methods and tools.

These findings have the potential to not only enhance student engagement and academic performance but also offer practical guidance for educators seeking to utilize technology to cultivate resilient and motivated learners. Ultimately, this research will contribute to broader educational conversations by providing evidence-based recommendations for improving student achievement through digital growth mindset interventions.

2. Literature Review

This review brings together the results of different studies that have looked at how a digital growth mindset can boost students' motivation and performance in chemistry. A digital growth mindset presumes one's belief in their ability to learn and grow from using digital technologies through hard work and perseverance. Research on business students in China reveals that a digital growth mindset has positive effects on students' academic performance, with more effects being realized among male students [4]. This, therefore, indicates that the development of a digital growth mindset has become an effective way to promote the achievement of students in business studies and could be applied to chemistry. Similarly, growth mindset interventions have been demonstrated to affect motivation, resilience, and attainment predominantly in students' learning contexts.

The study explored specific interventions to cultivate a growth mindset, explicitly influencing cultivation, classroom culture development, and technology usage, which are all such interventions transacted within a digital platform. Furthermore, [14] stated that the implicit beliefs on intelligence and effort described in Dweck's growth mindset theory develop into meaning systems that have implications for academic outcomes. The study also found that people with a growth mindset, who focus on smaller goals, tend to have better results, like getting higher grades and feeling less burned out. This can help improve motivation and performance in chemistry [15].

Furthermore, the study examined how students' attitudes influence their need to do well. It was also found that students who were motivated enough to learn increasingly performed better academically. Students' positive attitudes can be enhanced through digital platforms. This can result in better academic achievement [16]. Moreover, metacognitive interventions to sustain a growth mindset in a biochemistry course did not alter students' mindsets but enhanced their learning attitudes and academic performance. Consequently, it can be inferred that interventions to modify mindsets may be difficult; however, they can still determine the relationship between students' perceptions and results in chemistry subjects [17]. Various authors have studied the effects of intelligence and personality growth mindsets on academic performance. Many studies have found that these mindsets confer academic fitness, especially in verbal domains and standardized math scores [18]. This indicates that such interventions could help educational institutions by inducing a growth mindset among students, which may improve chemistry achievement. Teacher support of the growth mindset facilitates growth mindset description, task commitment, and achievement in secondary school.

This highlights the teacher's role in fostering a growth mindset and suggests that teachers might engage in digital growth mindset practices to improve chemistry achievement. The interconnection between economic determinants and inherent chemistry attainment is offered as evidence, with incentives targeted at pupils emerging as a robust determinant to teach within the entire pupil sample. However, this does not seem to be immediately related to the digital growth mindset, ensuring that socioeconomic status is not a barrier to the development of a growth mindset which is especially important for chemistry education. Furthermore, for the Indonesian language topic, we assessed the effect of instructor teaching efficiency and student learning desire on academic achievement.

Teachers are portrayed as playing a crucial role in initiating students and the academic success of students. Overall, teacher-led digital growth mindset initiatives may positively affect motivation and achievement in chemistry. Lastly, researchers assessed age, gender, and academic achievement motivation on academic performance, and more motivated students tend to perform better. This implies that the digital growth mindset, which can also be found in motivation, may play a significant role in the academic success of students in chemistry. In conclusion, the available literature supports the argument that digital intervention of a growth mindset can have a positive effect and impact on motivation and chemistry achievement. The above studies show that students who are involved in a growth mindset intervention, receive teacher support, and have a positive attitude toward learning tend to achieve better academic success.

3. Conceptual Framework

The conceptual framework of the demonstrated study can be viewed in Figure 1. The core concept of this study is the connection between digital growth mindset interventions and their impact on students' motivation and chemistry achievement. This idea is rooted in Dweck's growth mindset theory, which suggests that individuals who believe that their abilities can be developed through dedication and hard work are more likely to achieve higher academic success and maintain motivation. This framework expands the traditional growth mindset concept to the digital realm, proposing that digital tools and technologies can specifically support and enhance these psychological constructs. The framework specifically examines how digital platforms can facilitate personalized learning experiences, provide adaptive feedback, and foster interactive learning communities, thereby promoting a growth mindset. This study proposes that the incorporation of growth mindset principles through digital means leads to improved student motivation and performance in chemistry subjects. This framework was used to guide the methodology, inform the design of digital interventions, and assess their effects on student outcomes.

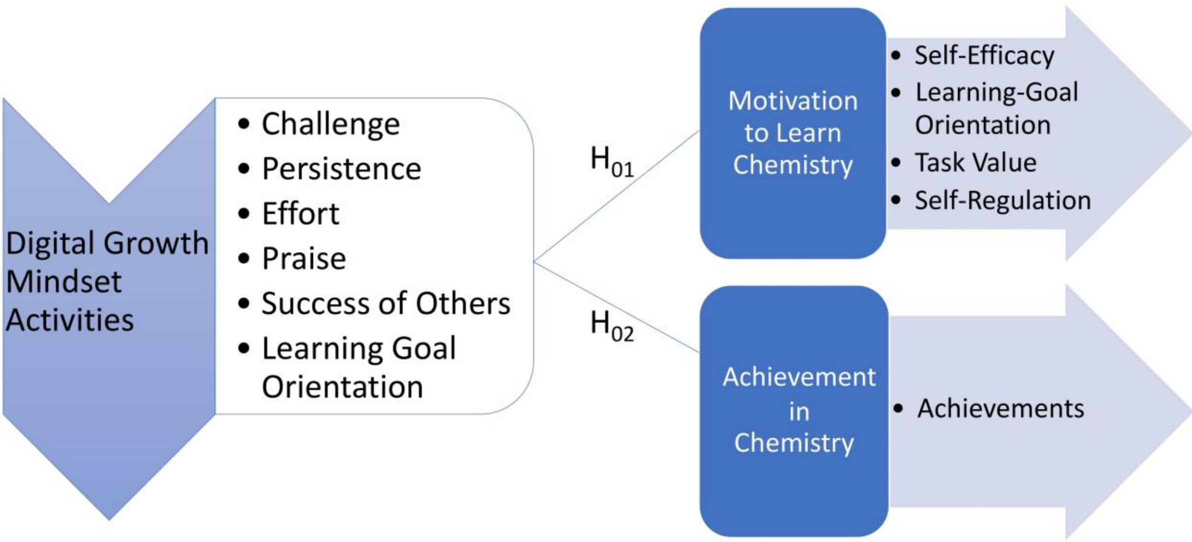


Figure 1. Conceptual framework of the study.

4. Aim of the Research

This research aimed to determine the impact of a digital growth mindset on enhancing the motivation and academic achievement of undergraduate chemistry students at a public sector university. In this context, answers were addressed for the following questions:

1. Is there a significant difference between the pre- and post-test motivation scores of the experimental and control groups?
2. Is there a significant difference between the pre- and post-test chemistry achievement scores of the experimental and control groups?
3. How do students, upon receiving teaching, feel about the effectiveness of a digital growth mindset?

5. Limitations of the Study

1. The sampled school did not allow for the random assignment of groups. This was a serious constraint of this study, as we could not do a random assignment.
2. It was difficult for us to have focus group interviews with students. We have to get help from school teachers to conduct focus group discussions.
3. MCQs were an achievement test used in the study which was confined to the first three cognitive domains of the six of Bloom's taxonomy.

6. Methods

This study utilized a mixed-method design of an ordered–explanatory type, as identified in one of the categories of mixed-method approaches, adequate to employ both quantitative and qualitative data together. The quantitative dimension of the study utilized a matching-only pre-test–post-test control group design. As per, this design distinguishes itself from a random assignment with matching by not employing a random assignment. Despite matching the subjects in both the experimental and control groups based on specific variables, the researchers cannot guarantee that they are equivalent in all aspects, as they are already part of the intact groups. Although this limitation is significant, it is sometimes unavoidable when intact groups are used instead of random assignments.

The researchers selected a secondary school from the district of Lahore, Pakistan, using a purposive sampling method for the experiment. The school was chosen based on its technological capabilities, including the availability of LCD, the Internet, sound systems, and an uninterrupted power supply.

In the current study, the researchers were unable to conduct random group assignments because of the restrictions imposed by the sampled school. This represented a significant limitation of the study, as random assignment was an essential component of the research design. However, the researchers had no choice but to use intact groups. The school had previously formed groups in 10th grade based on the annual exam results of 9th grade. There were five sections (A–E) in 10th grade, each consisting of 40 students. The first two sections (A and B) were selected for the study, and a coin toss was used to determine the experimental group. The intervention was designed to address the standards, benchmarks, and student learning outcomes specified in the 2006 National Curriculum for 10th-grade chemistry. The course was divided into four main units, each addressing the key concepts of 10th-grade chemistry. The units covered were chemical equilibrium, acids, bases, and salts, organic chemistry, analytical chemistry, and chemical industries.

The Table 1 shows the matching-only pre-test-post-test control group design. In Table 1, M means that the subjects in each group have been matched (on certain variables) but not randomly assigned to the groups.

Table 1. The matching-only pre-test–post-test control group design.

Treatment Group	M	O	X	O
Control Group	M	O	C	O

The qualitative dimension of the study was the conduct of focus group interviews with the students of the experimental group. Data were analyzed through content analysis. Prior to conducting the study, the researchers were granted permission from an official source for this research.

7. Measures

7.1. Students' Adaptive Learning Engagement in Science (SALES)

Students' Adaptive Learning Engagement in Science is an assessment tool was used to address for evaluating secondary school students' motivation to learn chemistry. This tool consists of four scales: learning-goal orientation, task value, self-efficacy, and self-regulation, each comprising 8 items (totaling 32 items). Respondents rate each item on a five-point Likert scale ranging from "Strongly Disagree" to "Strongly Agree". The present study finds all of these scales relevant to the context and believes that SALES provides the researchers and sample teachers with valuable data about the characteristics of students' motivation levels in chemistry lessons. The researchers obtained permission from the authors to use this scale to assess students' beliefs about their motivation to learn chemistry.

7.2. Chemistry Achievement Test (CAT)

The Chemistry Achievement Test was developed to evaluate students' proficiency in chemistry. It has 25 items and employs scientific procedures that follow the table of specifications to maintain the test's difficulty level [19]. The table of specifications ensured that the first three levels of the cognitive domain were proportionally represented in the test. The test adhered to the fundamental rules of the test's construction. To achieve a well-balanced test, 25% of the questions were easy, 50% moderate, and 25% challenging. However, the recommended difficulty level for the test is 0.6. After conducting an item analysis through pilot testing, [20], were chosen as the preferred reference.

8. Validity and Reliability of Instruments

The pilot study involved collecting data from a sample of students similar to those included in the study. Specifically, 50 10th-grade students from a government school in Lahore, Pakistan, were selected for this purpose. These participants were enthusiastic about the Students' Adaptive Learning Engagement in Science (SALES) scale and achievement test and expressed confidence in their ability to comprehend its content and format. The purpose of Students' Adaptive Learning Engagement in Science (SALES) was to investigate the crucial factors impeding students' motivation and self-regulation. SALES has not been applied in the Pakistani educational context. To establish the validity of the tool, the researchers provided evidence of its reliability and validity. In addition, a confirmatory factor analysis was conducted to ensure the validity of the SALES instrument. Prior to using the scale, the researchers first verified its reliability and validity to ensure its appropriateness.

The reliability and validity of the measures used to operationalize the construct through different means are commonly assessed using tests such as the Kaiser–Meyer–Olkin (KMO) and Bartlett's test of sphericity. The KMO value of 0.84 and the Bartlett's test of sphericity, with an approximate chi-square value of 3122.88 ($p < 0.000$, df = 276), indicated that the study measures had a normal distribution. Additionally, the Shapiro–Wilk test was conducted on the SALES data, and the results showed that the data were normally distributed. SmartPLS 4.x was used to examine the possibility of multicollinearity by calculating tolerance and variance inflation factor (VIF) values. The VIF value should be less than the cutoff value of 3.3. The highest VIF value of 2.61 indicated that there was no multicollinearity issue in the dataset [21]. Furthermore, all constructs had Cronbach's alpha values ranging from 0.52 to 0.90 and composite reliability values ranging from 0.78 to 0.93, suggesting reliability and convergent validity in the measurement model.

9. Item Analysis for the Chemistry Achievement Test

Item analysis for the Chemistry Achievement Test (CAT) provides two essential item-level statistics for dichotomously scored (correct/incorrect) items: the p-value and the point–biserial correlation. These statistics represent the difficulty and discrimination of items. According to [22], the p-value is the proportion of examinees who answered an item correctly, ranging from 0 to 1. A high p-value of 0.95 indicates that an item is easy, while a low p-value of 0.25 suggests that the item is difficult. The point–biserial correlation (Rpbis) is a measure of an item's discriminating power, which ranges from -1 to 1. A negative Rpbis indicates that a poor item is more likely to be answered incorrectly by lower-scoring examinees than by higher-scoring examinees. Item difficulty ranges from 0.50 to 0.68 for items 01 to 25, indicating that these items were of moderate difficulty, which can be considered "average" for measuring the intended variable in the study. The item analysis for item discrimination ranged from 0.039 to 0.312 for items 01 to 25, indicating that the items were "good" in terms of discrimination.

10. Procedure

Before the intervention, the researchers visited a school that was selected for a month, observing the teaching methods for chemistry in 8th grade five days a week. They found that most teachers employed textbook reading and lectures, along with some using models to clarify concepts. Consequently, the control group was instructed through textbook reading, lectures, and model usage, whereas the experimental group received the intervention of the independent variable, which involved digital growth mindset activities. Both groups had a 45 min class period six days a week. The experimental group's classroom was designated as the "Digital growth mindset classroom" and was labeled as such at the entrance.

The intervention aimed to foster a digital growth mindset, problem-solving skills, and scientific exploration among students through tailored face-to-face learning activities. The intervention included specific lesson plans, activities, and instructions designed to develop a digital growth mindset. To encourage a digital growth mindset, the researchers refrained from praising students for correct answers or intelligence, instead focusing on praising students for sharing their errors and persisting through challenging issues. The intervention aimed to convey that making errors is an inherent aspect of the learning journey. The central objectives of the intervention were to facilitate students' acceptance of the idea that the learning process involves errors, enable them to articulate the meaning of "digital growth mindset" in acquiring new abilities, and pinpoint a skill they have yet to perfect but wish to enhance. The students were exposed to video content about failure and were subsequently prompted to reflect on a difficult learning experience, including how they conquered it or if they were still grappling with it.

Moreover, the students were acquainted with the significance of the word "yet" and its capacity to change their mindset from a statement like "I can't do that" to "I can't do it yet". This was accomplished through videos, group discussions, and individual reflection on electronic notecards about the skills they had yet to acquire but aimed to learn. Throughout the intervention, the students were encouraged to engage in reflective conversations with their peers about the fresh ideas they had gained. Additionally, the program's objective was to have the students compare their brains to muscles and comprehend how their brains expand through learning and exertion. To attain these objectives, the students were divided into smaller groups and given an electronic article that drew a parallel between the human brain and muscle. Each group then shared the information they gathered from their designated sections with the entire class.

In the next phase of the intervention, the students were introduced to the concepts of fixed and growth mindsets, along with their respective definitions. The goals for this phase were to differentiate between the two mindsets, elucidate the advantages of having a growth mindset, and guide students in selecting their own mindset. To assess their current mindset, the students took an informal electronic test where they pondered whether they agreed with statements that represented a fixed or growth mindset. During group work, the students connected their previous learning about mistakes and brain growth to the concept of having a growth mindset and debated which mindset seemed to result in greater success. The fourth lesson's learning objectives focused on converting fixed mindset ideas and statements to align with a growth mindset. To accomplish this, the students commenced by reviewing and discussing the information they had learned in earlier lessons.

During their class session, students collaborated to change fixed mindset statements into growth mindset statements, creating a list of common fixed mindset thoughts. After compiling the list, the students worked individually to transform each statement into a digital growth mindset. The primary goal of the fifth lesson was to help students recognize the benefits of a digital growth mindset in various situations outside of school and to generate digital growth mindset statements in those circumstances. By concentrating on the idea that their brains could develop through effort and hard work in many areas of their lives, students were able to improve their understanding of the digital growth mindset.

A wide variety of situations were presented to students, who evaluated the usefulness of a digital growth mindset in each scenario and drafted a digital growth mindset statement to aid them in such situations. For example, a student might conclude that a digital growth mindset would be beneficial in motivating them to improve their performance or seek assistance from a friend if they received a lower grade on an assignment than their peers. Other instances related to various aspects of a student's life, such as their sports team or family at home. The classroom provided an authentic digital growth mindset environment during the intervention exercise through the display of motivational messages on the bulletin board and wall charts, as well as the teaching of intervention strategies. Figure 2 has been generated using an AI tool which shows the procedure for a digital growth mindset.

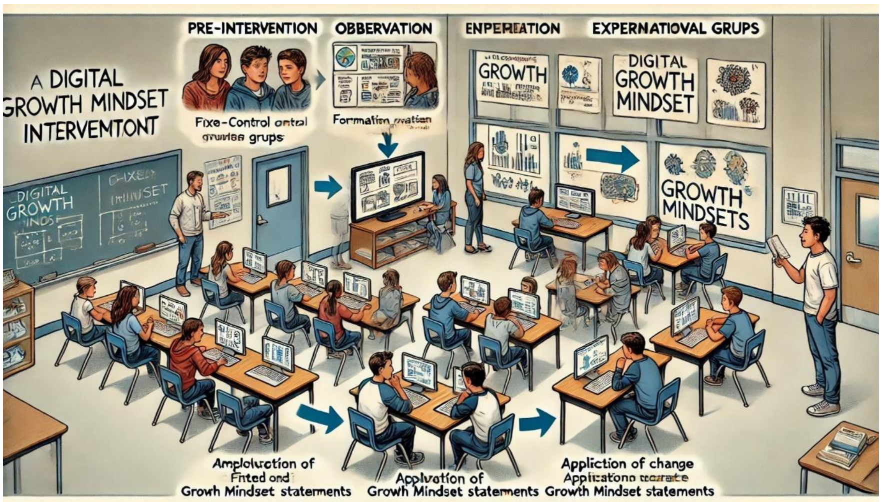


Figure 2. Procedure for the digital growth mindset.

During the intervention students were taught through digital concept maps. The digital concept maps of salt, goiter treatment, and wind are respectively depicted in Figures 3–5.

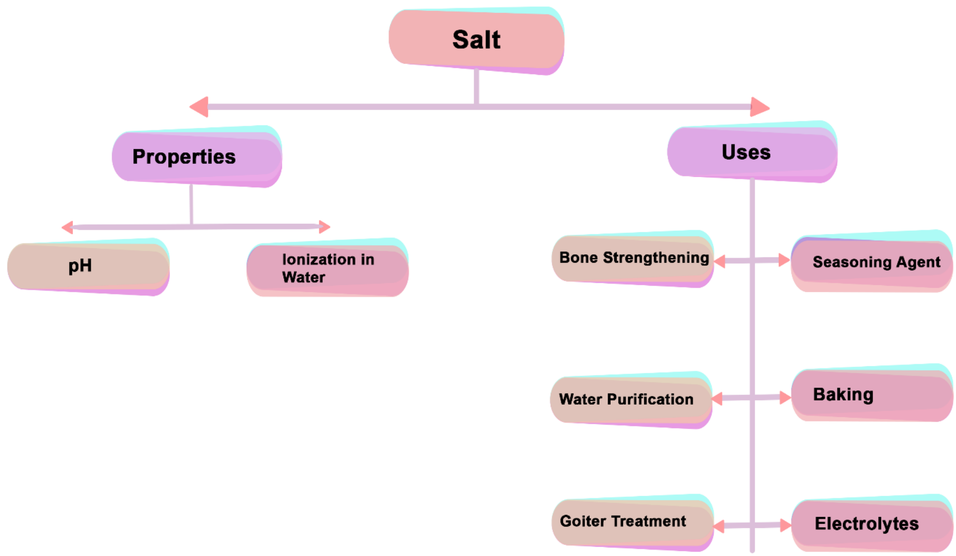


Figure 3. Digital concept map of salt.

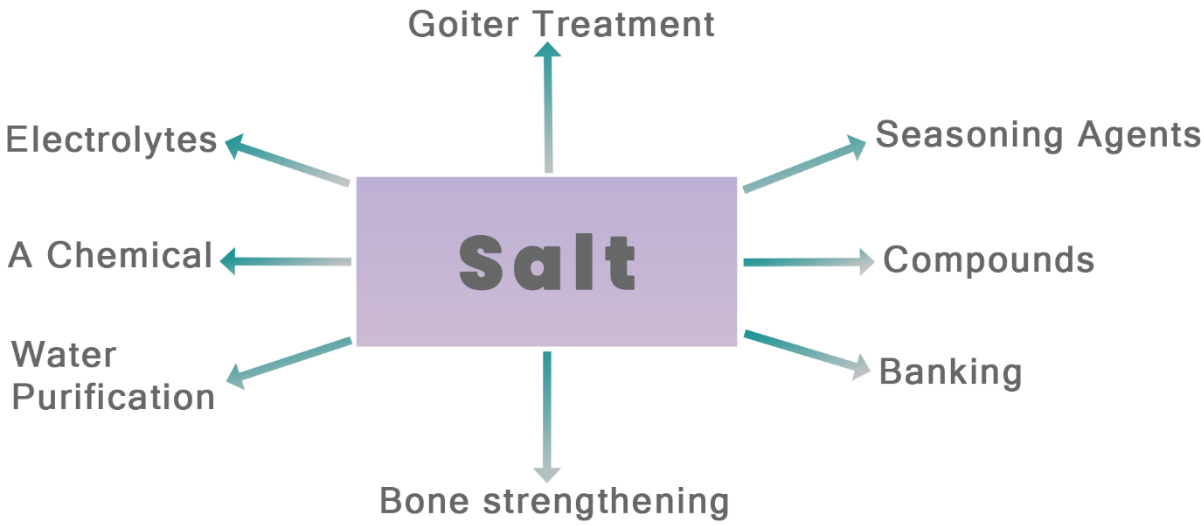


Figure 4. Digital concept map of goiter treatment.

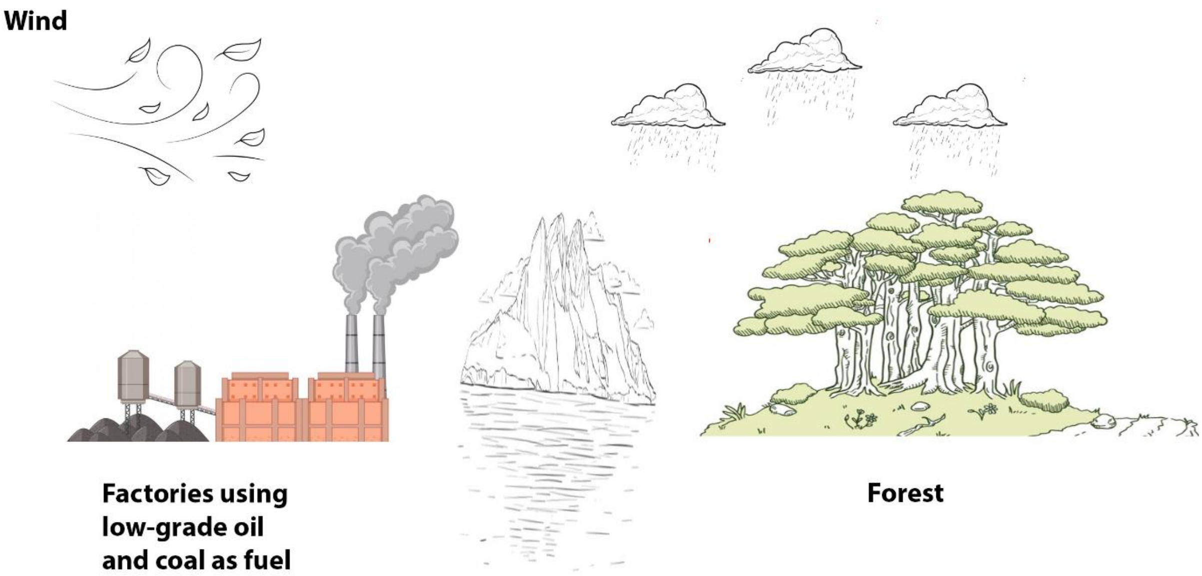


Figure 5. Digital concept map of wind.

Showed the word "Salts" on a computer screen and asked to give their ideas about it, students wrote their ideas on the computer screen.

Students were also instructed to visit different websites and watch videos on 20 November 2023. These websites have been developed by the Ministry of Education, Government of Punjab, Pakistan.

Video-1: (13a) Salts, Video-2: (14a) Salts, and Video-3: (What are salts), available at web address: https://www.elearn.gov.pk/elearn_app/videos/1059/0/6 (accessed on 30 May 2024).

Afterward, a digital growth mindset assessment sheet was used to assess students' performance during the intervention.

By applying this assessment sheet, we easily modified the students' marks on tests and assignments. For example, if a student earned 85% on a quiz, we gave them 8500 XP. We also awarded XP for completing assignments, participating in the class, and the demonstration of any effort to learn. Students participated in extra-curricular activities just like they played and completed levels in video games. We also gave XP for separate skills and topics. In this way, we kept track of the points students acquired. Figure 6 shows the results of the digital growth mindset assessment.

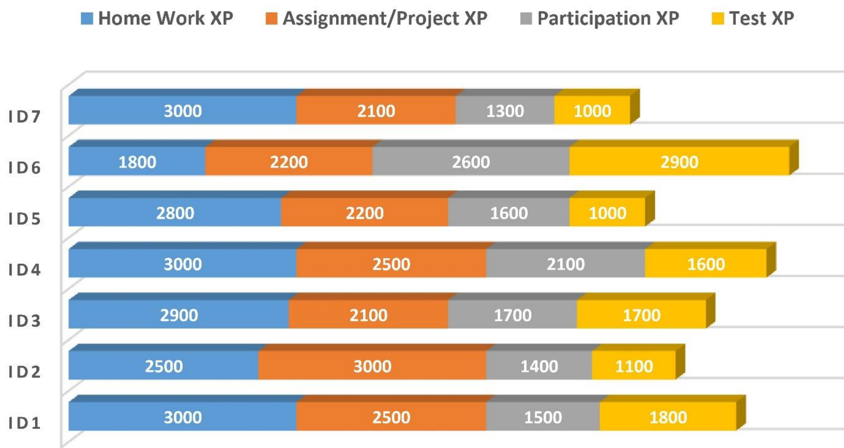
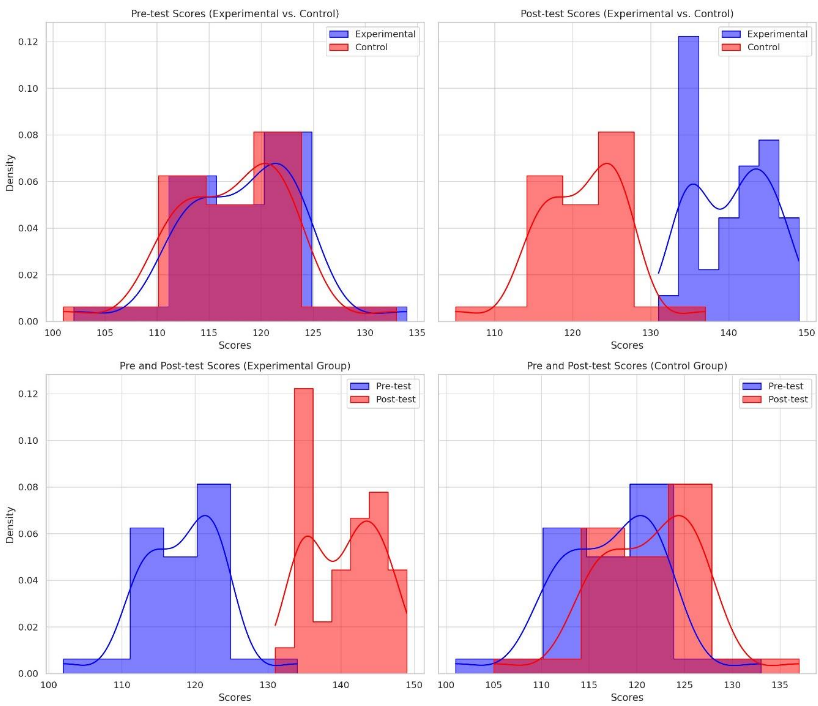


Figure 6. Digital growth mindset assessment sheet.

11. Data Analysis/Findings

A pre-test and post-test were administered to assess the effectiveness of the intervention in the subject of chemistry. The test scores were evaluated using both an independent samples t-test and a paired t-test to determine the mean values of the pre- and post-test scores across each domain, including motivation and achievement, for the experimental and control groups.

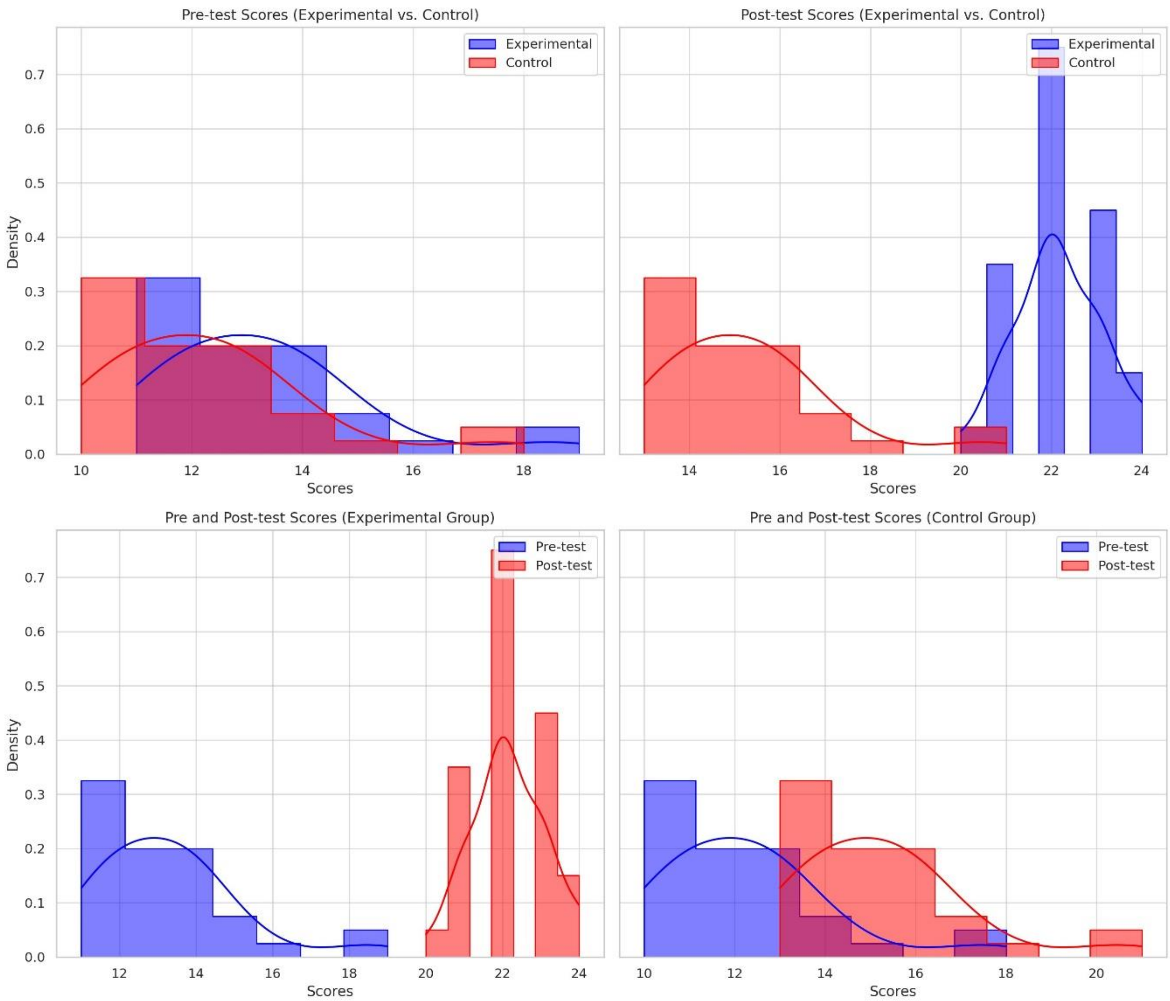
Figure 7 shows that the mean increased from 118.31 (pre-test) to 140.34 (post-test) in the experimental group, while the mean increased slightly from 117.31 (pre-test) to 121.31 (post-test) in the control group. The t-statistic: 0.73, *p*-value: 0.47 indicated no significant difference between the groups before the intervention. While the t-statistic: 14.80, *p*-value: <0.001 indicated a significant difference in favor of the experimental group post-intervention. The t-statistic: −17.75, *p*-value: <0.001 showed a significant result indicating improvement within the experimental group. The Cohen's d value was calculated as d = 4.10. The 0.70 < 4.10 effect size can be assumed as a strong effect [23].



Note.: N = 35, $p = 0.05$

Figure 7. Effect of the digital growth mindset on students' motivation to learn chemistry.

Figure 8 shows that the mean increased significantly from 13.29 (pre-test) to 22.17 (post-test) in the experimental group, while in control group, the mean changed from 12.29 (pre-test) to 15.29 (post-test). The t-statistic: 2.27, *p*-value: 0.026 indicated a statistically significant difference even before the intervention, with the experimental group scoring slightly higher. The t-statistic: 19.65, *p*-value: <0.001 indicated a significant difference in favor of the experimental group post-intervention, suggesting substantial effects from the intervention. The t-statistic: −24.74, *p*-value: <0.001 indicated a substantial improvement within the experimental group. The Cohen's d value was calculated as d = 6.06. The 1.63 < 6.06 effect size can be assumed as a strong effect [23].



Note. N = 35, *p* = 0.05.

Figure 8. Effect of the digital growth mindset on students' chemistry achievement.

12. Students' Experience during the Digital Growth Mindset Intervention

Following the intervention, a focus group discussion was held with students to gather their thoughts and opinions on their experiences with the digital growth mindset intervention. Students pointed out that, previously, chemistry teachers had implemented highly structured activities in classrooms. Questioning was discouraged, and participation was limited during lectures. These experiences left them uncomfortable and unfulfilled.

According to the students, the chemistry teachers mostly employed flexible instruction activities during the digital growth mindset intervention. This type of instruction enabled them to ask questions and provided ample opportunities for input, both during and after class. Prior to the intervention, the students reported feeling disorganized or disheartened by their learning experiences.

They revealed that the statements regarding the use of digital devices could potentially enhance the motivation levels of students. Mostly, students agreed that their chemistry teacher employed moderately challenging digital-technology-based activities when teaching chemistry. They acknowledged that if a task is too difficult, it can demotivate them. However, digital technology can also spark interest and facilitate problem-solving skills. The students stated that their teachers had never incorporated peer-model activities into their lessons, but they were later introduced. The students were instructed by their chemistry teacher to learn by observing a peer who successfully completed a task.

Chemistry teachers have reportedly presented a practical strategy for tackling tasks and assignments. This approach was useful for honing study skills such as preparing for an exam or completing a project using digital technology. Utilizing instructional technologies, stories, and games to align lesson plans with students' interests can greatly improve chemistry teachers' ability to engage their students effectively. Additionally, these teachers reported granting their students the autonomy to select their own assessment techniques, as indicated by the teachers.

The students reportedly receive consistent, dependable, and comprehensive encouragement, such as, "You have the ability to accomplish this task. We've provided you with a detailed plan for writing a lab report, along with a weekly schedule—simply follow the plan and you will achieve success". Unwavering praise and encouragement is vital to students' academic achievement.

The students explored during the intervention whether chemistry teachers utilized effective learning activities when addressing challenging assignments/tasks. The primary focus was on students' ability or intelligence, as well as their effort and strategy use. Students reported that when they succeeded in completing a task, they were praised for their effort or strategies employed to finish the task. Conversely, when students failed to complete the task, they received productive criticism regarding their effort and strategy use. Teachers emphasized that achievement was linked to the effort made by students.

According to students, when teachers implemented the digital growth mindset intervention, they emphasized that making mistakes is a natural part of the learning process and that it helps students improve their skills. Teachers also stopped posting grades in public spaces, and instead, they recognized students who did well on assignments or tasks by explaining, Instructors typically highlighted the benefits of tackling difficult tasks. Previously, students had found their lessons unstimulating, and teachers did not employ captivating methods like tales, riddles, or intriguing pursuits to kick off any lesson, assignment, task, or activity. Instead, educators started lessons with strict behavior.

The students further mentioned that during the digital growth mindset intervention, teachers began lessons by using digital technology to present intriguing puzzles, inconsistencies, or demonstrations that piqued students' interest. These activities were designed to align with the learning outcomes of the lesson plans. Students were then given the opportunity to demonstrate their understanding and mastery of the material in their own way.

The teacher did not focus on recitations or rote memorization of topics. Instead, they concentrated on engaging students with challenging material tailored to their current knowledge and skill levels. The teacher provided instruction that went beyond the students' skill range, aiming to stretch their abilities further. They also utilized pre-test techniques to assess students' prior knowledge of the material and skills that would be covered in the upcoming lesson. This was conducted to ensure that students had the necessary prerequisite skills and knowledge to succeed in the lesson.

The teacher was found to prefer activities that required active engagement or participation. On the other hand, passive forms of learning were not encouraged, and active forms of learning were given priority. Additionally, the students noted that they appreciated immediate feedback and enjoyed playing computer games because they provided immediate feedback.

The teacher incorporated electronic-game-like elements or elements of fantasy into classroom activities, as discovered by students. These elements included activities with contests, creative writing, or imaginative components, challenges to overcome, hidden information, and more. These activities were integrated into the lesson plans.

The students stressed that, during the intervention, it was essential for the teacher to concentrate on engaging students with powerful ideas that serve as a foundation for dependable applications. The teacher had a noble intention of considering a topic as interesting, fascinating, expressive, or significant, and they used good motives to do so. They then discussed these reasons with the students.

Mostly, students reported that their teacher promoted activities such as think-aloud, students' practice with reflective-dialogue group discussions, and hands-on learning activities to help them think through problems and cases. Additionally, the teacher praised the students' efforts and strategies, often using experiential learning activities to encourage the application of knowledge in a variety of situations. The teacher also encouraged students to focus their attention on real-life instances mixed with classroom information.

The students revealed that the teacher made the conceptual material more concrete and interesting by providing examples and connecting the material to their experiences or current events. The teacher assigned more varied tasks or encouraged students to cooperate in small groups, and focused lessons. The teacher did not allow the textbook to "carry the lesson" rather than elaborate extensively on textbook readings.

13. Discussion

The results of the current study add to and broaden the previous research in the area, as had the studies conducted by [24], which found that having a growth mindset led to increased student motivation and better achievement in chemistry. Our results, like earlier studies, confirm that the implanting of the mindset of learning and improvement can effectively be amplified to enhance educational outcomes [15]. However, the digital overlay of the traditional growth mindset has endowed our investigation with a new feature [25]. The digital growth mindset captures the more traditional view of embracing challenges and learning from feedback but adds relevance to the increasingly common modern digital tools developed for use in educational settings [26]. This integration seems to motivate even more the students with these dynamic, interactive, and individualized experiences. From our results, it seems that digital tools can effectively second the framework of mind growth, thereby providing a more engaging and responsive learning environment.

In return, because of the available digital resources, the learning process becomes more accessible and sensitive to personal learning style, which again leads to an increase in motivation and learning results [27]. The novelty and interactive nature that the digital element brings will most likely raise engagement and sustain attention accordingly [28]. The possible positive impact of a growth mentality originating from digital sources on chemistry achievement might be because of some of the features of digital tools which support students' search and exploration of the understanding of scientific concepts [29]. For example, real-time data-analysis-based simulators and virtual experiments serve to concretize otherwise abstract scientific principles and make them more feasible [30]. Such findings suggest that the present study aligns with earlier research, which underscores the theory of the great robustness of the growth mindset and shows its potential for amplification by digital tools. Future research is expected to more clearly allow identifying the mechanisms by virtue of which digital tools further promote a growth mindset and to determine specific digital practices that would work in enhancing educational gains maximally [31].

14. Conclusions/Recommendations

The discussion of the digital growth mindset in the context of the current study has added to the benevolent effect that the principles underlying the growth mindset have on students' motivation and their performance in chemistry, as this has already been reported in previous studies. Our results are therefore important for extending these established paradigms with the inclusion of the digital factor and to see how modern technologies in education could be used to enhance or even optimize the use of growth mindset strategies. In this regard, the incorporation of digital tools into interventions toward a growth mindset is a progressive step in improving educational methodologies. Most would probably just continue with activities much like how a traditional growth mindset intervention program would proceed, while others can extend new ways to interact with students through innovative support. For such aims, digital materials help educators provide students with an immersive experience that includes active learning, which may be very beneficial in scientific studies that embrace practical, visual, and experimental learning.

Our results suggest that a growth mindset toward digital tools does not mediate a positive orientation toward learning and challenge only, but it also harnesses the potential of digital tools to foster a better, more sustainable understanding of scientific knowledge. There is a call for this kind of synthesis between technology and mindset in an approach toward learning that is more engaged/persistent yet all the more crucial within the shifting sands of education. The current study takes the basic tenets of growth mindset research and extends them to show that when such tenets are operationalized by way of digital implementation, they hold even more promise. That should point toward a hopeful future for education practices and research where digital tools can be employed to continuously develop and foster growth mindsets in students.

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