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The Effect of Gerlach and Ely Model Instructional Modules on Systems Thinking Skills among 6th Grade Elementary Students in Saudi Arabia

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ABSTRACT

Addressing thinking in classrooms produces lifelong learners who possess self-learning tools and self-motivation to search for and acquire knowledge. The current study aimed to investigate the impact of the Gerlach and Ely Model (GEM) on developing systems thinking skills in science among sixth-grade elementary students in Riyadh, Saudi Arabia. Using a quasi-experimental design, the study sample was randomly selected, comprising 80 students, divided into two groups (40 students as a control group and 40 students as an experimental group). A Systems Thinking Skills Test (STSS) was developed and validated. Additionally, a teacher's guide (instructional plan) was designed based on the Gerlach and Ely Model. A purposive sampling with random assignment of groups was adopted. Descriptive analysis, Levene's test and independent sample t-test analyses were used to achieve research goals. The Gerlach and Ely Model was employed to design lesson unit plans on systems thinking skills in Saudi science teaching. The results indicate that the experimental group, as opposed to the control group, experienced meaningful changes on all subscales of systems thinking. Statistically significant differences favoring the experimental group were found on the measures of on three specific skills, including PMI Idea Processing, Redesign and Dynamic Handling of Problems. Analyses of gender revealed that there was no significant difference between scores of males and females, yet males ranked higher in related areas like modeling and redesign. The significance of the study's results lies in their confirmation of improved systems thinking skills in science among Saudi elementary school students. These significant gains confirm the effectiveness of the GEM instructional modules combining cognitive and creative skills in science education.

Keywords: Gerlach and Ely Model (GEM), Systems Thinking Skills, Science Education, Quasi-Experimental Design, Elementary Students (Saudi Arabia).

INTRODUCTION

Education, and the teaching of science in particular, aims to foster comprehensive growth in learners, encompassing cognitive, skills, and moral dimensions [1]. The subject of science has contributed immensely to students as it provides them with an understanding of the knowledge as well as adapts information to their daily life [2]. Developing 21st-century skills, such as critical thinking, problem-solving, systems thinking, and creativity, is essential due to inconsistent science knowledge and attitudes among students [3-5]. According to Gerlach, Ely (6], there should be a connection between learning strategies and learning objectives to create effective and efficient learning activities. Education researchers have advocated the use of systems thinking in schools. For example, Richmond (7] proposed systems thinking in schools to prepare "systems citizens," i.e., citizens who know how to bring the desired changes in society. Many of the recommendations that emerged suggest that students should be taught systems thinking through the Gerlach and Ely Model (GEM) Instructional Module separate from the school curriculum or through the curriculum provided to them, and system ally designing these GEM instructional modules [8]. GEM Instructional Modules play a crucial role in the learning and teaching of sciences, as they represent an organized and deliberate process to achieve specific objectives of the curriculum. They assist the teacher in diversifying activities and avoiding confusion and randomness. Additionally, they save time and effort, leading to student engagement with the study material [6, 9]. The active cognitive experiences become internalized experiences that help the learner to develop his thinking style and to develop refined thinking processes [10]. Many studies (e.g., [11-13]) have emphasized the need to review student preparation programs, so they target the development of thinking skills to ensure effective cognitive development that allows the individual to use his utmost mental potentials to solve the problems induced by change. However, systems thinking is challenging to measure directly, much like any cognitive process. However, it can be inferred by tracking its outcomes or, more precisely, by measuring the outputs associated with systems thinking skills. To measure systems thinking skills, various forms of system representation are utilized, such as mind maps, concept maps, information maps, negative feedback loops, flowcharts, and others [14, 15].

In the Saudi context, under Vision 2030 led by Crown Prince Mohammed bin Salman, emphasizes research, development and innovation to achieve a vibrant society and thriving economy, with a focus on enhancing educational systems [16-18]. The educational system in Saudi Arabia has witnessed reform and development movements through which curricula, teaching and evaluation methods have been developed to keep pace with global developments and to provide students with the competencies that refine their personalities and develop their thinking skills [19-21]. Educationists have striven to develop modern programs to modify and improve conditions affecting students' learning. Based on this research line, new concepts and theories have emerged in education [22].

The current situation of science education in the Kingdom of Saudi Arabia presents a number of important problems that affect both teaching methods and student learning outcomes. The current linear approach to curriculum design, which includes objectives, content, teaching techniques, assessment and evaluation, has led to fragmented and isolated learning experiences, especially in elementary schools [23, 24]. This disjointed approach contributes to the difficulty of retaining information and the lack of practical application in real life, as curricula are often unable to coherently integrate content and meet the psychological, moral and subject-specific needs of students. Traditional assessment approaches that emphasize memorization exacerbate this problem by ignoring the development of higher-order thinking abilities [22, 24, 25]. Facing these challenges in developing critical thinking skills, there is a need for systematic direct instruction in critical thinking and creativity, as well as better professional development for teachers [26, 27]. These changes could help align Saudi science education with international standards and prepare students for future challenges [23].

However, there is a lack of empirical studies looking at the effectiveness of the GEM teaching module based on Gerlach and Ely's model for sixth-grade students in Saudi Arabia [24]. The existing literature lacks comprehensive research on how such programs can improve systems thinking skills in primary science classrooms [25]. Although international evaluations provide wide-ranging evidence, integrating these frameworks into primary school curricula [28, 29]. Therefore, this study aims to address this gap by investigating the effectiveness of a Gerlach and Ely based GEM instructional module in developing systems thinking skills in sixth grade students in Saudi Arabia, thus contributing to educational psychology and curriculum development.

Systems thinking skills (STS) is a concept that was introduced in the late 20th century, but its roots can be found thousands of years back in the holistic ancient traditions of man's civilization [30-32]. It is a concept that is based on general systems theory according to Boardman, Sauser (33], which was first introduced by Ludwig von Bertalanffy way back in the 1920s–1930s [34], and further expanded and explained throughout the years [35-37]. The theory covers the idea that complex systems have shared organizing principles that can be determined and formed in ways that can be generalized beyond particular cases [38]. Systems thinking refers to a thinking approach that involves the comprehension of the systems structure viewed from a holistic framework – through the understanding of the relationships of the components of the system, the feedback, and the systems behavior, while taking into account dynamism and change [39, 40]. With regards to the important position of systems thinking skills in education, emphasis has been placed on systems thinking implementation to develop school curricula, and as such, more research needs to be carried out to examine systems thinking skills in the education environment towards better overall learning results [41, 42]. Implementing project-based learning methodology entails involving students in practical projects that necessitate the analysis and comprehension of intricate systems [43]. An additional efficacious approach is to integrate modules on systems thinking within the curriculum, equipping students with the essential vocabulary, conceptual frameworks, and quantitative modeling abilities required to enhance their systems-thinking capabilities [44]. Additionally, using learning tools based on the STEM (Science, Technology, Engineering, and Mathematics) can augment pupils' aptitude for creative thinking, a skill that is intricately linked to systems thinking [45, 46]. The advancement of the area has been furthered by the creation and verification of tools, such as the System Thinking Assessment (STA) [47] and the Systems Thinking Scale (STS) [48-50].

The Gerlach and Ely model, developed by Vernon S. Gerlach and Donald P. Ely in 1980, is a systematic approach to instructional design that provides a structured framework for developing educational systems. This model is based on the premise that effective instruction is the result of careful planning, implementation, and evaluation. In addition to this, it is widely used in educational and training program settings to create engaging learning experiences [6]. Several scholars have highlighted the systematic nature of the model, emphasizing that it provides a structured framework for teachers to follow, ensuring that all key aspects of instructional design are addressed. While the model provides this framework, it is also flexible and adaptable to different instructional contexts [51, 52]. Another key feature of the Gerlach and Ely model that has been widely discussed is its emphasis on learning outcomes [52]. GEM instructional module has been extensively examined in literature, revealing diverse approaches and their impacts on student outcomes. Thus enhancing cognitive and non-cognitive skills, improving academic achievement, critical thinking, and social-emotional development among students [29, 53, 54]. In addition to enhancing student outcomes, studies on GEM instructional module frequently highlight the role of teacher professional development and its impact on program efficacy. Effective GEM instructional module are often supported by robust professional development initiatives that equip teachers with the necessary skills and knowledge to implement innovative instructional strategies and learning models resulting with GEM instructional module that have a maximum amount of efficiency [55]. Such GEM instructional module emphasizes continuous and reflective learning, enabling teachers to adapt to new pedagogical approaches and evolving classroom dynamics [56]. The success of GEM instructional module is closely linked to the quality of teacher-student interactions, which are fostered through taking comprehensive steps in areas such as classroom management, differentiated instruction, and formative assessment [57].

The Gerlach and Ely model is highly relevant to this study which explores the effect of GEM instructional module in developing systems thinking skills in the Kingdom of Saudi Arabia, providing a solid framework for designing and implementing an effective GEM instructional module that meets the specific needs of students, especially for the science subject [6]. Its systematic approach and emphasis on learner-centered instruction make it a valuable tool for achieving the study's objectives and contributing to the overall improvement of education in the region.

The purpose of this study is to investigate the impact of GEM instructional modules (Gerlach & Ely Model) on the fostering of students' systems thinking in science for sixth grade pupils in elementary schools in the Kingdom of Saudi Arabia. The findings of this study can be used as a guideline for a range of educational contexts such as teaching in classrooms, curriculum planning, and teacher preparation and development programs. This research seeks to answer the following questions:

RQ1: What is the impact of the instructional unit plan on students' systems thinking skills in the experimental group compared to the control group among sixth-grade students?

RQ2: Are there statistically significant differences between the mean scores of the experimental and control groups?

RQ3: Are there any significant differences in the mean score of systems thinking according to gender?

MATERIALS AND METHODS

Research Design

A quasi-experimental approach with an equivalent group design was used in this study, which was chosen due to its consistency with the aims and objectives of the study. Quasi-experimental designs create a control group that is similar to the experimental group in terms of baseline (pre-intervention) characteristics. The control group reflects the outcomes that would have been achieved in the absence of the intervention. Therefore, it can be concluded that the intervention led to any differences in outcomes between the experimental and control groups [58]. In this study, the intervention is an instructional module based on Gerlach and Ely's model, and the outcome is the development of systems thinking skills in sixth grade elementary students. Accordingly, the independent variable is the GEM instructional module and the dependent variable is the systems thinking skills.

Participants

The population of the study involves the 12-year-old students attending schools under the Department of Education in Riyadh, Saudi Arabia, for the 2024 academic year. In Riyadh, there are 478 schools with around 6,165 students aged 12, comprising 2,312 males and 3,753 females [59]. Using a purposive sampling technique, 80 sixth-grade students in Riyadh, distributed equally between boys and girls. This includes 40 students in the experimental group (20 boys and 20 girls) and 40 students in the control group (20 boys and 20 girls). Two private schools were selected, one for boys and the other for girls. Four classrooms were randomly selected from the sixth-grade classes—two per school, one for each gender group. Using purposive sampling with random assignment of groups helps control for external factors, ensuring internal validity [60].

Instruments

A Proposed Instructional Unit

An instructional unit for teaching the third unit (Environmental Systems and Their Resources) and the fourth unit (Space) within the sixth-grade science curriculum was proposed. The unit is designed in light of the Gerlach and Ely Model [6] with a graphic organizers strategy for the experimental group, while the usual traditional teaching approach was used with the control group, as specified by the Ministry of Education's teacher guide. Graphic organizers are visual representations in which information is organized as mental concepts, table charts/comparisons, sequential graphic organizers of steps, information, and problem-solving organizers. They help students become strategic learners when they learn science. As students learn new concepts and try to connect them, they develop higher-order thinking skills [61]. The unit includes the development of both a Teacher's Guide and a Student Workbook to facilitate effective instruction and active student engagement. The Teacher's Guide provides structured lesson plans, instructional strategies, and assessment tools to support educators in delivering the content effectively. The Student Workbook contains interactive activities, concept maps, and problem-solving exercises that encourage students to explore scientific concepts through a systems-thinking lens. By integrating these components, the proposed instructional unit aims to enhance students 'systems thinking skills and deep understanding of scientific concepts related to environmental systems and space.

Scale of Systems Thinking Skills (STSS)

The Systems Thinking Scale (STSS) was developed by the researcher, drawing upon insights from previous studies [62-65]. The STSS is designed to challenge students and stimulate deep thinking, thereby enhancing their systems thinking abilities in environmental and space sciences [66].

In its initial form, the scale consists of 12 basic dimensions of systems thinking skills, including 34 tasks (sub-dimensions), as shown in Table 1. The systems thinking skills include the information gathering skill, the system analysis skill, the comprehensive thinking skill, the reasoning skill, the skill of using time and place relationships, the skill of dynamic handling of the problem, the skill of drawing thinking diagram, the (Plus- Minus- Interesting) PMI idea processing skill, the interpretation skill, the redesigning skill, the modeling skill, and the system evaluation skill. The questions (tasks) in the scale were shown in a multiple-choice pattern and came in two types. "Type 1" is a multiple choice questions using verbal sentences followed by verbal alternatives. While "Type 2" is a multiple choice questions using verbal sentences followed by figural alternatives. Each correct answer earning the student two points, with a total possible score ranging from 0 to 68. To interpret the results, specific ranges based on the interval (68/3=22.7), were established to classify the students' performance levels into three categories: (weak: 0-22), (good: 23-45), and excellent (46-68).

Table 1. Specifications of the Systems Thinking Skills Scale

Dimension	Number of tasks	Number of questions		Maximum score	Relative weight
		Type 1	Type 2		
Information gathering skill (observation and insight)	4	3	1	8	%12
System analysis skill (analyzing the system into its main components)	4	6	0	12	%18
Comprehensive thinking skill (the big picture)	2	1	0	2	%3
Reasoning skill	4	1	2	6	%9
The skill of using time and place relationships	2	1	2	6	%9
The skill of dynamic handling of the problem	2	1	0	2	% 3
The skill of drawing systems thinking diagrams	2	2	3	10	%14
The skill of processing ideas PMI	2	1	0	2	% 3
Interpretation skill	4	1	0	2	%3
Redesign skill	2	0	1	2	% 3
Modeling skill	2	1	1	4	% 6
System evaluation skill	4	2	4	12	%17
Total	**34**	**20**	**14**	**68**	**%100**

The difficulty coefficient for each task in the test was calculated using the arithmetic mean of correct responses. Table 2 presents the difficulty coefficients of the STSS. A task (question) is considered acceptable if its difficulty coefficient falls within the range of 0.15–0.85 [67]. Accordingly, the tasks 12, 24 and 29 were excluded from the scale. Consequently, the number of systems thinking test items became 31 questions, measuring 12 skills.

Table 2. The Difficulty Coefficients of STSS

Task #	Difficulty Coefficient (%)	Task #	Difficulty Coefficient (%)	Task #	Difficulty Coefficient (%)
1	53	13	53	25	55
2	42	14	42	26	68
3	65	15	65	27	57
4	28	16	28	28	83
5	52	17	52	**29**	**88**
6	47	18	47	30	18
7	45	19	45	31	83
8	43	20	43	32	73
9	40	21	40	33	72
10	48	22	48	34	83
11	65	23	65		
12	**90**	**24**	**90**		

Pilot study

To ensure the validity and reliability of the STSS scale, it was applied on a sample consisting of (60) sixth grade students from within the study community and outside the target sample. To verify the apparent validity, the scale was presented in its initial form to a group of specialists who hold a doctorate degree in educational sciences, where linguistic modifications were made to (5) paragraphs, and paragraph (24) was deleted due to its similarity to paragraph (23). Consequently, the number of test items became (30). To verify the construct validity, Pearson's correlation coefficient was used to extract the values of the correlation coefficients of the items with the dimension to which they belong, and the values of the correlation coefficients of the items with the total score of the scale, as shown in Table 3.

Table 3. Correlation coefficients of the items of the STSS with the total score of the scale (n=60).

Item #	Correlation Coeff.	Item #	Correlation Coeff.	Item #	Correlation Coeff.
1	**0.45	13	**0.48	25	**0.68
2	**0.38	14	**0.40	26	**0.41
3	*0.31	15	Excluded	27	**0.37
4	**0.58	16	**0.64	28	**0.49
5	**0.11**	17	*0.33	29	Excluded
6	*0.32	18	**0.37	30	**0.59
7	**0.47	19	**0.39	31	**0.63
8	**0.33	20	**0.58	32	**0.41
9	**0.39	21	**0.61	33	**0.48
10	**0.05**	22	**0.68	34	**0.38
11	**0.41	23	**0.50		
12	Excluded	24	Excluded		
Statistically significant at the significance level (p < .05). **Statistically significant at the significance level (** p < .01)					

It can be noted that the values of the correlation coefficients of the items ranged between (0.05 - 0.68). The values of the correlation coefficients that are less than 0.30 are considered weak [68]. Accordingly, the two tasks 5 and 10 are excluded from the scale. Thus, the number of items of the scale became (28).

The reliability (Internal consistency) of the scale was calculated using Cronbach's Alpha method. In addition, its stability was tested using "test-retest" method between the students' scores in two application times. The results are depicted in Table 4.

Table 4. Reliability coefficient of the systems thinking scale using the Cronbach's Alpha and retest method.

Dimension #	Dimension name	Number of items	Skills distribution	Cronbach's alpha	Stability
1	Information gathering skill (observation and insight)	4	21 ‹18 ‹8 ‹6	0.80	0.93
2	System analysis skill (analyzing the system into its components)	4	34 ‹22 ‹13 ‹1	0.83	0.86
3	Big picture thinking skill	1	28	0.71	0.83
4	Reasoning skill	2	19 ‹9	0.73	0.86
5	Skill of perceiving time and space relationships	2	33 ‹26	0.70	0.80
6	Dynamic problem-solving skill	1	7	0.76	0.89
7	Systematic drawing skill	4	32 ‹31 ‹30 ‹14	0.88	0.91
8	PMI Thought Processing Skill	1	16	0.76	0.86
9	Interpretation skill	2	17 ‹2	0.79	0.86
10	Redesign skill	1	4	0.77	0.86
11	Modeling skill	2	27 ‹20	0.78	0.80
12	System evaluation skill	4	25 ‹23 ‹11 ‹3	0.76	0.89
	Total score	**28**		**0.89**	**0.94**

It is clear from Table 4 that the values of (Internal consistency) through Cronbach's alpha coefficient for the dimensions of the systems thinking scale ranged between (0.70-0.88) and for the total score (0.89), which indicates that the dimensions ranged between the good and excellent level in internal consistency stability. The stability coefficients by the retest method for the dimensions ranged between (0.80-0.93) and for the total score 0.94, which shows the stability of the students' answers to the skills.

Data Collection Procedures

The STSS scale was used as an intervention tool in the experimental group. Participants were trained in classroom learning for a week. The scale was administered after the educational treatment to assess the effects of the intervention on the participants' outcomes. Data were collected to verify the treatment effects. In addition, the researcher developed a checklist to observe teachers during their lessons, to assess their use of flowcharts and to ensure consistency in the delivery of each session.

Data Analysis Methods

To analyze the data, SPSS software was employed. Descriptive analysis, including mean and standard deviation (SD), was used to evaluate the STSS scale scores. In addition, Levene's test was used to test the equality of variances, while independent sample t-test analysis was used to compare the means of STSS scale scores for the two groups (control and experimental).

Ethical Statement

This study was approved by the Institutional Review Board (IRB), Princess Nourah bint Abdulrahman University, Riyadh, Saudi Arabia (Reference No. HAP-01-R-059). Prior to data collection, all participants received written information about the study and signed written informed consent forms. Before giving consent, participants were given the opportunity to ask questions. All participants had the right to withdraw from this research at any time without giving any reason. They were informed that this study was confidential, and all information related to their identities would remain confidential

RESULTS

Research Question 1: What is the impact of the instructional unit plan on students' systems thinking skills in the experimental group compared to the control group among sixth-grade students?

The means and the standard deviations of the systems thinking variables across the control and experimental groups are summarized in Table 5 for the entire data collected at both pre- and post-measures after the intervention via the GEM instructional modules.

Table 5. Means and Standard deviations for System thinking skills scale results.

Dimension	Score	Control group	Experimental group
Information Gathering Skill (observation and insight)	**Mean**	1.53	2.63
	SD	1.06	0.95
System Analysis Skill (analyzing the system into its components)	**Mean**	1.75	2.35
	SD	0.90	0.98
Comprehensive Thinking Skill (the big picture)	**Mean**	1.40	2.50
	SD	0.90	0.91
Reasoning Skill	**Mean**	1.50	2.53
	SD	0.99	0.99
The Skill of Using Time and Place Relationships	**Mean**	1.43	2.48
	SD	0.90	0.93
The Skill of Dynamic Handling of the Problem	**Mean**	1.45	2.55
	SD	0.88	0.99
The Skill of Drawing System Figures	**Mean**	1.45	2.50
	SD	0.81	1.04
PMI Idea Processing Skill	**Mean**	1.38	2.50
	SD	0.95	0.91
Interpretation Skill	**Mean**	1.30	2.33
	SD	1.07	1.00
Redesign Skill	**Mean**	1.65	2.80
	SD	0.98	0.88
Modeling Skill	**Mean**	1.60	2.43
	SD	0.81	0.96
System Evaluation Skill	**Mean**	1.48	2.50
	SD	1.04	0.96
Total	**Mean**	**1.49**	**2.51**
	SD	**0.25**	**0.32**

A comparison between the control and experimental groups demonstrates quite a gain provided by GEM instructional modules, with a total mean of 1.49 (control group) and a total mean of 2.51 (experimental group). This increase in total mean confirms that the interventions had a clear impact in promoting systems thinking among the students. In addition, the experimental group achieved higher scores on all twelve skills compared with the control group.

Research Question 2: Are there statistically significant differences between the mean scores of the experimental and control groups?

A full detailed analysis of the independent samples t-test was used to compare the scores of the control and experimental groups after the application of the GEM instructional modules, as given in Table 6.. This examination is vital to determine the success of the intervention toward improving system thinking abilities in several aspects. The examination includes Levene's test for equality of variances and t-test for equality of means to reveal any differences between the two groups.

Levene's test for "Information Gathering Skill" shows an F value of 1.248 with a p-value of 0.267, suggesting homogeneity of variances. Based on this, the t-test value of -4.877 was obtained, and with the significance value p = 0.000, it can be seen that there is a major difference between control group and experimental group. The mean difference of -1.100 suggests that the experimental group were strong compared to the control group in ability to gather information after intervention and the confidence interval is from –1.549 to –0.651. For "System Analysis Skill", the F value of 0.681 (p = 0.412) indicates equal variances. A t-test value of -2.861, p = 0.005 indicates a statistically significant difference between the two groups with the experimental group showing a high mean score. In relation to system analysis skills, the computed mean difference is -0.600, representing a significant gain for the experimental group, with the confidence interval ranging from -1.017 to -0.182. The assumption of equal variances is confirmed in "Comprehensive Thinking Skill", with an F value of 0.002 (p = 0.961). The t-test result of -5.448 (p = 0.000) indicates a significant difference (high), and the mean difference of -1.100 suggests a high level of gain in the comprehensive thinking skills of the experimental group. This finding demonstrates that the GEM module is effective in promoting holistic thinking with a 95% confidence interval between -1.501 and -0.698. For the "Reasoning Skill", the Levene's test (F = 0.001, p = 0.972) justified the assumption of homogeneity of variances. Post-intervention, there was a significant difference in the reasoning skills as evidenced by the t-test value of -4.645(p=0.000). This average difference of -1.025 contrasts the significant increase in reasoning skills demonstrated by the experimental group (CI= -0.585, -1.464). The "Skills of Time and Place Relationships" shows an F = 0.043 (p = 0.836), meaning homogeneity in variances. The t-test value of -5.115 (p = 0.000) indicates that this difference is statistically significant (95% CI for the mean difference was -1.458 to -0.641), showing that the experimental group performs better in the knowledge of time and place relationships with a mean of -1.050 time units. For "Dynamic Relaxation of the Problem", the F value is 1.111 (p = 0.295) which means equal variances can be assumed. The results of the t-test indicate that the t-value is -5.276 (p = 0.000), indicating that the average performance of the experimental group has changed significantly. This mean difference of -1.100 indicates that the GEM modules made a significant improvement to students' dynamic task-solving competencies, 95 % CI (-1.515 to -0.684). Within "Drawing System Figures" test, the F value of 3.925, (p = 0.051) is approaching significance, which suggests possible differences in variances. However, the t-test value of -5.033 (p = 0.000) indicates the difference between the groups is significant, with a mean difference of -1.050, reiterating that the experimental group's drawing system figures had considerably improved. For "PMI Idea Processing Skill", equal variances are supported by the Levene's test (F = 0.129, p = 0.720). The t-test of -5.413 (p = 0.000) indicates that there is a statistically significant difference in the level of enhancement in PMI idea processing skills in the experimental group, meaning the mean difference is -1.125, with confidence interval between -1.538 and -0.711. A Repeated Measures ANOVA on "Interpretation Skill" demonstrates an F value of 0.168 (p = 0.683), indicating homogeneity of variances. The t-test statistic of -4.439 (p = 0.000), shows that there is a statistically significant difference in interpretation scores among the experimental group; -1.025 was the mean difference. With respect to "Redesign Skill", an F of 1.253 (p = 0.266) indicates no significant variance difference. The t-test result (t = -5.529, p = 0.000) showed a significant gain between the two groups, and mean difference was -1.150, demonstrating a favorable impact on redesign skills of GEM model. For "Modeling Skill", the F value of 1.626 (p = 0.206) indicates that the variances are equal. Results of the t-test (t = -4.159, p = 0.000) showed a significant difference means of the experimental and the control groups, and the post-test has been able to increase the modeling skill and the t-table gave the result of 0.000 as t value (-4.159), it can be concluded that the intervention is able to increase the modeling skill of the experimental group rather than the control group, with average different means (¯= -0.825). The equal variances of error in "System Evaluation Skill" are also supported by Levene's test (F = 0.460, p = 0.500). T-test statistics (t = -4.585, p = 0.000) indicate that there was a significant t improvement on the system evaluation of the experimental group and the magnitude of the difference was -1.025.

An overall analysis reveals a value F = 2.017 (p = 0.160) and the homogeneity of variances is verified. The t-test results (t = -15.929, p = 0.000) show that there is a significant increase in the mean system thinking skills, with a mean difference of -1.014, thus revealing the overall effectiveness of the GEM modules towards promoting system thinking skills.

Table 6. Independent Samples Test of control group and experimental group.

Dimension	Equal variances	Levene's Test		t-test						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Information Gathering Skill (observation and insight)	assumed	1.248	.267	-4.877	78	.000	-1.10000	.22553	-1.54900	-.65100
	not assumed			-4.877	77.094	.000	-1.10000	.22553	-1.54909	-.65091
System Analysis Skill (analyzing the system into its components)	assumed	.681	.412	-2.861	78	.005	-.60000	.20970	-1.01748	-.18252
	not assumed			-2.861	77.484	.005	-.60000	.20970	-1.01753	-.18247
Comprehensive Thinking Skill (the big picture)	assumed	.002	.961	-5.448	78	.000	-1.10000	.20191	-1.50198	-.69802
	not assumed			-5.448	77.997	.000	-1.10000	.20191	-1.50198	-.69802
Reasoning Skill	assumed	.001	.972	-4.645	78	.000	-1.02500	.22069	-1.46435	-.58565
	not assumed			-4.645	78.000	.000	-1.02500	.22069	-1.46435	-.58565
The Skill of Using Time and Place Relationships	assumed	.043	.836	-5.115	78	.000	-1.05000	.20530	-1.45872	-.64128
	not assumed			-5.115	77.913	.000	-1.05000	.20530	-1.45872	-.64128
The Skill of Dynamic Handling of the Problem	assumed	1.111	.295	-5.276	78	.000	-1.10000	.20847	-1.51504	-.68496
	not assumed			-5.276	76.929	.000	-1.10000	.20847	-1.51513	-.68487

The Skill of Drawing System Figures	assumed	3.925	.051	-5.033	78	.000	-1.05000	.20863	-1.46535	-.63465
	not assumed			-5.033	73.848	.000	-1.05000	.20863	-1.46571	-.63429
PMI Idea Processing Skill	assumed	.129	.720	-5.413	78	.000	-1.12500	.20782	-1.53874	-.71126
	not assumed			-5.413	77.805	.000	-1.12500	.20782	-1.53875	-.71125
Interpretation Skill	assumed	.168	.683	-4.439	78	.000	-1.02500	.23091	-1.48470	-.56530
	not assumed			-4.439	77.645	.000	-1.02500	.23091	-1.48473	-.56527
Redesign Skill	assumed	1.253	.266	-5.529	78	.000	-1.15000	.20801	-1.56412	-.73588
	not assumed			-5.529	77.239	.000	-1.15000	.20801	-1.56419	-.73581
Modeling Skill	assumed	1.626	.206	-4.159	78	.000	-.82500	.19835	-1.21989	-.43011
	not assumed			-4.159	75.914	.000	-.82500	.19835	-1.22006	-.42994
System Evaluation Skill	assumed	.460	.500	-4.585	78	.000	-1.02500	.22357	-1.47010	-.57990
	not assumed			-4.585	77.545	.000	-1.02500	.22357	-1.47014	-.57986
Total	**assumed**	**2.017**	**.160**	**-15.929**	**78**	**.000**	**-1.01425**	**.06367**	**-1.14101**	**-.88749**
	not assumed			**-15.929**	**74.059**	**.000**	**-1.01425**	**.06367**	**-1.14112**	**-.88738**

Research Question 3: Are there any significant differences in the mean score of systems thinking according to gender?

Tables 7 and 8 give the gender's differences in system thinking skills ob control group and experimental group, respectively. In control group, the gender difference is negligible for all STSS scale dimensions ($p > 0.05$), except for "Dynamic Handling of the Problem" ($p = 0.010$), and "System Evaluation Skill" ($p=0.046$). This suggests that overall either males or females were found with higher solutions that could be due to differential learning effects across the time, indicating also that one gender has the higher ability to evaluate or criticize system better. However, the total system thinking skills are not significantly different between male and female ($p = 0.244$), which means that in spite of pattern specific differences, the overall system thinking skill level is the same between males and females in the control group. In experimental group, the gender difference is negligible for all STSS scale dimensions ($p > 0.05$), except for " Comprehensive Thinking Skill" ($p = 0.013$), which indicates that one of the gender made larger gains in connecting and synthesizing information across systems for the post- intervention. In spite of this marked distinction, the total system thinking skills are not significantly different between male and female ($p = 0.433$), demonstrating that overall system thinking abilities are similar between gender regardless of some diverging skill levels in the comprehensive thinking factor.

Table 7. Control group vs gender in thinking system skills

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Gender	**Information Gathering Skill (observation and insight)**	.225	1	.225	.195	.661
	System Analysis Skill (analyzing the system into its components)	1.600	1	1.600	2.033	.162
	Comprehensive Thinking Skill (the big picture)	.100	1	.100	.121	.730
	Reasoning Skill	.000	1	.000	.000	1.000
	The Skill of Using Time and Place Relationships	.225	1	.225	.271	.606
	The Skill of Dynamic Handling of the Problem	4.900	1	4.900	7.448	.010*
	The Skill of Drawing System Figures	.000	1	.000	.000	1.000
	PMI Idea Processing Skill	2.025	1	2.025	2.307	.137
	Interpretation Skill	.400	1	.400	.345	.560
	Redesign Skill	2.500	1	2.500	2.746	.106
	Modeling Skill	.400	1	.400	.603	.442

	System Evaluation Skill	4.225	1	4.225	4.253	.046*
	Total	**.086**	**1**	**.086**	**1.401**	**.244**
Significance at 0.05 level						

Table 8. Experimental group vs gender in thinking system skills

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
gender	**Information Gathering Skill (observation and insight)**	2.025	1	2.025	2.307	.137
	System Analysis Skill (analysing the system into its components)	.900	1	.900	.945	.337
	Comprehensive Thinking Skill (the big picture)	4.900	1	4.900	6.871	.013*
	Reasoning Skill	1.225	1	1.225	1.267	.267
	The Skill of Using Time and Place Relationships	.625	1	.625	.712	.404
	The Skill of Dynamic Handling of the Problem	1.600	1	1.600	1.675	.203
	The Skill of Drawing System Figures	1.600	1	1.600	1.505	.227
	PMI Idea Processing Skill	.100	1	.100	.119	.732
	Interpretation Skill	2.025	1	2.025	2.094	.156
	Redesign Skill	.100	1	.100	.125	.725
	Modeling Skill	.225	1	.225	.241	.627
	System Evaluation Skill	1.600	1	1.600	1.767	.192
	Total	**.063**	**1**	**.063**	**.627**	**.433**
*Significance at 0.05 level						

DISCUSSION

The purpose of the present study was to investigate the effects of the Gerlach and Ely Model (GEM) modules on developing systems thinking skills among 6th grade science students in Saudi Arabia. The study was focusing on the development of an instructional plan, evaluating its effects on systems thinking, and examining gender differences in these skills.

The findings showed that the experimental group significantly developed their systems thinking in comparison to the control group. In particular, the experimental group achieved dramatic progress in complex system understanding, causal reasoning, and the ability to consider different parts as a system in solving scientific problems. The provided modules facilitated structured activities that helped students to visualize relations among science concepts, think critically to recognize patterns and apply system tools (such as concept maps and flow charts) to organize and display science data. The results are consistent with the features of the Gerlach and Ely model by which systematic instructional strategies and structured learning activities for processing contribute to the development of cognitive strategies [6, 53, 69]. These findings are especially significant, as they correspond with previous research which highlights the efficacy of systems-type teaching approaches for the development of systemic thinking and practical problem solving skills within scientific education [29, 54, 70]. Prevailing literature is in consensus with the effectiveness of instructional modules in fostering systems thinking by involving students in activities that demand them to notice patterns, establish causal links and construct interconnected models [71, 72]. These studies are consistent with present findings which indicated a significant improvement in systems thinking for the experimental group.

The fact that we did not find gender differences in systems thinking does not agree with previous studies such as Al-Taban and Naji (73] which indicated that males usually surpass females in tasks that require a systemic analysis and complex problem solving. Present findings do not however support that such gender differences would have occurred anyway due to the structured nature of the instructional modules, structuring an equal representation for opportunity to engage in system thinking tasks.

The Gerlach and Ely model had been effective in developing systems thinking among the science students in the sixth grade. For example, the instructional modules developed in this research could potentially be expanded for use in wider educational settings (i.e., within other STEM content areas when introducing systems thinking). Similarly, the same principles may be applied to other grade levels. Teachers can use the instruction program blueprint to develop lesson designs that engage students in critical thinking, and systems analysis. Additionally, the strong enhancements found for systems thinking skills and creativity imply the potential for utilization of graphic organizers, concept mapping, and inquiry based learning as regular instructional methods to foster cognitive valences. The implications are also practical in new measures within teacher preparation, where the instructional plan model can be utilized to enrich the teaching methodologies about systems thinking and creativity and to prepare teachers to carry out these modules in a holistic manner within the very work-rich classroom landscape.

CONCLUSION AND IMPLICATIONS

The research addressed three research questions about the effect of the instruction of the unit plan of the Gerlach and Ely model on being thinking systemically in an elementary science school for Saudi students. The Results indicated that the development of systems skills such as PMI idea processing, redesign and dynamic handling of problems was significantly greater in the experimental group. Gender gaps were small but just slightly larger among boys for modeling and redesign tasks.

The findings have practical implications for a range of educational contexts such as teaching in classrooms, curriculum planning, and teacher preparation and development programs. Instructional modules derived from the Gerlach and Ely model can be easily carried out in science lessons to develop systems analysis with guided problem solving tasks. The results can also be used as a basis for developing curriculum guidelines at the elementary school level, including system thinking as a core competency, with the recognition of the use of graphic organizers.

LIMITATIONS

The study has some limitations. First, there are important issues with the methodological design of the study, particularly the quasi-experimental approach. Intervention studies may have good face validity (in observing the dimensions of the development, implementation and monitoring of the intervention), but lack the experimental control that mimics the robust nature of true randomization. In addition, Second, the sample was small, 80 students divided evenly into half (experimental and control groups). Though this is a sizable sample for the detection of moderate effects, generalization to the wider population of Grade 6 science students across Saudi Arabia may be constrained. Furthermore, this research was carried out in only one educational district, also limiting the external validity of the results. Third, the lack of more sophisticated statistical procedures (e.g., structural equation models, multivariate analysis) restricts the depth of analysis, and the interactions among variables may be oversimplified.

In view of the results of this study, there are several directions that future researchers may consider to expand the knowledge of the effects of structured instructional modules that adopt the Gerlach and Ely model in educational settings. First, research can investigate whether students retain their systems thinking, in the long run. Future research might also examine the extent to which the Gerlach and Ely model generalizes to other content areas, like math or language arts, in order to evaluate its efficacy across cognitive domains.

Supporting Information

S1 File. Systems thinking skills scale. It shows the final 28 tasks communicated to students.
S2 File. Teachers' checklist. This checklist serves the researcher to observe teachers during their lessons, to assess their use of flowcharts and to ensure consistency in the delivery of each session.

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