

Effects of STEM-integrated movement activities on movement and analytical thinking skills of lower secondary students

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Abstract

Problem Statement: Physical Education (PE) provides learners with essential lifelong experience for whole-person development. Not only it develops learners' physical competence and health fitness, but also provides a blended learning and teaching environment to actualize "STEM" (Science, Technology, Engineering, and Mathematics) concepts through various physical and sports activities. Learners are encouraged to strengthen their integration and application of knowledge and skills so as to nurture their curiosity in learning, creativity and innovation, and develop critical thinking, collaboration and problem solving skills, which are the essential skills and qualities required in the 21st Century. **Approach:** Designing the STEMe and CLM innovative learning management lesson plans indicated the processing and resulting efficiency qualities (E1/E2) was threshold of the standardized criterion at 80/80. Designing the 30-item Movement Skills Assessment (MSA), and the 20-Analytical Thinking Skills Assessment (ATSA) instruments were assessed students' movement and analytical thinking skills. These instruments are valid and reliable. **Purpose:** Creative the pre-test-post-test-design method was examined the effects of STEM education (STEMe) and conventional learning management (CLM) on physical education learning core to integrate movement activities on movement and analytical thinking skills of 66 lower secondary students at the grade 8th level from Srisuriyathai Female School, Thailand. To divide 33-experimental STEMe group and 33-CLM-control group was compared. **Results:** The CLM lesson showed the E1/E2 as 79.67/78.00, and the STEMe showed as 88.10/86.50 that higher than the standardized criterion at 80/80. Comparisons between pre- and post-test for the control and experimental groups of their MSA and ATSA are differences, significantly ($p < .01$) and the classified levels are neither satisfied nor dissatisfied and somewhat levels for the pre-test and post-test. The STEMe was differentiated significantly ($p < .001$) and the classified levels indicated that of neither satisfied nor dissatisfied, and very satisfied levels for the pre- and post-test-MSA-ATSA, respectively. The ATSA and the MSA instruments were relative significantly, when using a simple correlation analysis (r) and standardized regression validity (β). The multiple correlations (R) and the efficient determination predictive efficiency (R^2) value indicated that 41% and 66% of the variances in students' analytical thinking skills of the control and experimental groups were attributable to their post MSA learning assessment to their physical education environmental classes. **Conclusions:** It provides a measure of how well observed outcomes are replicated by the STEM education method, based on the proportion of total variation of students' learning outcomes explained by the STEM Education instructional model is better than the conventional instruction management, differently.

Keywords: Pre-test-post-test-design, comparisons between groups, associations between variables, physical education, movement skill, analytical skill, lower secondary students

Introduction

The term '21st century learning' has been used to refer to skills students must master, such as problem solving skills, analytical thinking skills, and digital literacy. The idea of what 21st century learning is open to interpretation and controversy. Being a 21st century educator means having the ability to teach and reach all learners. That means the ability to differentiate learning so that all students can learn using their own unique style and/or by their ability or readiness level. A 21st century educator is able to anticipate the future and plan for it to forward student thinking (Cox, 2016). Numerous studies and reports have emerged over the past decade that seek to identify the life, career, and learning skills that define the skills needed for success in the 21st century world (Morrison, 2018).

All of the frameworks emphasize the need to ground 21st skills for students entering the workforce were not facts and basic skills; they were applied skills that enable workers to use the knowledge and basic skills they have acquired. Infusing 21st century skills with subject area content, and especially cross-curricular content, provides students with strong learning capacity and helps them retain the learning for ongoing use (Oxford University Press ELT, 2013). The STEM curriculum incorporates the 'four C' of skills of the 21st century: creativity, analytical thinking, collaboration, and communication. Students work together to create innovative solutions to real-world problems and communicate their solutions to others

(Haines, 2011). A STEM classroom an inviting and challenging environment that incorporates their need to be interactive participants in their learning using appropriate technology tools to complete their task, students discover the most effective and efficient ways to access and manage the world of digital information that is available to them (Ian et al., 2010).

STEM education has become more significant for the world as it poses a range of advantages in a myriad of fields. As most of the sectors are dependent on STEM fields, it indirectly plays a significant role in the flourishing of the economy. In the coming years, the STEM sector is expected to be one of the largest employers in the world. It engages students and equips them with analytical thinking, problem solving, creative and collaborative skills, and ultimately establishes connections between school, work place, community and the global economy. STEM develops a set of thinking, reasoning, teamwork, investigative, and creative skills that students can use in all areas of their lives. Teachers and students use their bodies to act out or gesture the meaning of words or concepts. In many schools around the country, administrators are encouraging teachers to evaluate their teaching methods (Science Foundation Arizona, 2017).

STEM education in Thailand, teaching STEM in primary and secondary education can help students become interested in STEM careers and build a nation's STEM-educated workforce that can be used to meet the demands of business and industry in a complex and technology-driven economy. The British Council Thailand is working with the *Institute for the Promotion of Teaching Science and Technology* (IPST) and the Office of Vocational Education Commission (OVEC) to develop STEM Education programme for the national curriculum in Thailand. The programme will support knowledge exchange and partnership opportunities and increase the understanding of and engagement with science, technology, engineering, and mathematics in Thailand (British Council in Thailand, 2015).

By integrating STEM into different content areas, such as physical education, students are encouraged to build the skills they need to be successful in the 21st century and enthusiasm for the class will skyrocket (Collom, 2020). Physical activity is an important component of everyday life. Strong foundational skills in gross motor coordination are typically developed informally in young learners, providing a strong foundational basis for movement skills. Research stipulates that there has been a decrease in physical activity among preschoolers. Therefore, structured movement activities could potentially play a role in facilitating teaching and assessment in a school setting (Omidire et al., 2018).

Analytical skills refer to the ability to collect and analyze information, problem-solve, and make decisions. Learners who possess these skills can help solve a teacher's problems and improve its overall productivity and success. Analytical skills refer to the ability to collect and analyze information, problem-solve, and make decisions (Doyle, 2020). Analytical skills are soft skills that help you identify and solve complex problems. Some popular analytical skills include critical thinking, data analysis, research and communication. Teaching, practice, and reinforcement afford learners systematic opportunities to learn fundamental physical skills that contribute to a lifetime of physical activity (Kozub 2012).

In this research study, the research team was interested in developing a movement activity that integrates STEM education linking knowledge in many subject areas including science, technology, engineering processes, and mathematics with physical education by organizing physical activities and games as media situations and problems are defined to enable students to develop basic movement-coordinated thinking.

These activities help develop the ability to perceive distance and dimensions, as well as the development of the brain to have a normal balance. However, traditional education is focused on replicating the correct hypothesis, while one of the most important pillars of STEM module is to build creativity. STEM is focused on stimulating the brain and giving it a free reign to create, rather than simply replicate what is already known to the world. This research design in which the same assessment measures are given to participants both before and after that could be attributed to the treatment or condition with the pre-test-post-test-design method was compared. An experimental group is the group that receives the variable being tested in an experiment. The control group is the group in an experiment that does not receive the variable is testing and associations.

Materials and Methods

In this research study was designed on the standard H3.1 in the third section to compare the efficiency of movements patterns affecting sports and activities in daily life that was planned to learning management in 5 hours, 2 weeks with the two different innovative lesson plans to Conventional Learning Management for the control group of six lesson plans and STEM Education that planned to have a lesson plan and six physical activities, namely ASK: Define the problem; IMAGINE: Brainstorm solutions; PLAN: Consider how to best solve the problem; CREATE: Construct your solution; TEST: Determine how well your solution works; and IMPROVE: Make your solution better of their physics movement activities and critical skills. It serves as an instrument in holistic development in all respects; physical, mental, emotional, social, and intellectual, as well as imparting capacities for health and sports that follows as the 2017 Thailand Basic Education Core Curriculum for the Health and Physical Education Learning Area is necessary to learn health and physical education (Ministry of Education, 2017).

Research aims

1. To develop innovative instructional lesson plans with the conventional learning management and the STEM education approaches to integrate movement activities into movement and analytical thinking skills of lower educational students for the control and experimental groups, respectively.

2. To assess students' physical activities movement skills with the *Movement Skills Assessment* (MSA) of their post-learning outcomes to their instructional design according to the conventional learning management approach and the STEM education approach, those indicate of the effective criteria as 80% for the control and experimental groups to their integrated effects of the movement activities on movement and analytical thinking skills of lower educational students.

3. To associate the learning achievements of students from their post-test assessment with the assessment of movement skills (MSA) and their assessment of analytical thinking skills (ATSA) with the management of conventional learning and STEM education learning for lower educational students at the eighth grade level by innovative instructional lesson plans.

Research procedures

Creative quasi-experimental research consisting of a nonrandomized control and group-pre-test-post-test design method was compared.

Sample size A sample size consisted of 66 lower secondary educational students in two groups in the eighth grade level at the Satri Si Suriyothai School, consisting of 2 classrooms, divided into 1 experimental group, 33 students and 1 control group, 33 students. Samples were selected using the purpose-based random sampling method. Before the study, these two groups had no difference in motor skills scores and analytical thinking skills scores.

Research instruments

1. The *Innovative Learning Management Lesson Plan* (ICLMLP) for movement activities integrating according to the Conventional Learning Management approach consisted of six plans.

2. The 30-item *Movement Skills Assessment* (MSA), the MSA items according to the purpose of this research study.

3. The 20-item *Analytical Thinking Skills Assessment* (ATSA) was assessed students' analytical thinking skills

Data analysis

The mean scores between pretest and posttest design method were compared. Associations between the variables were assessed with simple and multiple correlations, standardized regression weight skill, and coefficient determination predictive values.

Interpretation of the mean scores

The mean score ranges from 1.00-1.80 refers to Very Dissatisfied, from 1.81-2.60 refers to Unsatisfied, from 2.61-3.40 refers to Neither satisfied nor dissatisfied, from 3.41-4.20 refers to Satisfied or Somewhat satisfied; and from 4.21-5.00 refers to Very satisfied.

Results

Innovative lesson plan efficiency

In these research designs was planned to assess the performance of students in their assignments in terms of three phases; the 10-Report Paper, the 10-Activity Paper and the 10-Delivering Instructional Content, often online, outside of the classroom, each article was evaluated as a five scoring score, the tantalizations indicate of 150 all the scores of this innovative instructional lesson plans with the CLP for the control group and STEM education for the experimental group that was the Processing Performances Efficiency (E1). Student learning achievements were assessed with the 30-item Movement Skills Assessment (MSA) and the 20-item Analytical Thinking Skills Assessment (ATSA), which are the Efficiency Resulting from Performance (E2). Determining the efficiency of the processing performances and the performance results (E1/E2) indicates that the percentage of E1/E2 as a result shows the statistically significant as reported in Tables 1 and 2.

Table 1: Means, standard deviation, percentage, total score for the efficiency of processing performances, and the performance results (E1/E2) of conventional learning management lesson plans for the control group

Efficiency Types	Total Score	Students' Account	Mean	S.D.	Percentage
Efficiency of the Processing Performances (E1)	150	33	119.50	2.96	79.67
Efficiency of the Performance Results (E2)	50	33	39.00	2.98	78.00
Efficiencies of the Innovative Instructional Lesson Plan for the MSA and the ATSA (E1/E2) = 79.67/78.00					

Table 2: Means, standard deviation, percentage, total score for the efficiency of processing performances, and the performance results (E1/E2) of the STEM education learning management lesson plan for the experimental group

Efficiency Types	Total Score	Students' Account	Mean	S.D.	Percentage
Efficiency of the Processing Performances (E1)	150	33	132.15	2.14	88.10
Efficiency of the Performance Results (E2)	50	33	45.25	1.50	86.50
Efficiencies of the Innovative Instructional Lesson Plan for the MSA and the ATSA (E1/E2) = 88.10/86.50					

Tables 1 and 2 report the effectiveness of the learning outcomes, innovative instructional lesson plans with innovative conventional learning lesson plans for the control group and innovative STEM education plan in six physical activities and analytical thinking skills were responded with efficiency of processing performance and performance results (E1/E2) indicated evidence of 79.67/78.00 for the control group, which was lower than with criteria of 80/80. In terms of E1/E2, the evidence of 88.10/86.50 for the experimental group, which was significantly higher than the criteria of 80/80, was indicated.

The movement skills assessment (MSA) was analyzed with means ($\bar{X}$) and standard deviation (SD) of the learners' scores in physical activities with the 30-item-MSA and analytical thinking skills with the 20-item-ATSA. The results were used to compare the mean scores between pre-post-MSA and pre-post-ATSA that total scores of 50 for the control and experimental groups, using the t-test for independent and dependent statistics reported in Tables 3 and 4.

Table 3: Item mean scores, means, standard deviations, internal consistency (Cronbach Alpha Reliability), and t-test of the control group for the MSA and the ATSA

Scale	Item Mean (50)	Scale Mean (5)	Standard Deviation by Score Mean	Cronbach alpha reliability	t-test	Sig.	Classified level from scale mean
Pre-test	32.42	3.24	2.47	0.62	7.84	.013*	Neither satisfied nor dissatisfied
Post-test	37.77	3.78	2.14	0.71			Somewhat Satisfied

$N = 33$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The results given in Table 3 show the item mean scores for each of the actual control groups of the pre-post-test design method. The item mean scores as 32.42 and 39.00, the standard deviation are 2.47 and 2.14, the mean average scores are 3.24 and 3.90, the internal consistency with Cronbach alpha reliabilities are 0.62 and 0.71 for the pre-test and post-test, respectively. Comparisons between mean scores before and after the test are significant differences for the control group in their physical movement activities and analytical thinking skills, significantly ($p < .01$). Classified level from scale means is neither satisfied nor dissatisfied and somewhat levels for the pre-test and post-test actually.

Table 4: Means and standard deviation (SD) of pre-MSA and post-MSA of the control group using the MSA and the ATSA

Scale	Score Mean (50)	Scale Mean (5)	Standard Deviation by Score Mean	Cronbach alpha reliability	t-test	Sig.	Classified Level from Scale Mean
Pre-test	32.73	3.27	2.46	0.63	15.91	.000***	Neither satisfied nor dissatisfied
Post-test	45.25	4.52	1.50	0.82			Very Satisfied

$N = 33$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4 shows the item mean scores for each of the actual experimental group of the pre-post-test design method. The item mean scores as 32.73 and 45.25, the standard deviation is 2.46 and 1.50, the mean average score is 3.27 and 4.52, the internal consistency with Cronbach alpha reliabilities is 0.63 and 0.82 for the pre-test and post-test, respectively. Comparisons between mean scores of the pre- and post-test are differences for the control and experimental groups in their physical movement activities and analytical thinking skills, significantly ($p < .001$) and the level classified from the scale means is neither satisfied nor dissatisfied and somewhat levels for the pre-test and post-test, and the level classified from the scale means is neither satisfied nor dissatisfied and very satisfied levels for the pretest and posttest, respectively.

Comparisons between the results of students in their movement skills for the control and experimental groups

Using the 30-item movement skills assessment (MSA), the movement skills of the students were assessed for the post-control and post-experimental groups with mean average scores, standard deviation, and t-test. Minimum and maximum scores range from 0-30. The results are reported in Table 5.

Table 5: Means, standard deviation, and t-test of the post-control and post-experimental groups for the MSA

Trial	n	Mean	S.D.	t	P-Value
Experimental group	33	27.45	1.502	13.641	.000***
Control group	33	23.40	2.447		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The results given in Table 5 show the mean scores, standard deviation, and t test of the post-control and post-experimental groups for the MSA of 30 items. The control group and the experimental group are

compared against each other in an experiment. The only difference between the two groups is to investigate the differences between mean average scores of 27.57 and 23.40 for the experimental and control groups, which are differences, significantly with the analysis ($p < .001$).

Comparisons between the results of students' analytical thinking skills for the control and experimental groups

Successful critical thinkers in physical education are able to apply learned motor skills strategically, as well as develop a physical activity habit of the student outcomes of their analytical thinking skills for the control and experimental groups to their physical education with the conventional leaning and STEM education learning managements were compared. The results are reported in Table 6.

Table 6: Means, standard deviation, and t-test of the post-control and post-experimental groups for ATSA

Trial	n	Mean	S.D.	t	P-Value
Experimental group	33	15.12	1.78	7.88	.000***
Control group	33	12.00	1.41		

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The results given in Table 6 show the mean scores, standard deviation, and t test of the post-control and post-experimental groups for the ATSA 20 items. The difference between the two groups is to investigate differences between mean average scores of 15.12 and 12.00 for the experimental and control groups, which are differences, significantly with the analysis of the t-test analysis ($p < .001$).

Associations between the physical activity outcomes of the movement skill assessment of the students with analytical thinking skills

These involved: simple correlation analyzes of associations between the physical activity results of the movement skill assessment of students with analytical thinking skills; the multiple regression analyzes of relationships between the set of coalition protests of the lower secondary students at the 8th grade level on the scales of the physical activity movement environment as a whole with MSA and ATSA using simple correlation (r), multiple correlations (R), standardized regression coefficient (β), and predictive values for the determination of the coefficient were assessed. The results are reported in Tables 7 and 8.

Table 7: Associations between MSA assessment and ATSA with conventional learning management activities in physical education by the control group in terms of movement and analytical thinking skills

Variables	Simple Correlation (r)	Standardized Regression Coefficient (β)	Multiple Correlation (R)	Efficiency Predictive Value (R^2)
Independent variable (MSA)	0.517***	0.414**	0.643*	0.414*
Dependent variable (ATSA)				

$N = 33$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 8: Associations between MSA assessment and ATSA with STEM education learning management activities on physical education by the experimental group in terms of movement and analytical thinking skills

Variables	Simple Correlation (r)	Standardized Regression Coefficient (β)	Multiple Correlation (R)	Efficiency Predictive Value (R^2)
Independent variable (MSA)	0.728***	0.652***	0.814**	0.663**
Dependent variable (ATSA)				

$N = 33$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Tables 7 and 8 Simple correlation values (r) are reported in Tables 7 and 8, which show statistically significant correlations ($p < .01$) between the results of analytical thinking skills of the lower secondary control and the students of the experimental group of movement skills of the MSA. These are the analytical thinking skills of physical activity movement environments, perceived as the MSA and the ATSA are related. The second types of analysis consisted of the more conservative standardized regression coefficient (β) which measures the associations between the student's assessment results on the MSA tests and their analytical thinking skills toward physical activities on physical education learning environments when the effects of the relationships between the MSA and the ATSA are controlled. The multiple correlations Rare significant for the actual control and experimental groups of the MSA of the lower secondary students who follow and show that when the scales are considered together, there is a significant ($p < .01$) association ($p < 0.05$) with the ATSA.

The R^2 values indicate that 41% and 66% of the variance in the analytical thinking skills of the lower secondary students in two groups with their effects of the learning management environments of conventional and STEM education are integrated movement activities on movement and analytical thinking skills were attributable to their physical movement tests of the movement skills and their analytical thinking skills, respectively. It provides a measure of how well observed outcomes are replicated by the STEM education

method is better than the conventional learning approach, based on the proportion of total variation of student learning outcomes explained by the STEM education instructional model.

Discussions

In this research design on an experiment, data from an experimental group is compared with data from a control group. These two groups should be identical in every respect except one: the difference between a control group and an experimental group is that the independent variable is changed for the experimental group, but is held constant in the control group. The control group and the experimental group are compared against each other in an experiment. The independent variable is "controlled" or held constant in the control group, and associations between independent and dependent variables. Compare Groups examines independent samples and makes inferences about the differences between them. Independent samples occur when observations are made on different sets of items or subjects. If the values in one sample do not tell you anything about the values in the other sample, then the samples are independent. Association between two variables means that the values of one variable relate in some way to the values of the other (Statistical Reference Guide, 2021).

As the results of the innovative instructional lesson plan for the MSA and the ATSA (E1/E2) are 79.67/78.00, this result is lower than the standardized criterion at 80/80. In terms of STEM education, the efficiency of the innovative instructional lesson plan for the MSA and the ATSA (E1/E2) is 88.10/86.50 that is higher than the standardized criterion at 80/80. An efficiency criterion refers to the level of efficiency of the teaching lesson plan that will help learners learn. It is assessed in two ways: continuous behavior assessment (process) and final behavior assessment (outcome). Continuous behavior assessment determines the value of E1 efficiency, which is the efficiency of the process, and the final behavioral assessment is set to E2 which is the efficiency of the result. In short, E1 and E2 are the efficiency of the process and the efficiency of the results (Promwong, 1988).

The students' outcomes of their analytical thinking skills for the control and experimental groups are compared. Analytical thinking in physical education allows students to make "reasonable and defensible decisions about movement tasks or challenges". Successful analytical thinkers in physical education, for example, are able to apply learned motor skills strategically and develop a habit of physical activity. Analytical thinking learned in physical education can also be positively transferred to the resolution of challenges and problems that arise in other academic domains and in life (Lodewyk, 2009).

Pretest–posttest designs are used in both experimental and quasi-experimental research and can be used with or without control groups. For example, quasi-experimental pretest–posttest designs may or may not include control groups, while experimental pretest–posttest designs must include control groups. Furthermore, despite the versatility of the pre-test and post-test designs, in general, they still have limitations, including threats to internal validity. Although such threats are of particular concern for quasi-experimental pretest-posttest designs, experimental pretest–posttest designs also contain threats to internal validity (Salkind, 2010).

This research study was associated with the correlation with the simple correlation and multiple regression analyzes were conducted to examine whether there are associations between the movement of the learning activity of the students and the analytical skills of their posttest assessment to their testing of their analytical thinking skills with innovative instructional lesson plans based on the learning management model in the conventional instruction model and the STEM education method. Very frequently, social scientists want to determine the strength of the association of two or more variables (Chanthala, Ponkham & Santiboon, 2018).

Conclusions

Due to this research study, the designation for E1/E2 [(Efficiency of the Processing Performances (E1) and Efficiency of the Performance Results (E2)] of the standardized criterion was thresholded at 80/80. Conventional learning management lesson plans for the control group showed the effectiveness of the innovative instructional lesson plan for the MSA and the ATSA (E1/E2) as 79.67/78.00, this result is lower than the standardized criterion at 80/80. In terms of STEM education, the efficiencies of the innovative instructional lesson plan for the MSA and the ATSA (E1/E2) = 88.10/86.50 higher than the standardized criterion at 80/80.

Comparisons between mean scores of the pre- and post-test are differences for the control and experimental groups in their physical movement activities and analytical thinking skills, significantly ($p < .01$) and the classified level from scale means are neither satisfied nor dissatisfied and somewhat levels for the pre-test and post-test for the control group. Focused on the experimental group, students' responses to their MSA and ATSA of their physical movement activities and analytical thinking skills, significantly ($p < .01$), respectively.

The students' outcomes of their movement skills and analytical thinking skills for the control and experimental groups are compared. The two groups investigate differences between mean average scores of 27.57 and 23.40 for the experimental and control groups, which are differences, significantly with the analysis of the t-test analysis ($p < .001$). The students' responses to their analytical thinking skills for the experimental and control groups, which are differences, significantly with the analysis of the t-test analysis ($p < .001$).

The ATSA and MSA instruments were relative significantly, when using a simple correlation analysis (r) and standardized regression validity (β). Multiple correlations (R) and the predictive efficiency value of efficient determination (R^2) indicated that 41% and 66% of the variances in students' analytical thinking skills of

the students of the control and experimental groups were attributable to their post MSA learning assessment in their physical education environmental classes. It provides a measure of how well observed outcomes are replicated by the STEM education method, based on the proportion of total variation of student learning outcomes explained by the STEM Education instructional model, which is better than conventional instruction management, differently.

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