REVIEW OF INTERNATIONAL GEOGRAPHICAL EDUCATION
ISSN: 2146-0353 • © RIGEO • 11(9), SPRING, 2021
www.rigeo.org
Research Article

Effect of Tpack Strategies on Mathematical Ability by Factoring Out Differences of Certain Variables with Ancova

Vrinda Vijayan[1]
Research Associate, Department of Education,
Central University of Kerala, Kasaragod, India
Vrindav28@gmail.com

Joshith, V. P.[2]
Assistant Professor, Department of Education,
Central University of Kerala, Kasaragod, India
getjoshith@gmail.com

Thiyagu, K.[3]
Assistant Professor, Department of Education,
Central University of Kerala, Kasaragod, India
thiyagusuri@gmail.com

Abstract

The study was intended to focus the main and interaction effects of instructional strategies (TPACK strategies and activity-oriented method of instruction) and gender, intelligence, learning style on mathematical ability of higher secondary school students. The experimental method using quasi-experimental non-equivalent pre-test – post-test groups design was used to test the effectiveness of TPCK Strategies on enhancing the mathematical ability of higher secondary school students. TPCK is a strategy where epistemological and transformative views proved to be a unique body of knowledge mainly existing through interaction of its very different knowledge bases (Angeli & Valanides, 2009). Analysis of Covariance (ANCOVA) was used to give a valid conclusion to the collected and tabulated data. The findings of the study indicated that, the main effect, TPCK Strategies contribute significantly to enhance mathematical ability. Further the study gives very significant conclusions that, TPCK Strategies can be used for enhancing the mathematical ability of higher secondary school students irrespective of their gender, intelligence and learning style. The results of the study implied that when the groups of students are heterogeneous, TPCK Strategies could be able to provide the subject knowledge to the learner according to their individual differences.

Keywords
Instructional Strategies, Technological Pedagogical Content Knowledge Strategies, TPCK, Activity Oriented Method of Instruction, Mathematical Ability, Analysis of Covariance

To cite this article: Vijayan V, Joshith, V. P., and Thiyagu, K. (2021). Effect of Tpack Strategies on Mathematical Ability by Factoring Out Differences of Certain Variables with Ancova. Review of International Geographical Education (RIGEO), 11(9), 1157-1171. Doi: 10.48047/rigeo.11.09.99

Submitted: 02-11-2020 • **Revised:** 05-02-2021 • **Accepted:** 16-03-2021

Introduction

Instructional strategies are the pillars of the teaching-learning process for ensuring the quality of instruction to encounter the distinct requirements of the teaching context. They include all approaches that a teacher may take to engage students in the learning process actively. TPCK is an instructional strategy where basic science process skills and scientific attitude interact positively and integrated science process skills interact negatively (Juhji & Nuangchalerm, 2020). Normally instructional strategies deliver a structure for planning, developing and evaluating instruction in accordance with learner's needs, instructional requirements and teaching methods. More than that the factors like prior knowledge and TPCK scores along with gender play a prominent role for integrating technology in classrooms (Chen et al., 2019). There are as many variety of teaching methods with their focus specific pros and cons. So it must be crucial to integrate the right strategy on the right time. Therefore, selecting the strategy is critical and must be done by keeping in mind the intended learning outcome and the specific competencies to be nurtured for the leaners in accordance with the special focus of the subject (Vijila & Thiyagu, 2019). A paradigm shift compromises tangible anticipations for solving the major difficulties facing in the current educational scenario. The era of globalization is challenging a paradigm shift under the rapid expansion of information and communication technology. This also affects learning. The shift of learning is from traditional learning systems to technologically enhanced systems. The new paradigm of learning calls for distinctive techniques of course design, instructional strategies, and evaluation. In the context of learning teacher shall be competent to extrapolate the different dimensions of the concept with the help of technology and the taught should be trained enough to accomplish the learning outcome by becoming skillful in integrating the pedagogy and apt technology with content. The conceptual framework of the teacher shall be perfectly blend with the integration of three factors bringing out the strategy called Technological Pedagogical Content Knowledge (TPCK).

Review of Related Literature

The rapid advancement in technology and even further integration of artificial intelligence in classroom spaces teachers need to redesign their instructional practices and equipped with technical integration in their subject specific areas (Tanak, 2020). Technological pedagogical content knowledge (TPACK) has become a skill that an educationist needs to learn to design their courses blended with learning outcomes and those innovative teachers need to comprehend the basics of TPACK literacy in all domains of their teaching. The literacy level of higher education teachers are found to be on average in the domain specific areas like technology, pedagogy and content knowledge (Ammade et al., 2020). The TPACK model in research mainly focus on higher education especially in teacher training with studies reported as case studies, empirical and mixed studies (Moreno, Montoro, & Colón, 2019). Even though the research is progressing highly in TPACK model, many studies failed to report its influence with gender, context and age, at the same time the seven components of the TPCK model and its validity were not established empirically (Castéra et al., 2020). In the case of pre-service teachers pedagogical knowledge become the key component in predicting the confidence in adopting TPACK in their content transactions (Valtonen et al., 2020). The ability of the mathematics teachers to construct a learning environment supported by cloud computing to promote and focus their attitude towards TPACK , created a new modern approach in mathematical curricular transactions grounding at technology (Alqallaf, 2016). Numerous factors like the learning environment, gender, personality, intelligence, metacognition, spatial ability, learning styles, etc. affect mathematical ability. The established notion of mathematical ability is in favour of boys. Comparing the two different models like standard model and the nested factor clearly explains that individual differences on mathematical ability are attributed to general cognitive ability and specific mathematical ability (Brunner, Krauss, & Kunter, 2008). Comparing the different learning style on scholastic achievement the dominant learning style was the assimilator and this influence the academic achievement along with gender (Bhatti & Bart, 2013). Technology has acted as a new platform of our curriculum transactions. Technology integration in the classroom transaction provides an opportunity flexibility in the academic transactions (Thiyagu & Joshith, 2021). Childs mathematical gift is based on two intelligent methods were compared and it was found that pupil is more mathematically gifted than teachers and it was totally attributed to the intelligence of the child.

This further gives an understanding that in the studies of mathematical ability it becomes always important to control all other variables before implementing the instructional strategies (Pavlekovic, Zekic-Susac, & Djurdjevic, 2009). Further, considering the learner's characteristics and the nature of the content material there is scope for developing an instructional strategy based on TPCK and determining its effectiveness. Such an instructional strategy prevents the occurrence of learning gaps and enables learners to sustain interest that leads to better achievement. Hence, from such consideration, the significance of the study is clearly discernible. Problem solving becomes an important constituent of mathematical ability (Vijayan & Joshith, 2018).

Theoretical Background - TPACK

Technological Pedagogical Content Knowledge (TPCK) is a cornerstone of effective teaching with technology. This is a complex interplay where mathematical knowledge, technology, and pedagogy fuse together. The TPCK framework is grounded on the theoretical notion of PCK (Pedagogical Content Knowledge) proposed by Gudmundsdottir and Shulman (1987) which explained teacher knowledge as the intersection of pedagogical and content knowledge. TPCK is teachers’ knowledge of integrating educational technologies with pedagogy and content which results in effective teaching with technology. Systematic research efforts for the purpose of developing theory and frameworks to ground research in the areas of teaching with technology are done by different authors (Angeli & Valanides, 2009; Lee et al., 2006; Mishra & Koehler, 2008; Niess, 2002) though often using different labelling schemes. The conception of TPCK described in the present study is based on the descriptions of the framework found in Mishra and Koehler (2008). In the framework by Mishra and Koehler (2008), there are three central components of teachers’ knowledge: content, pedagogy, and technology. This presentation reveals multiple interactions between and among these bodies of knowledge, represented as shown in figure 1.

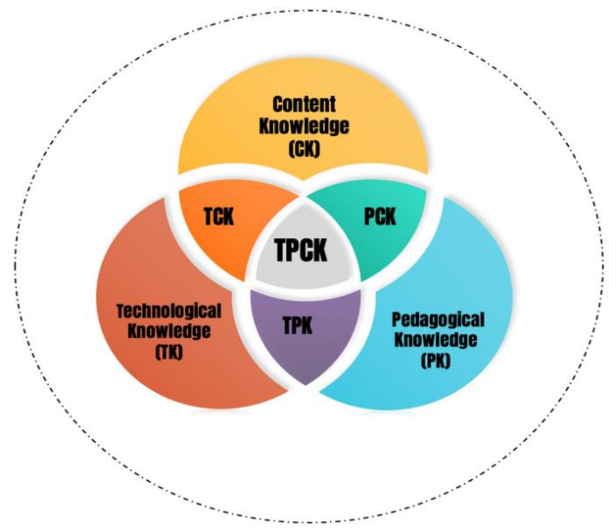


Figure 1. The TPCK framework by Mishra and Koehler (2008)

Research Questions

1. Whether the interaction between the effect of treatment and gender on mathematical ability is significantly predominant when groups were equated statistically?
2. Whether the interaction between the effect of treatment and intelligence on mathematical is ability significantly predominant when groups were equated statistically?
3. Whether the interaction between the effect of treatment and intelligence on mathematical is ability significantly predominant when groups were equated statistically?

Methodology

The experimental method using a quasi-experimental pre-test – post-test non-equivalent groups design was used to test the effectiveness of TPCK Strategies on enhancing the mathematical ability of higher secondary school students. The independent variables involved in the study were Technological Pedagogical Content Knowledge (TPCK) Strategies & Activity Oriented Method of Instruction (AOMI)) for the teaching of Mathematics. Mathematical Ability was the dependent variable. Gender, Intelligence, and Learning Styles were taken as the control variables.

Tools

The tools and materials developed by the investigators namely, Mathematical Ability Test, Mathematics Learning Style Inventory, Technological Pedagogical Content Knowledge (TPCK) Strategies Framework, TPCK-based lesson transcript, Lesson transcripts based on Activity Oriented Method of Instruction (AOMI) along with Standard Progressive Matrices Test (Raven, 1958) were used for the study. The deals with the population of higher secondary school students of Kerala following the state board syllabus. The sample were drawn randomly and consists of 116 students from the higher secondary schools in Kerala state. Mathematical ability of the experimental and control groups were found in Pre and Post stages using mathematical ability test. The pre-test of mathematical ability, intelligence test (Standard Progressive Matrices Test) and mathematics learning style inventory were administered before experimentation. The teacher selected three chapters Conic Sections, Introduction to Three-dimensional Geometry and Limits and Derivatives and prepared 40 lesson transcripts for the same in TPCK Script and based on Activity-oriented method of teaching. Experimental and control groups were taught by Technological Pedagogical Content Knowledge (TPCK) Strategies and Activity Oriented Method of Instruction in accordance with TPCK Script and lesson transcripts of AOMI respectively. Post-test on mathematical ability was conducted immediately after the treatment. The reliability and validity of the tools were ensured on standardization.

Statistical Methods

The major statistical methods used in this study were
- Analysis of Covariance

One Way ANCOVA
2X2 Factorial Design ANCOVA
2X3 Factorial Design ANCOVA

- Descriptive statistics
- Effect size partial η^2
- Graphical Representation – Means Plot

Analysis and Findings

Analysis 1: Interaction of Treatment, Gender on Mathematical ability using 2x2 factorial ANCOVA

The objective was to study the effect of treatment, gender and their interaction on mathematical ability by taking pre-mathematical ability as covariate. There were two levels of treatment namely, TPCK Strategies and AOMI. The two categories of gender were male and female.

Results of two-way ANCOVA

A 2x2 factorial design ANCOVA was used to examine the effects of treatment, gender and their interaction on mathematical ability among a sample of 116 higher secondary students while holding their scores of pre-mathematical ability as constant. Thus the data were analysed and the results are given in tables 1 and 2.

Table 1
Analysis Reports of 2X2 factorial design ANCOVA of Mathematical ability & Gender

Source of Variance	Sum of Squares	df	Mean Square of Variance	F	p	Significance	Partial η^2
Pre-mathematical Ability (covariate)	7326.39	1	7326.39	116.28	.001	$p < 0.01$	.512
Treatment	7350.39	1	7350.39	116.66	.001	$p < 0.01$	.512
Gender	911.67	1	911.67	14.47	.001	$p < 0.01$	.115
Treatment X Gender (Interaction)	125.64	1	125.64	1.99	0.16	$p > 0.05$	.018
Error	6993.80	111	63.01				
Total	22052.24	115					

Note: $R^2 = .68$

Table 2
Analysis Reports of Adjusted Mean Scores of Mathematical ability based on Gender

Group	Gender	N	Adjusted mean scores of mathematical ability	Standard Error (SE)
Experimental Group	Male	24	57.38	1.62
	Female	34	61.02	1.36
	Total	58	59.20	1.06
Control Group	Male	20	38.76	1.78
	Female	38	46.71	1.29
	Total	58	42.74	1.10
Total	Male	44	48.07	1.20
	Female	72	53.87	0.94
	Total	116	50.97	0.76

Note: Pre-mathematical ability is 42.83

Discussion of Results

Covariate

The results of the data analysis showed a significant as the relationship between pre-mathematical ability and mathematical ability at post stage with $F_{(1,111)} = 116.66$ (table value=6.90) which is significant at 0.01 level. From the results of η^2 value = .512, it showed that variances accounted for about 51 percent in mathematical ability. Further the results showed that 11.5% variance was accounted by another main effect gender ($\eta^2 = .115$) and only 1.8% variance was accounted in the case of interaction between mathematical ability and gender ($\eta^2 = .018$). So the final percentage of variance exhibited by the main effect mathematical ability is very much significant compared to other effects.

Main effect 1(Treatment): Effect of Treatment on Mathematical ability by taking Pre-mathematical ability as covariate

In the case of main effect of treatment on mathematical ability, the adjusted F-value 116.66 (table value= 6.90) which is significant at 0.01 level with df=1/111, which showed that, in the case of two different treatments the experimental treatment (TPACK Strategies) was significantly effective compared to the control treatment (AOMI). It was further visible as the mean scores of TPACK strategies is 59.20 compared to AOMI strategies which is 48.07. In the case of treatment as a whole, it accounted 51 percent of the variance in mathematical ability (η^2 =.512), indicating a large effect of treatment while controlling for pre-mathematical ability.

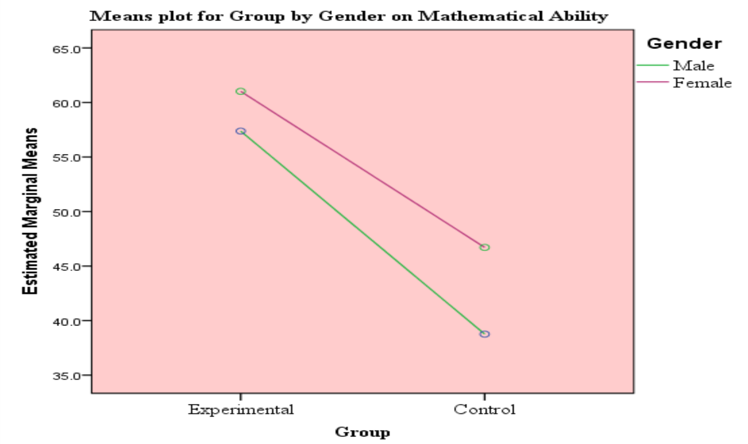
Main effect2 (Gender): Effect of Gender on Mathematical ability by taking Pre-mathematical ability as covariate

In the case of main effect of gender on mathematical ability, the adjusted F-value 14.47 (table value= 6.90) which is significant at 0.01 level with df=1/111, which showed that in the case of two different levels in gender, mathematical ability of female students (53.87) was significantly better than male students (48.07) and in the case of gender as a whole, it accounted 11.5 percent of the variance in mathematical ability (η^2 =.115), indicating a large effect of gender while controlling for pre-mathematical ability.

Interaction Effect (Treatment & Gender): Effect of Interaction between Treatment and Gender on Mathematical ability by taking Pre-Mathematical ability as covariate

In the case of interaction of treatment and gender on mathematical ability, the adjusted F-value 1.99 (table value = 6.90) is not significant. This showed that there is no interaction between treatment and gender, so the developed TPACK strategy, showed 51.2% of variance can be significantly used on a broader sample irrespective of the gender. So finally it can be concluded that mathematical ability was found to be independent of interaction between treatment and gender, because interaction effect accounts for only 1.8% variation.

Graphical Representation of the Interaction Effect



Note: Pre-Mathematical ability is 42.83
Figure 2.Interaction Means Plot for Treatment by Gender on Mathematical Ability

Figure 2 displays two lines. Each line presents the adjusted mean scores of mathematical ability for gender (male and female) for both experimental and control groups. As it appears in the graph, the female students (experimental and control groups) have higher mathematical ability than male students (experimental and control groups). Male and female students of experimental group appear to have higher mathematical ability than the male and female students of control group.

Analysis 2: Interaction of Treatment, Intelligence on Mathematical ability using 2x2 factorial ANCOVA

The objective was to study the effect of treatment, intelligence and their interaction on mathematical ability by taking pre-mathematical ability as covariate. There were two levels of treatment namely, TPCK Strategies and AOMI. The two categories of intelligence were above average intelligence and below average intelligence.

Results of two-way ANCOVA

A 2x2 factorial ANCOVA was utilized to examine the effects of treatment, intelligence and their interaction on mathematical ability among a sample of 116 higher secondary students while holding their scores of pre-mathematical ability as constant. Thus the data were analyzed and the results are given in tables 3 and 4.

Table 3
Analysis Reports of 2X2 factorial design ANCOVA of Mathematical ability & Intelligence

Source of Variance	Sum of Squares	df	Mean Square of Variance	F	p	Significance	Partial η^2
Pre-Mathematical ability (covariate)	6031.90	1	6031.90	87.75	.001	$p < 0.01$	.442
Treatment	7224.97	1	7224.97	105.10	.001	$p < 0.01$	.486
Intelligence	273.04	1	273.04	3.97	.049	$p < 0.05$	.035
Treatment X Intelligence	145.17	1	145.17	2.11	.149	$p > 0.05$	.019
Error	7630.27	111	68.74				
Total	22052.24	115					

Note: $R^2 = .65$

Table 4
Analysis Reports of Adjusted Mean Scores of Mathematical ability based on Intelligence

Group	Intelligence	N	Adjusted Mean Scores of Mathematical Ability	Standard Error (SE)
Experimental Group	Above Average Intelligence	24	60.08	1.70
	Below Average Intelligence	34	59.10	1.43
	Total	58	59.59	1.11
Control Group	Above Average Intelligence	42	45.57	1.29
	Below Average Intelligence	16	39.79	2.11
	Total	58	42.68	1.22
Total	Above Average Intelligence	66	52.83	1.07
	Below Average Intelligence	50	49.45	1.28
	Total	116	51.14	0.82

Note: Pre-Mathematical ability is 42.83

Discussion of Results

Covariate

The results of the data analysis showed a significant results as the relationship between pre-mathematical ability and mathematical ability at post stage with $F_{(1,111)} = 105.1$ (table value=6.90) which is significant at 0.01 level. From the results $\eta^2 = .486$, it showed that, the values accounted for about 48.6% percent of the variance in mathematical ability. Further the results showed that 3.5% variance was accounted by main effect intelligence and only 1.9% variance was accounted in the case of interaction between mathematical ability and intelligence. So final the percentage of variance exhibited by the main effect mathematical ability, is very much significant compared to other effects.

Main effect 1(Treatment): Effect of Treatment on Mathematical ability by taking Pre-mathematical ability as covariate

In the case of main effect of treatment on mathematical ability, the adjusted F-value 105.1 (table value= 6.90) which is significant at 0.01 level with df=1/111, which showed that in the case of two different treatments, the experimental treatment (TPACK Strategies) was significantly effective compared to the control treatment (AOMI). It was further visible as the mean scores of TPACK strategies is 59.59 compared to AOMI strategies which is 42.68. In the case of treatment as a whole, it accounted 48.6 percent of the variance in mathematical ability ($\eta^2 =.486$), indicating a large effect of treatment while controlling for pre-mathematical ability.

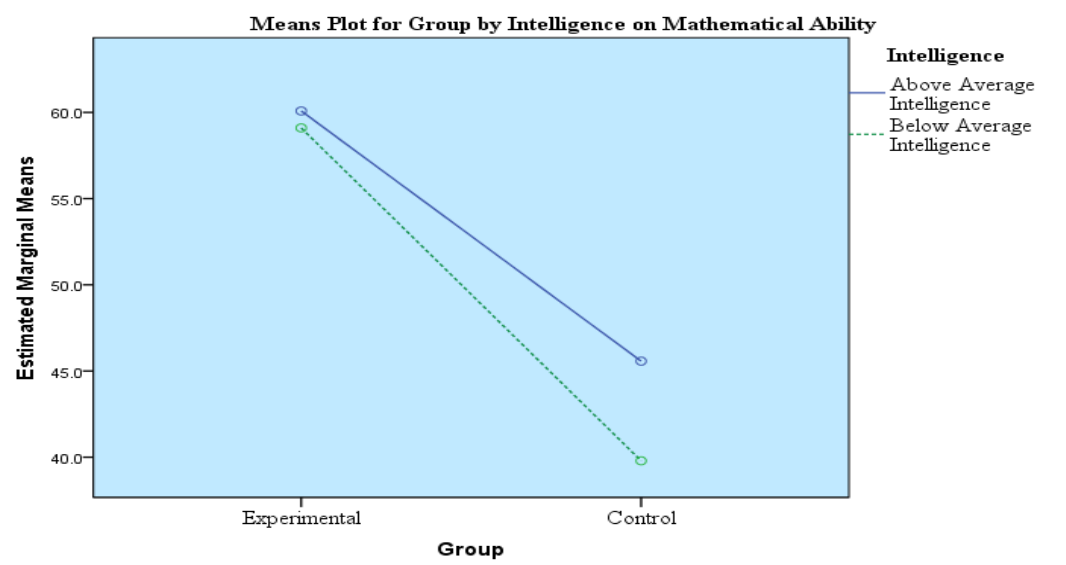
Main effect 2 (Intelligence): Effect of Intelligence on Mathematical ability by taking Pre-mathematical ability as covariate

In the case of main effect of intelligence on mathematical ability, the adjusted F-value 3.97 (table value= 6.90) which is significant at 0.01 level with df=1/111, which showed that in the case of two different levels in intelligence, mathematical ability of above average students (52.83) was significantly better than below average students (49.45). In the case of intelligence as a whole, it accounted 3.5 percent of the variance in mathematical ability ($\eta^2 =.035$), indicating a substantial effect of intelligence while controlling for pre-mathematical ability.

Interaction Effect (Treatment & Intelligence): Effect of Interaction between Treatment and Intelligence on Mathematical ability by taking Pre-Mathematical ability as covariate

In the case of interaction effect of treatment & intelligence on mathematical ability, the adjusted F-value 2.11 (table value= 6.90) which is not significant. This showed that there is no interaction between treatment and intelligence so the developed TPACK strategy which showed 48.6% of variance can be significantly used on a broader sample irrespective of their intelligence. So finally it can be concluded that mathematical ability was found to be independent of interaction between treatment and intelligence, because interaction effect accounts for only 1.9% variation

Graphical Representation of the Interaction Effect



Note: Pre-Mathematical ability is 42.83

Figure 3. Means plot for Group by intelligence on Mathematical Ability

Figure 3 displays two lines. Each line presents the adjusted mean scores of mathematical ability for intelligence groups (above average and below average) for both experimental and control groups. As it appears in the graph, the above average intelligence students (experimental and control groups) have higher mathematical ability than below average intelligence students (experimental and control groups). Above average and below average intelligence students of experimental group appear to have higher mathematical ability than above average and below average intelligence students of control group.

Analysis 3: Interaction of Treatment, Learning style on Mathematical ability using 2x3 factorial ANCOVA

The objective was to study the effect of treatment, learning style and their interaction on mathematical ability by taking pre-mathematical ability as covariate. There were two levels of treatment namely, TPCK Strategies and AOMI. The three categories of learning styles sensory learning style, intelligence-based learning style and multi learning style

Results of two-way ANCOVA

A 2x3 factorial ANCOVA was utilized to examine the effects of treatment, learning style and their interaction on mathematical ability among a sample of 116 higher secondary students while holding their scores of pre-mathematical ability as constant. Thus the data were analyzed and the results are given in tables 5 and 6.

Table 5

Analysis Reports 2X3 factorial design ANCOVA of Mathematical ability & Learning Style

Source of Variance	Sum of Squares	df	Mean Square of Variance	F	p	Remarks	Partial η^2
Pre-Mathematical ability (covariate)	7059.69	1	7059.69	98.53	.001	$p < 0.01$	.475
Treatment	3578.09	1	3578.09	49.94	.001	$p < 0.01$	.314
Mathematics Learning Style	193.73	2	96.87	1.35	0.26	$p > 0.05$	.024
Treatment X Mathematics Learning Style (Interaction)	1.29	2	0.64	0.01	0.99	$p > 0.05$	.000
Error	7810.19	109	71.65				
Total	22052.24	115					

Note: $R^2 = .65$

Table 6
Analysis Reports Adjusted Mean Scores of Mathematical ability based on Learning Style

Group	Learning Style	N	Adjusted Mean Scores of Mathematical Ability	Standard Error (SE)
Experimental Group	Sensory Learning Style	24	58.15	1.73
	Intelligence-based Learning Style	31	60.31	1.52
	Multi-Learning Style	3	62.23	4.92
	Total	58	60.23	1.81
Control Group	Sensory Learning Style	22	42.27	1.81
	Intelligence-based Learning Style	29	44.77	1.57
	Multi-Learning Style	7	46.02	3.20
	Total	58	44.35	1.33
Total	Sensory Learning Style	46	50.21	1.25
	Intelligence-based Learning Style	60	52.54	1.10
	Multi-Learning Style	10	54.12	2.93
	Total	116	52.29	1.12

Note: Pre-Mathematical ability is 42.83

Discussion of Results

Covariate

The results of the data analysis showed a significant as the relationship between pre-mathematical ability and mathematical ability at post stage with $F_{(1,111)} = 49.94$ (table value=6.90) which is significant at 0.01 level. From the results $\eta^2 = .314$, it showed that, the values accounted for about 31.4% percent of the variance in mathematical ability. Further the results showed that 2.4% variance was accounted by another main effect learning style and only 0% variance was accounted in the case of interaction between mathematical ability and learning style. So final the percentage of variance exhibited by the main effect mathematical ability is moderately significant compared to other effects.

Main effect 1(Treatment): Effect of Treatment on Mathematical ability by taking Pre-mathematical ability as covariate

In the case of main effect of treatment on mathematical ability, the adjusted F-value 49.94 (table value= 6.90) which is significant at 0.01 level with df=1/111, which showed that in the case of two different treatments, the experimental treatment (TPACK Strategies) was significantly effective compared to the control treatment (AOMI). It was further visible as the mean scores of TPACK strategies is 60.23 compared to AOMI strategies which is 44.35. In the case of treatment as a whole, it accounted 31.4 percent of the variance in mathematical ability ($\eta^2 =.314$), indicating a moderate effect of treatment while controlling for pre-mathematical ability.

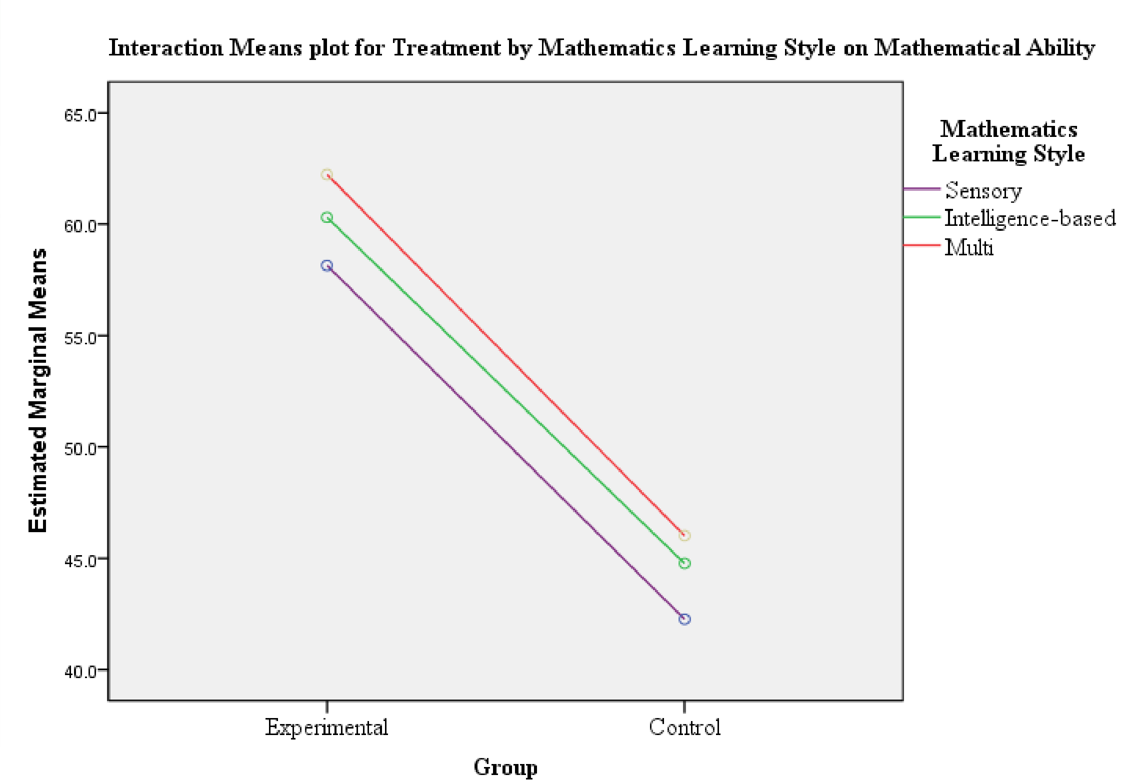
Main effect 2 (Learning Style): Effect of Learning style on Mathematical ability by taking Pre-mathematical ability as covariate

In the case of main effect of learning style on mathematical ability, the adjusted F-value 1.35 (table value= 6.90) which is not significant, which showed that in the case of three different levels in learning styles, sensory learning style (50.21), intelligence based learning style (52.54) and multi learning style (54.12) there is no much difference on mathematical ability. In the case of learning style as a whole, it accounted 2.4 percent of the variance in mathematical ability (η^2 =.024), indicating a very small effect of learning styles while controlling for pre-mathematical ability.

Interaction Effect (Treatment by Learning Styles): Effect of Interaction between Treatment and Learning Styles on Mathematical ability by taking Pre-Mathematical ability as covariate

In the case of interaction effect of treatment & learning styles on mathematical ability, the adjusted F-value 0.01 (table value= 6.90) which is not significant. This showed that there is no interaction between treatment and learning styles so the developed TPACK strategy which showed 31.4% of variance can be significantly used on a broader sample irrespective of the intelligence. So finally it can be concluded that mathematical ability was found to be independent of interaction between treatment and learning styles, because interaction effect accounts for only 0% variation.

Graphical Representation of the Interaction Effect



Note: Pre-Mathematical ability is 42.83

Figure 4. Interaction Means plot for Treatment by Mathematics Learning Style on Mathematical Ability

Figure 4 displays three lines. Each line presents the adjusted mean scores of mathematical ability for learning style (sensory learning style, intelligence-based learning style and multi-learning style) for both experimental and control groups. As it appears in the graph, the students (experimental and control groups) with multi-learning style have higher mathematical ability than the students with intelligence-based learning style and sensory learning style (experimental and control groups).in both groups, the students with intelligence-based learning style have higher mathematical ability than the students with sensory learning style. Students of experimental group with sensory learning style, intelligence-based learning style and multi-learning style appear to have higher mathematical ability than the students of control group with sensory learning style, intelligence-based learning style and multi-learning style respectively.

Summary of Covariate analysis

Results of ANCOVA undertaken to study the effectiveness of instructional strategies, particularly TPCK strategies over activity oriented method of instruction on mathematical ability of standard XI pupils by controlling Gender, Intelligence, and Learning Style are summarized in table 4.

Table 7
Analysis Reports of Covariate analysis

Variable	Covariate	F-value of treatment	Significance	Effect Size of treatment (in %)
Effect of treatment, gender and their interaction on mathematical ability	Pre-mathematical ability	116.66	Significant at 0.01 level	51.2
Effect of treatment, intelligence and their interaction on mathematical ability	Pre-mathematical ability	105.10	Significant at 0.01 level	48.6
Effect of treatment, learning style and their interaction on mathematical ability	Pre-mathematical ability	49.94	Significant at 0.01 level	31.4

Findings & Discussion

The results of the two-way ANCOVA show overall significant mathematical ability differences based on treatment among higher secondary students ($F_{(1,111)} = 116.66$, $p<0.01$).There exists a significant difference between experimental and control groups ($p<0.01$), with students of experimental group reporting significantly higher levels of mathematical ability (mean=59.20, SE=1.06) than students of control group (mean = 48.07, SE = 1.10).The results of the two-way ANCOVA also show a significant mathematical ability difference between Male and Female students ($F_{(1,111)} = 14.47$, $p<0.01$). Mathematical abilities like problem solving and special visualization has got a significant variation with respect to gender is only a belief but in actual practice there seems no differences for these traits respect to gender (Ramírez-Uclés & Ramírez-Uclés, 2020). The results are in agreement with the study done by Brunner et al. (2008) in empirical studies of high school mathematics using two models which indicated gender differences in mathematical ability in favour of boys and in contrast to the finding of Priya (2017) that the mathematical problem solving ability of girl students is significantly higher than boys. The results of the two-way ANCOVA show no significant treatment by gender interaction effect on Mathematical ability ($F_{(1,111)} = 1.99$, $p > 0.05$). The results of the two-way ANCOVA also show a significant mathematical ability difference between above average intelligence and below average intelligence students ($F_{(1,111)} = 3.97$, $p<0.05$).In this study, above average intelligence higher secondary students reported significantly higher levels of mathematical ability. The results of the two-way ANCOVA show no significant treatment by intelligence interaction effect on Mathematical ability ($F_{(1,111)} = 2.11$, $p > 0.05$). The results of the 2x3 factorial design ANCOVA show overall significant mathematical ability differences based on treatment among higher secondary students ($f_{(1,111)} = 49.94$, $p<0.01$).there exists a significant difference between experimental and control groups ($p<0.01$), with students of experimental group reporting significantly higher levels of mathematical ability (mean=60.23, SE = 1.81) than students of control group (mean=44.35, se=1.33). The results of the two-way ANCOVA also show no significant mathematical ability difference based on mathematics learning style ($f_{(2,109)} = 1.35$, $p > 0.05$). In this study, higher secondary students with sensory learning style (mean=50.21, SE=1.25), intelligence-based learning style (mean=52.54, SE=1.10) and multi-learning style (mean=54.12, SE=2.93) reported no significant difference in terms of mathematical ability. The results of the two-way ANCOVA show no significant treatment by mathematics learning style interaction effect on mathematical ability (f

$_{(2,109)} = 0.01$, $p > 0.05$). The variables like gender, intelligence and learning style were found to be independent of interaction with the strategies. The effectiveness of TPCK Strategies was empirically established among students irrespective of their gender, intelligence and learning style. Analysis of the research data came up with very interesting findings. On comparing the TPACK strategies with AOMI strategies it was found that TPACK strategies shown to be significantly effective when the controlling variables like gender, intelligence and learning styles were used to control the effect of treatment at various stages. The f-ratios for gender, intelligence and learning styles were given as 116.66, 105.10 and 49.94 respectively, the percentage of variance showed the extent of influence of the treatment at three different control conditions like gender (51.2%), intelligence (48.6%) and learning styles (31.4%). All the analysis was done by factoring out the initial differences that may interfere in the output. When the effect of control variable gender was analyzed with the treatment, the two main effect of treatment and gender was found to be significant and the interaction between gender and treatment was found to be not significant. Similarly when effect the other variable intelligence was analyzed with treatment it was found that the two main effect treatment and intelligence was found to be significant and interaction between treatment and intelligence was not significant. When the three different levels of learning styles were used to control the effect of treatment it was found that only the main effect of treatment is significant and the other main effect learning style and interaction effect was found to be not significant. Mathematical ability is a concept were studies already reported the influence of treatment with gender and intelligence but mathematical reasoning ability do not differ between male and female (Kadarisma et al., 2019). The variation in mathematical creative thinking of male is slightly higher than female students (Marzuki, Cahya, & Wahyudin, 2020).

Educational Implications

Based on the results of the study, the following discussion presents the implications for research and teaching mathematical ability of higher secondary school students. There were confounding results of various researchers which predicted the influence of gender in mathematical ability, but the study undoubtedly showed that both male and female students can have equal chances of acquiring the anticipated mathematical ability. This gives a broader scope for the policy makers to design the instructional strategies grounding in TPACK for nurturing the competencies for mathematical ability. Mathematical were not interacting with gender even there are differences in abilities of spatial recognition (Ramírez-Uclés & Ramírez-Uclés, 2020). Another important factor which is of interest to the policy makers is about intelligence. Intelligence has been proved to interact with almost all variables showing some effects on studies of achievement, problem solving, logical understanding and mathematical inferences. The study specially showed that both classifications on intelligences are benefitted through the TPACK strategies. TPACK has been related to mathematical subdivisions like set theory, data reduction and estimation of dependencies using artificial intelligence (Özgen & Narli, 2020). Learning style is varying among students and the variation or the groups cannot be treated as discrete and independent entities, students with varied learning styles can be taught through TPCK Strategies. When the groups of students are heterogeneous, TPCK Strategies could be able to provide the subject knowledge to the learner according to their individual differences. The standardized tool on mathematics learning style is a valid and reliable tool that can be widely used for assessing the mathematics learning style of higher secondary school students. When learning is initiated through different types of digital gadgets changes are happening in the ways of leaning and it is always depended on the other complex and conflicting factors around (Kontkanen et al., 2017). A well-furnished Mathematics Laboratory with TPCK Strategies can bring experiential learning. TPCK Strategies in the classroom will go a long way to tackle classroom management issues. This will provide a platform for sharing subject matter and the scope of feedback. The recent research trends in the field of TPCK and mathematical ability provide a vibrant orientation for the upcoming researches in these areas and rewarding experience and motivate researchers to undertake further research.

References

Alqallaf, N. (2016). Mathematical teachers' perception: Mobile learning and constructing 21 st century collaborative cloud-computing environments in elementary public schools in the State of Kuwait. (Doctoral Dissertation), University of Northern Colorado Retrieved from https://digscholarship.unco.edu/dissertations/321/.

Ammade, S., Mahmud, M., Jabu, B., & Tahmir, S. (2020). TPACK Model based instruction in teaching writing: An analysis on TPACK literacy. International Journal of Language Education, 4(2), 129-140. doi: https://doi.org/10.26858/ijole.v4i2.12441

Angeli, C., & Valanides, N. (2009). Epistemological and methodological issues for the conceptualization, development, and assessment of ICT–TPCK: Advances in technological pedagogical content knowledge (TPCK). Computers & Education, 52(1), 154-168. doi: https://doi.org/10.1016/j.compedu.2008.07.006

Bhatti, R. U., & Bart, W. M. (2013). On the effect of learning style on scholastic achievement. Current Issues in Education, 16(2), 1-6. doi: https://cie.asu.edu/ojs/index.php/cieatasu/article/view/1121/498

Brunner, M., Krauss, S., & Kunter, M. (2008). Gender differences in mathematics: Does the story need to be rewritten? Intelligence, 36(5), 403-421. doi: https://doi.org/10.1016/j.intell.2007.11.002

Castéra, J., Marre, C. C., Yok, M. C. K., Sherab, K., Impedovo, M. A., Sarapuu, T., . . . Armand, H. (2020). Self-reported TPACK of teacher educators across six countries in Asia and Europe. Education and Information Technologies, 25(4), 3003-3019. doi: 10.1007/s10639-020-10106-6

Chen, H.-J., Liao, L.-L., Chang, Y.-C., Hung, C.-C., & Chang, L.-C. (2019). Factors Influencing Technology Integration in the Curriculum for Taiwanese Health Profession Educators: A Mixed-Methods Study. International Journal of Environmental Research and Public Health, 16(14), 1-16. doi: 10.3390/ijerph16142602

Gudmundsdottir, S., & Shulman, L. (1987). Pedagogical content knowledge in social studies. Scandinavian Journal of Educationl Research, 31(2), 59-70. doi: https://doi.org/10.1080/0031383870310201

Juhji, J., & Nuangchalerm, P. (2020). Interaction between scientific attitudes and science process skills toward technological pedagogical content knowledge. Journal for the education of gifted young scientists, 8(1), 1-16. doi: http://dx.doi.org/10.17478/jegys.2020.XX

Kadarisma, G., Nurjaman, A., Sari, I. P., & Amelia, R. (2019). Gender and mathematical reasoning ability. Journal of Physics: Conference Series, 1157, 1-7. doi: 10.1088/1742-6596/1157/4/042109

Kontkanen, S., Dillon, P., Valtonen, T., Eronen, L., Koskela, H., & Väisänen, P. (2017). Students' experiences of learning with iPads in upper secondary school – a base for proto-TPACK. Education and Information Technologies, 22(4), 1299-1326. doi: 10.1007/s10639-016-9496-7

Lee, K., Suharwoto, G., Niess, M., & Sadri, P. (2006). Guiding Inservice Mathematics Teachers in Developing TPCK (Technology pedagogical content knowledge). Paper presented at the Society for Information Technology & Teacher Education International Conference 2006, Orlando, Florida, USA. Retrieved from: https://www.learntechlib.org/p/22684

Marzuki, Cahya, E., & Wahyudin. (2020). Relationship between mathematical creative thinking ability and student's achievement in gender perspective. Journal of Physics: Conference Series, 1521, 1-7. doi: 10.1088/1742-6596/1521/3/032039

Mishra, P., & Koehler, M. J. (2008, March 24–28). Introducing technological pedagogical content knowledge. Paper presented at the Annual meeting of the American Educational Research Association, New York doi: http://www.matt-koehler.com/publications/Mishra_Koehler_AERA_2008.pdf.

Moreno, J. R., Montoro, M. A., & Colón, A. M. O. (2019). Changes in Teacher Training within the TPACK Model Framework: A Systematic Review. Sustainability, 11(7), 1-10. doi: 10.3390/su11071870

Niess, M. L. (2002). Preparing Teachers to Teach Science and Mathematics with Technology. In D. Watson & J. Andersen (Eds.), Networking the Learner: Computers in Education (pp. 689-697). Boston, MA: Springer US doi:https://doi.org/10.1007/978-0-387-35596-2_69.

Özgen, K., & Narli, S. (2020). Intelligent Data Analysis of Interactions and Relationships among Technological Pedagogical Content Knowledge Constructs via Rough Set Analysis.

Contemporary Educational Technology, 11(1), 77-98. doi: https://doi.org/10.30935/cet.646769

Pavlekovic, M., Zekic-Susac, M., & Djurdjevic, I. (2009). Comparison of intelligent systems in detecting a child's mathematical gift. Computers & Education, 53(1), 142-154. doi: https://doi.org/10.1016/j.compedu.2009.01.007

Priya, J. J. (2017). Mathematical Problem Solving Ability of Eleventh Standard Students. Journal on Educational Psychology, 11(2), 36-44. doi: https://eric.ed.gov/?id=EJ1169548

Ramírez-Uclés, I. M., & Ramírez-Uclés, R. (2020). Gender differences in visuospatial abilities and complex mathematical problem solving. Frontiers in psychology, 11, 1-10. doi: https://doi.org/10.3389/fpsyg.2020.00191

Raven, J. C. (1958). Guide to using the coloured progressive matrices: H. K. Lewis & Company. Retrieved from: https://psycnet.apa.org/record/1960-00085-000.

Tanak, A. (2020). Designing TPACK-based course for preparing student teachers to teach science with technological pedagogical content knowledge. Kasetsart Journal of Social Sciences, 41(1), 53-59. doi: https://doi.org/10.1016/j.kjss.2018.07.012

Thiyagu, K., & Joshith, V. (2021). Perception Towards The Use Of Digital Technology And Factors Generating Techno-Stress Among Teacher Educators. Review of International Geographical Education Online, 11(5), 4182-4192. doi: https://doi.org/10.48047/rigeo.11.05.300

Valtonen, T., Leppänen, U., Hyypiä, M., Sointu, E., Smits, A., & Tondeur, J. (2020). Fresh perspectives on TPACK: pre-service teachers' own appraisal of their challenging and confident TPACK areas. Education and Information Technologies, 25(4), 2823-2842. doi: 10.1007/s10639-019-10092-4

Vijayan, V., & Joshith, V. (2018). Technological pedagogical content knowledge: A framework for 21st century teacher cognition. International Journal of Research and Analytical Reviews, 5(3), 325-329. doi: http://ijrar.com/upload_issue/ijrar_issue_1232.pdf

Vijila, C., & Thiyagu, K. (2019). Awareness Questionnaire on Massive Open Online Course (MOOCs): A Tool Construction and Standardization. International Journal of Recent Technology and Engineering (IJRTE), 8(3), 6522-6524. doi: 10.35940/ijrte.C5209.098319