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The 5Es inquiry-based Lesson plan activities and the Preservice Science Teachers' Technological Pedagogical Content Knowledge (TPACK) Development

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Abstract: *Science is a piece of knowledge as well as a process. The knowledge of science has been expanded day-to-day; however, the process of doing science in the classroom remained unchanged. Our classroom followsa very conventional way of doing science. Even used of information and communication technology are popular in teaching-learning of science but how to integrate ICT effectively according to pedagogical demand of teaching-learning of science is remained an issue. Many researchers concluded that ICT tools have great affordances in pedagogical strategies of teaching-learning of science. For example, computer simulation, animation, data logging, and online discussion forum have great affordances in the process of doing science where learners construct their knowledge by themselves. The present study is a pre-experimental, pretest-posttest design of study where investigator developed 5Es inquiry-based ICT integrated lesson plan activities with the following of the TPACK model framework. The finding revealed that 5Es inquiry-based ICT integrated lesson plan activities effective for the development of preservice science teachers' TPACK construct i.e. TK, PK, TCK, PCK and TPACK, which is useful for effective ICT integration in classroom teaching and learning of Science.*

Keywords: *ICT, 5Es inquiry model cycle, pedagogy, affordances, TPACK, etc.*

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I. Introduction

Many national standards of science have priority for using the technology in engaging students in scientific inquiry, reasoning ability, critical thinking and problem-solving activities (ISTE, 2008). The classroom environment should be such as to provoke questioning, reasoning, scientific inquiry, discussions, debates and enhances students' Metacognitive skills (NFG on science, 2005). The effective use of technology makes it easier for students to design science experiments, interact with simulated phenomena, and receive feedback to refine their scientific understanding (Ibrahim, 2016). The interactive features and multiple functions of new technologies can enhance the learning of science i.e. interactive computer simulation and visualization can solve problems that are difficult to demonstrate in traditional science classrooms (Chien, Chang, Yeh, & Chang, 2012; Khan, 2008). With interactive computer technology, students are able to visualize physical phenomena by revisiting its several times. Opportunities like these are expected to encourage science teachers to support student-centered learning environments, as well as providing incentives to students to participate in their own learning (Hofstien, 2004; Jonassen, 2004) and that is the demand of modern constructivist approach to teaching and learning where learners get the freedom to construct their knowledge by own self. Therefore, science teachers must take advantages of integration of the technology in their classrooms with respect to facilitate and support students' learning and to address the pedagogical needs for enhancing the learning of science because the teachers are more confident in epistemological needs of the learners. Mishra and Koehler (2006) emphasized that effective ICT integration is possible only with the combined interaction of "technology, pedagogy, and content" and develop a model called "TPACK" i.e. "Technological Pedagogical & Content Knowledge" Model. He emphasized that the above three domains separately cannot integrate technology effectively into our classrooms and never achieve our goals.The TPACK framework is an important framework as well as an effective tool for effective ICT integration in science teaching and learning (Ansari, I., 2015). ICT module based on the TPACK model develops insight among preservice science teachers to know about the affordances of ICT tools regarding the appropriate pedagogy within a subject-specific context (Ansari & Bhatia, 2019).

Aligning with this vision, some studies inferred that science teachers should be offered with opportunities to develop instructions that consider the great affordance of technology integration to enhance classroom and students teachers' interaction (Lubin & Ge, 2012). More importantly, to fully benefit from computer technology, teachers need to develop a pedagogical understanding and subject context-specific technology uses. This involves understanding the significant role of technology in science education, how it can be beneficial for a "science curriculum", the "teaching and learning contexts" in which technology is most useful and which technological features most support students' learning of science, and which technologies are appropriate for simulating particular scientific concepts and why? However, many teachers lack an ample understanding of such knowledge, and they often faced problems in relation to the integration of technology in everyday teaching practices (Phelps & Ellis, 2002; Lubin & Ge, 2012). The reason is that they have not found appropriate training atmospheres at the pre-service and in-service training stages. Lubin and Ge (2012) have reported that new teachers often face challenges in designing technology-based teaching-learning activities. Most of them fail to select technological and pedagogical strategies that are suitable for their science teaching and learning needs. Overall, they are often unable to recognize the dynamic interplay between the types of technology used and the epistemology of science, nature of science content, and classroom context. Thus, many researchers inferred that the impact of computer technology in enhancing science instruction lags far behind as what has been expected by science knowledge society (Chien *et al.*, 2012; Lubin & Ge, 2012; Phelps & Ellis, 2002).

Therefore, innovative and student-centered approaches of teaching and learning activities design has been used that focused for effective technology integration and clarify the relationship between technology, science pedagogy, and science content (Chien, 2012; Mishra & Koehler, 2006; Niess, 2005).

The current study focused on the following objectives:

1. Development of the ICT based lesson plan activities
2. Is the ICT based lesson plan activities are effective for preservice science teachers' TPACK development?

Development of the ICT based lesson plan activities

The 5Es inquiry-based lesson plan activities consider the progress of the pre-service science teachers' TPACK that provoke effective ICT integration in science teaching and learning. It focuses on multiple ways of pedagogical strategies of ICT integration for specific science subject context. These types of pre-service science teachers' TPACK development facilitate to decide why, when, where, and how ICT tools will be most appropriate to stimulate learning (Kohlor & Mishra, 2006). The ICT module also offered the opportunities of 'hand-on experiences', investigation and develop scientific inquiry regarding the natural phenomenon of the world. Affordances of technology like Simulation, useful link/websites and online discussion for the development of teacher's professionals are the main focus.The 5Es instructional cycle model for science teaching and learning which is carefully crafted to promote the construction of knowledge independently, the teacher role is only a facilitator or guide. The effective use of ICT in specific subject context with appropriate pedagogical strategies is a difficult process; it is only accomplished by ensuring some set of rules focused on this module. For the development of 5Es inquiry-based lesson plan activities by the following of the TPACK model, the following criteria haveadapted by the investigator, which is suggested by Angeli & Valanides, (2009).

Table 1: Criteria for blending technology, pedagogy and content.

S.N.	Criteria	Examples
1	To identify the topics which cannot be comprehended easily by students or difficulties faced by teachers to teach in traditional classrooms	Abstract nature of the structure of cell components in biology needs visualization through simulation. Facts and events in physical sciences need animation (i.e., force and motion) Complex systems (i. e. Osmosis) in which certain events occur systemically needs computer simulation or model to clarify the events
2	To identify the process of transforming the content which is easily comprehensible to learners than traditional ways	Interactive illustration. Active transformation of data (i. e. Test of acids and bases through titration). Active processing of data. Manifold immediate representations of data. Multimodal demonstration of data
3	To identify pedagogical approaches which are difficult or not possible to implement in traditional ways	Exploration and discovery in virtual worlds. Testing of hypotheses and or application of ideas into contexts, which are not possible to be experienced in the natural world. Complex decision-making. Creation of cognitive conflict. Communication and collaboration with Peers and experts. Personalized learning Adaptive learning
4	To select suitable ICT tools	Computer simulation has great affordances in science subject context-specific teaching and learning
5	To identify the suitable strategies for the infusion of ICT tools in classroom teaching	Pedagogical strategies include: Engage, explore, explain, elaborate and evaluate

Table 2: 5Es inquiry model cycle activities (Ansari & Bhatia, 2019)

Phages	Activities
Engage	Demonstration: Qualitative and Quantitative demonstration of the difference between diffusion and osmosis using a sac made of dialysis tubing 1. An iodine-potassium iodide solution moves across the membrane into a sac field starch solution. The starch turns black (Diffusion). 2. A sac field with a saturated sugar solution is immersed in a beaker of water. Measurement of mass before and after reveal that water moved across the membrane (osmosis)
Explore	A qualitative investigation of osmosis in potato cells using different saline solution. We can use PhET simulation videos related to osmosis of http://Phet.colorado.edu or www.olab.edu.in
Explain	Concepts: the role of cell organelles in Homeostasis The teacher can provide an online facility for group discussion and concept formation of homeostasis
Elaborate	Investigation: Design a lab to measure the rate of Osmosis in cells The teacher can use LabQuest tools for measurement of the rate of osmosis in cells. http://www.vernier.com
Evaluate	Assessments that include laboratory investigation, multimedia presentation, digital poster, videos, application questions and concept map.

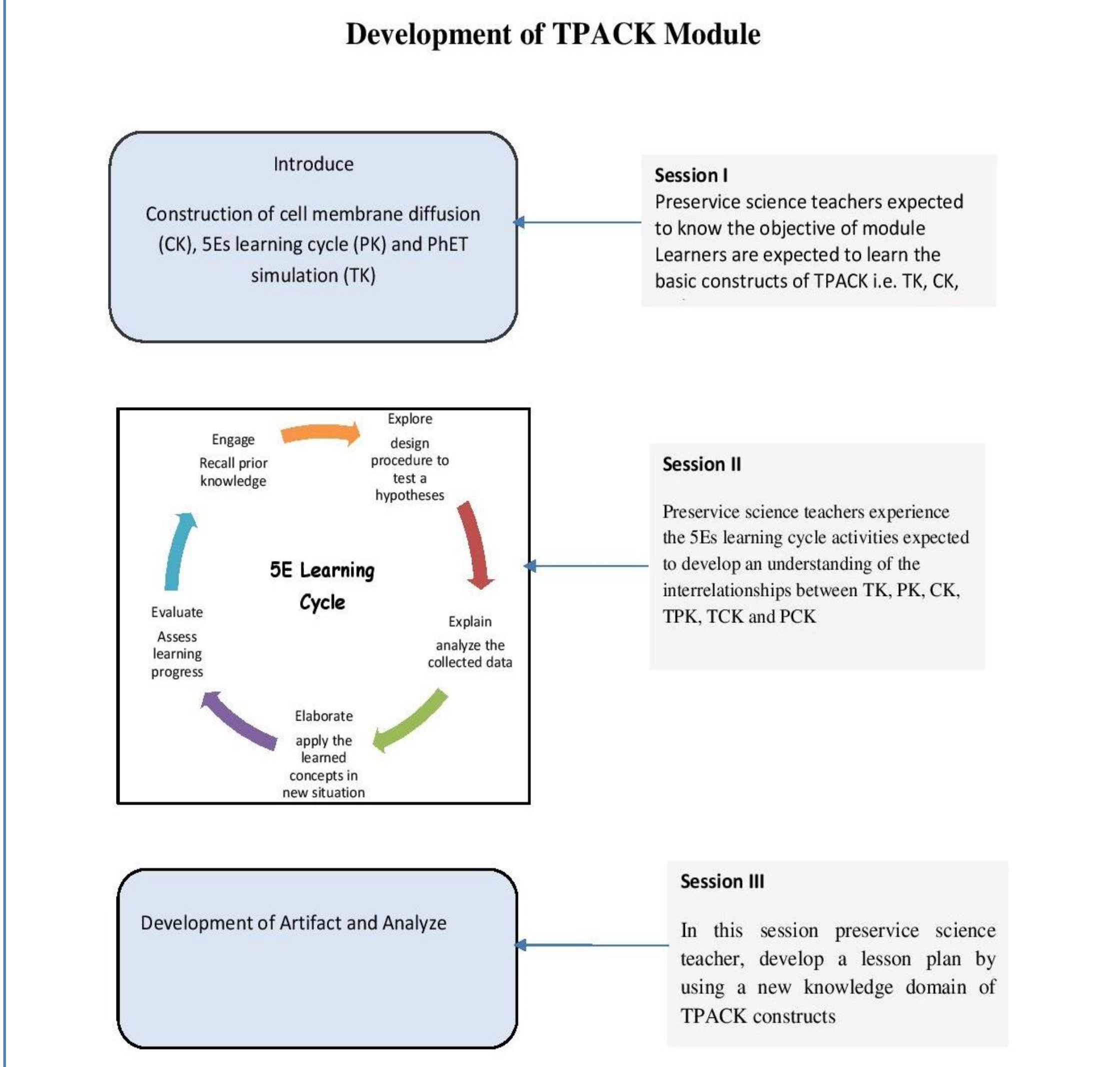

Figure: 4.1 Inquiry-based teaching-learning strategies based on TPACK model constructs

In this module, there are three important sections: the first section focuses on the understanding of theoretical underpinning of effective ICT integrated science teaching and learning includes exploration of TPACK constructs, 5Es instructional cycle model and affordances of ICT tools. The second section focuses the pre-service science teachers' pedagogical practices by the using of ICT tools (PhET simulation, onlinelabs.com digital videos, useful websites links and online google group discussion forum). The third section focuses on the development of ICT based lesson plan by pre-service science teachers based on experiences gained during the TPACK module intervention. In this module, it ICT tools are adopted from different free online open-source resource i.e., Colorado PhET project, Vernier.com, and onlinelabs.com. These open-source simulations are user-friendly and provide very extensive guidelines for teacher educators and learners where they can easily design, customize and implement according to their learning needs.

In this module, the various useful websites links are used for exploration and validation of knowledge through scientific reasoning with the interaction of science knowledge society. This module also guides for the pre-service science teachers to use online tutorials group/google group discussion forum to develop a platform of sharing ideas to being an active scientific inquirer.

II. Method of the Study

For the aboveconcern, investigator developedsimulation-based lesson activities by following the 5Es inquiry model cycle instruction for the development of preservice science teachers' TPACK construct which is useful for effective technology integrated science teaching and learning. The preservice science teachers are taught by such lesson plan activities for the development of their TPACK. To design the TPACK based lesson plan activities the investigator has selected three topics of science, i.e. cell membrane diffusion, acid-base test and construction of electric circuits. The 5Es inquiry model cycle stages, engagement, exploration, explanation, elaboration, and evaluation was used for designing activities. The open-source science simulation resources (Phetcolorado.com, onlinelabs.com, Vernier.com) are used for technological intervention. After the intervention of lesson plans, the pretest-posttest of teachers' TPACK survey assessment data analyzed to see the effectiveness of simulation-based science activities. In this study,26 preservice science teachers have participated and 21 days they have taught with science simulation activities developed by the investigator for their TPACK development. During the teaching of the simulation-based activities online group, discussion support and feedbacks are also provided. Before the intervention, the preservice science teachers' TPACK assessment was conducted which is called pretest of TPACK assessment.

III. Result and Discussion

After the intervention of the 5Es inquiry-based lesson plan activities, the pretest-posttest data were analyzed. For inferential statistics, the Wilcoxon Sign Ranked Test is measured to see the significant difference between the pretest and posttest. Medians and z values are used to see significant differences. However, if the z values are found significant then effect size was also calculated to see the magnitude of effect by the Cohen's benchmark (r) value. Cohen (1988) specified Cohen's (r) value for the analysis of "effect sizes: r=0.2 small, r=0.5 medium and r=0.8 large effect size".

A statistical test of Pretest Posttest of Technological Pedagogical Content Knowledge (TPACK) construct

Table 3: Pre-service science teachers' Pretest Posttest Technological Pedagogical Content Knowledge (TPACK) constructs

N=26	Mean		Median		S.D.		Wilcoxon Signed Rank Test (Posttest-Pretest) Z	Asymp. Sig.	Effect Size
	Pre-	Post-	Pre-	Post-	Pre-	Post-			
TK	20.85	27.15	20.50	27.00	3.003	1.736	-4.377[b]	.000	0.858
PK	14.46	27.19	14.50	27.00	3.51	1.96	-4.469[b]	.000	0.876
CK	29.15	30.27	30.00	30.50	3.875	2.359	-.796[b]	0.426*	NA
PCK	6.42	7.85	7.00	8.00	2.003	.834	-2.983[b]	.003	0.585
TCK	10.81	11.96	11.00	12.00	2.689	1.311	-2.009[b]	.044	0.394
TPK	14.54	15.88	14.50	16.00	2.611	1.818	-1.764[b]	.078*	NA
TPACK	15.54	20.19	15.00	20.0	3.513	1.357	-3.898[b]	.000	0.764

a. "Wilcoxon Signed Ranks test" * NS

b. "Based on negative ranks"

The above table 3shows, the mean score of pretest and posttest of "Technological Knowledge" of pre-service science teachers are pre- M=20.85, S.D.=3.003 and post- M=27.15, S.D. 1.736 showing higher mean score of posttest technological knowledge. It means intervention may change the confidence in pre-service science teachers regarding technological knowledge. The test statistics of the "Wilcoxon Signed Rank Test" depicts that, the posttest technological knowledge is significantly higher (Mdn= 27.00), z=-4.377, p<.001. The z value is significant at both 0.05 and 0.01 level; therefore, the effect size is calculated by using Cohen's benchmark (r) to get the magnitude of the effect. In the test of statistics result r=0.858 shows a large effect size of the intervention of 5Es inquiry-based lesson plan activities for the growth of technology knowledge of pre-service science teachers. It means the module has a significant role in changing the pre-service teachers' TPACK growth. The result is also consisted with, Baran, Chuang & Thompson (2011) conducted a study on pre-service teachers' TPACK development where they find a large level of effect size in Technological knowledge (TK) in pre and posttest mean score. Another study conducted by Chai, Koh, & Tsai (2010) find a moderate size of the effect for TK and inferred that skilled-based activities in the designed course were effective for enhancing their technological knowledge (TK). In this study, simulation tools, useful links/websites, and online discussion are used which are useful for pre-service science teachers' technological knowledge enhancement.

Moreover, the above table 3 depicted that as similarly with TK, the PK, TCK, TCK and TPACK of posttest of preservice science teachers show significant change. For the PK of preservice science teachers, the Cohens' benchmark r= 0.876 shows large effect size of magnitude whereas TCK and TPACK shows r=0.585 and r=0.764 moderate effect size of magnitude additionally TPK r=0.394 small effect size of magnitude. However, no significant change founded in preservice science teachers' CK and PCK.Manystudies have found consistent results i.e. Baran E., Chuang H., & Thompson A. (2011) conducted a study on pre-service teachers' TPACK development where they find a large level of effect size in pedagogical knowledge (PK) in pre and posttest mean score. Another study conducted by Chai, Koh, & Tsai (2010) find a large size of the effect in PK and inferred that using instructional strategies is effective for teachers' pedagogical knowledge development. Investigator used 5Es instructional cycle for inquiry-based science teaching-learning activities, which are a very effective pedagogical technique for enhancing their pedagogical knowledge (PK). Mustafa, (2016), also stated that the 5Es learning cycle preferred as a general framework for developing teachers' pedagogical knowledge (PK) because 5Es consist of different types of distinguished events that start with recalling the prior knowledge (Engagement phase) to applying new knowledge in different situations (Elaboration phase). Alayar & Voogt (2012) conducted a study on "developing technological pedagogical content knowledge in pre-service science teachers: support from blended learning". They stated that training creates a significant mean difference in pedagogical content knowledge with large effect size (Cohen's r=1.1) and PCK have effective knowledge domain for pre-service science teachers' teaching-learning instructional design. Many studies explored that; PCK is a "topic-specific" and "context-specific" where teachers try to develop "pedagogical content knowledge" (PCK) respond their experience as teachers (Loughran *et al.*, 2008). Shulman 1986 reported that "Pedagogical Content Knowledge" is a combination of "content knowledge" and "pedagogical knowledge" this is a unique domain of teachers and their professional understandings. Koh & Chai (2014) reported that ICT based lesson plan design has a potential effect on teachers' TPACK development. Park, Lee & Kim explored that science simulationis best to describe tools that allow the student to explore complex concepts into a simple visualize model of real-life situations. The results consistent to Schmidt *et al.* (2009) provided descriptions of the instruments in pre-service teachers' TPACK development where they find a large level of effect size in "technological pedagogical content knowledge" (TPACK) in pre and posttest mean scores and explored that, TPACK has a potential to provide a new model for preparing a learning experiences for future teachers. Another study conducted by Chai, Koh & Tsai (2010) reported, the largest effect size (r=0.69) was found for TPACK showing, the course activities experiences had a significant influence in supporting to teachers' expertise for technology-integrated teaching and learning. The results also consistent with Koh & Divaharan (2011) obtained that TPACK is useful for ICT courses designed that required for comprehending the aspect of confidence building, content-focused pedagogical modeling, and hands-on experience program. Like the above, it has been concluded that 5Es inquiry-based investigative teaching-learning activities through ICT supported experience have a considerable effect on developing pre-service teachers' competency in technology-integrated science teaching and learning. The result was also consistent with, Baran E., Chuang H., & Thompson A. (2011) conducted a study on "pre-service teachers' TPACK" development where they find a low level of effect size (Cohen's d<0.5) in content knowledge (CK) for pre-service science teachers. Another study conducted by Koh & Chai (2014) on teachers' TPACK development through ICT lesson design found a similar result that pretest-posttest result for content knowledge shows insignificant different. The main reason insignificant difference of pre-service science teachers' content knowledge (CK) is that content knowledge did not focus during the experience of ICT module.

IV. Conclusion

The main purpose of the study was to develop pre-service science teachers' TPACK construct for effective ICT integration in science teaching and learning. For the above purpose, the inquiry-Basedlesson plans were developed by using computer simulations (PhET Colorado, onlinelabs.com & vernier.com). After the intervention of the 5Es inquiry-based lesson plan activities, the pretest and posttest of perceived TPACK development analyzed. The findings revealed that TPACK module has a significant role in enhancing the pre-service teachers perceived TPACK, which is useful for ICT integrated science teaching and learning. Significant changes have seen in posttest of preservice science techers' TK, PK, TCK, PCK and TPACK development except in CK and TPK. In preservice science teachers' CK no significant change occurred because the lesson plan developed by investigator did not focus onthe development of content knowledge. However, an insignificant change occurred in TPK is questionable. It might be possible due to the short duration of intervention periods. The results are consistent with various research studies conducted by Brown &Warschauer, 2006 & Lee *et al.*, 2008. Tsai, Chai & Koh (2010) reported that the ICT course designed according to TPACK framework determine the moderate size of the effectand significant change in pretest and posttest results of pre-service teachers' TK, PK, CK, and TPACK construct. Hence, the use of the science simulations of PhET Colorado and various websites links, online group discussion in 5Es inquiry-based ICT module has great potential for pre-service science teachers' professional development with respect to the effectiveness of ICT integrated teaching and learning activities designed. The simulations provide opportunities to design and test the hypothesis to reach the correct responses, have an extra advantage of learning in science. According to steel and Koing (2006), "time is a significant factor influencing motivation, people tend to value immediate rewards than delayed". Independence in the experimentation of using simulation sim can encourage students, in deciding the appropriate goals, objectives & pedagogical strategies. Use of simulation has a significant role in teachers' intrinsic motivation (Steel and Koing, 2006).

The implication of the study

The findings indicate when ICT based lesson taught to pre-service science teachers emphasized on uses of appropriate technological affordances i.e. simulations, animations, useful website links and group discussion forum. By following the above, the pre-service science teachers develop insight to understand the affordances and effective use of ICT tools in the subject-specific context. As the findings indicated that when we taught, the ICT based lessonplan based on the TPACK model the pre-service teachers followed 5Es instruction cycle inquiry activities in their Lesson Plan. Teacher educators to enhance the use of the process approach should use this 5Es approach.The findings indicated that effective ICT integration is not possible only focused on hardware and software technical skills development but it should be focused on subject-specific pedagogical context. Therefore, the findings helpful for designing of the suitable teachers training program with consideration of content, technology and pedagogy.

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- http://www.mysciencesite.com
- http://www.phet.clorado.edu
- https://phet.colorado.edu/forteacher
- https://wise.berkeley.eud/
- http://onlinelabs.com
- www.vernier.com,

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