Exploring the Technological Factors Affecting Creativity in Computational Thinking-centered Learning Context

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Abstract: - The attempt of applying technology in education has started with ICT education and spread into e-learning, u-learning, m-learning and SMART learning in Korea. Computational Thinking is crucially needed as the center of educational environmental change. Although educational circumstances are expected to change dramatically in the near future, the theoretical consideration on the effect of applying educational technology towards creativity is rare. Therefore, we have explored some technological factors affecting creativity in the context of computational thinking-centered learning which is referred to as SMART learning. 67 subjects participated in the survey exploring the technological factors of SMART learning. Throughout the study, 4 technological factors such as technological self-efficacy, cooperativity, resource free and interactivity were revealed as main factors affecting student's creativity.

Key-Words: - Technological factor, Computational thinking, SMART learning, Creativity.

1. Introduction

Modern society has become more complex than the past. Thus, it demands individuals to demonstrate various abilities in complicated and unforeseeable situations. Among the diverse abilities 'creativity' is the key capacity in adapting to modern society. The word 'creativity' has various definitions according to the perspectives of the researchers. However, the researchers reached a general consensus about the definition. The key component of creativity contains novelty and appropriateness [1][2][3][4][5][6].

The beginning of creativity research in 1950 mainly focused on internal individual factors, such as personality, intelligence, motivation and so on. However, external individual factors have been under consideration within creativity research. Thus, environmental factors, organizational atmosphere, freedom, fundamental resources, colleagues' support, organizational compensation, administrator's encouragement, supports of task group, fundamental resources, and challengeable tasks are now being examined. [1]. Alencer, & Bruno-Fara(1997) suggested challengeable tasks, freedom, autonomy, supports of administrator, limited hierarchical structure, flexible standards, dispersion of power, supports of organization, physical environment, incentives, technological supports, and supports of teams as environmental factors that affect creativity[7]. Runco(2007) recorded environmental factors such as positive colleague groups and administrators, fundamental resources, challengeable tasks, clear tasks, autonomy, cohesiveness, intellectual stimulation, proper compensation, flexibility, emphasis on the output, active participation, organizational integration, positive personal relations[8]. Though the educational circumstances are rapidly changing as educational technology is developed, the prior research has solely focused on person related factors and tasks rather than the technological factors influencing creativity[2].

The usage of educational technology that started in ICT education has spread into e-learning, u-learning, m-learning and SMART learning as the development of technology has progressed[9]. SMART learning creates an intellectually customized educational system that strengthens learners' ability through innovations in educational environments, contents, methodology and evaluation. SMART is an acronym for Self-directed, Motivated, Adapted, Resource free, Technology embedded education[10].

Changing the educational environment through using various modern educational technologies is not a phenomenon appearing only in Korea. It is a global trend. 17 Korean Metropolitan and Province

Offices of Education are now operating 13 SMART learning model research schools[11].

In the United States, the Minister of Education, Arne Duncan announced in 2012 a plan to change all textbooks into digital textbooks over the next several years. Digital textbooks can save printing costs, offer rapid updates and operate interactively. iHTs (interactive heritage traits) exploring program offers real-time interaction using ICT (GPS, broadband communications network etc.) and Smart phone technologies in Singapore. It appears that students using iHTs are personally in control and responsible for their learning through using technology. It creates an abundance of everyday educational moments.

Even though the global trend of actively introducing educational technology using computational thinking along with the needs of creative ability in society is apparent. Theoretical consideration of the effects of educational technology in enhancing creativity is scarce in comparison with the research about practical use of educational technology. Thus, through this study, we aim to explore the technological factors affecting creativity through researching the preceding studies related to educational technology and creativity.

2. Theoretical Background

2.1. Computational Thinking

The concept of computational thinking was introduced by Papert (1996) and it was re-emphasized recently as Wing (2008) started to apply computational thinking as a problem solving process in the educational scene. Computational thinking is considered a new strategy to introduce computers in schools. The trend and purpose of computer classes in the world has been changed from computer skills training to the effective application of computers to solve the problems [12][13].

It is considered a necessity to know how to utilize ICT tools and their tasks in various industries and in daily life. Wing(2006) and Guzdial (2008) argue that computational thinking should become part of basic literacy knowledge in the 21st century along with the 3R's (Reading, Writing and Arithmetic) [13][14].

In the US, a computer education curriculum was reorganized in 2011, and computational thinking was placed at the forefront. Barr, D., Harrison, J., & Conery, L. (2011) proposed computational thinking as one of standard curriculums of K-12 computer science subjects. According to the previous research, 9 main concepts or capacities have been categorized as follows; Data Collection, Data Analysis, Data representation, Problem Decomposition, Abstraction, Algorithms & Procedures, Automation, Simulation, Parallelization [15].

Computational thinking can be successfully applied to SMART learning context. As smart devices are rapidly adopted in every field of society, the Korean Ministry of Education set the master plan for SMART education[10]. According to the master plan for SMART learning, 'SMART' in SMART learning means that self-directed(S), motivated(M), adaptive(A), resource free(R), technology embedded(T) education.

2.2. Creativity in context

The research of creativity began with Gilford's speech in 1950. According to his speech, psychologists have to study personality traits of creative people. The early stages of creativity research focused on the psychological determinants for individual genius and giftedness[20].

But research into creativity in the 1980s and 1990s became rooted in the effect of social structures on individual creativity[20]. This research is called social psychology and confluent theory of creativity.

The confluent theory of creativity is concerned with the various intra personal factors affecting creativity like personal traits, motivation, intelligence as well as the extra-personal factors such as environmental facilities, environmental atmosphere and social interaction.

There are some representative theories - 'componential theory of creativity' [1][17], 'system theory'[4][5][6] and 'investment theory' [18][19][20]. In this paper, Amabile's Componential model of creativity will be used as a main reference.

2.3. Technological Factors Related to Creativity

To find the missing link between technology and creativity we have investigated Eric, Science Direct, RISS and KISS which offers a domestic and foreign journal.

The research keywords were 'educational technology' and 'creativity'. After researching the technological factors relating to creativity, 4 factors - Technological self-efficacy, Cooperativity, Resource Free, Interactivity - have been chosen as key factors affecting creativity.

TABLE1. Technological factors relating to creativity

Factors	Research
Technological self-efficacy (TSE)	Eyadat, & Eyadat(2010)[25] Aquda, et al(2011)[26]
Cooperativity (CO)	Koh(2012)[27] McLellan, & Nicholl(2013)[28] Winters, et al.(2005)[29] Vinu, et al.(2011)[30] Loveless(2002,2007)[31][32] Watson(2011)[33] Noh, et al. (2013)[34]
Resource Enriched (RE)	Korea Ministry of education (2011)[10] Keris(2011)[35] Vinu, et al.(2011)[30] Moore, et al.(2011)[36] Watson(2011) [33] Dodge(1991)[37] Watson(2011) [33]
Interactivity (IN)	Torres-Gil, et al. (2010)[38] Noh(2011)[28] Aquda, et al.(2011)[26] Loveless(2003)[39] Loveless(2002,2007)[31][32] Watson(2011) [33] Wang, et al.(2014)[40]

3 Method

3.1. Experimental Process

This study aims to explore the technological factors relating to creativity. The experimental process to achieve the research objective is stated below.

1. We have investigated the preceding literature relating to our research topic.
2. Some technological factors relating to creativity were extracted through the research.
3. We have explored relevant questionnaires which focus on the extracted factors.
4. 67 subjects have been selected for the survey.
5. Analysis of validity and reliability and descriptive statistics has been completed to verify if the factors suggested are valid or not.

3.2. Instruments for assessing factors

Instruments for assessing factors are shown in Table 2. Mccoy(2001)'s Technological self-efficacy scale was used to assess the TSE factor[21]. The Cronbach's alpha of TSES .941 means the results are reliable. Generally, researchers determine the reliability of a scale if the Cronbach's alpha is greater than .7.

In Song(2009)'s scale assessing CO, the Cronbach's alpha recorded .787. In Song(2009)'s scale assessing RE recorded .761 which means the results are reliable[22]. Lee(2010)'s scale assessing IM is also reliable since the Cronbach alpha is .871. Lastly, the scale assessing CR (Song, 2009), recorded .770[23].

TABLE 2. Instruments for assessing each factor

Factor	Researcher	Name of Instrument
TSE	Mccoy (2001)[21]	Online Technologies Self-efficacy scale(OTSES)
CO	Song (2009)[22]	KEYS Korean ver.
RE	Song (2009)[22]	KEYS Korean ver.
IN	Lee (2010)[23]	Interactivity assessment Tool
CR	Song (2009)[22]	KEYS KEYS Korean ver.

3.3. Participants

Every participant has had experience with SMART learning for at least 1 year. 67 participants were sampled to validate the explored technological factors. 41 questions have been given to them(see Table 2).

After answering the questions, inappropriate or untrustworthy questionnaires have been removed before beginning the analyzing process.

4 Result

4.1. Analysis of Descriptive Statistics.

To investigate the approximate data tendency of the sample, an analysis of descriptive statistics was conducted. This analysis included mean, standard deviation using 65 participants' and questionnaires excluding 2 unreliable questionnaires.

4.2. Analysis of reliability

Analysis of reliability was done to determine whether the questionnaires used in this study were reliable or not. If the Cronbach's Alpha value computed is above .7, we can decide the questionnaires specific factor reliably [24]. Table 3 shows the results of the reliability analysis.

The value of Cronbach's alpha ranged from .707 to .866 which means that the questionnaires have reliability assessing TSE, CO, RF and IN.

TABLE 3. Result of reliability analysis

Factors	Cronbach's alpha
TSE	.707
CO	.820
RE	.749
IN	.866

4.3. Analysis of validity.

Confirmatory factor analysis (CFA) was conducted to validate the questionnaire using AMOS. Convergent validity and discriminant validity are revealed after the analysis of CFA.

Convergent validity considers the eigen values, C.R. value, AVE(Average variance extracted) and construct validity. Table 4 shows the standards of validity analysis. Generally, if the eigen value exceeds .45, C.R. value exceeds 1.965, AVE surpasses .5 and construct reliability is over .7, the show valid data.

TABLE 4. Standards of validity analysis

	Verification value	Method
Convergent Validity	Eigen value Significance	.45~.95, C.R.>1.965
	AVE Construct reliability	>.5 >.7
Discriminant validity	AVE and ϕ^2	AVE>ϕ^2
	$\phi \pm 2 \times S.E.$	$\phi \pm 2 \times S.E.$ not include 1
	Non restricted and restricted model $\Delta\chi^2$	$\Delta\chi^2 > 3.84$

Discriminant validity stands for the discrimination of independent factors. Lower correlation coefficient (ϕ) represents the better discriminant validity. Table 5 and Table 6 present the result of validity analysis.

TSE 1~6 indicate item numbers assessing TES factor. CO 1~7 indicate item numbers assessing CO factor. RE 1~5 indicate item numbers assessing RE factor. IN 1~4 indicate item numbers assessing IN factor, CR 1~6 indicate item numbers assessing CR factor. Shaded items indicate that they don't have enough validity assessing each factor or so that the 5 item shaded needs to be removed.

TABLE 5. Result of validity analysis(1st step)

	C.R.	P	AVE	Construct reliability
TSE→TSE1				
TSE→TSE2	1.985	.047		
TSE→TSE3	3.470	***		
TSE→TSE4	3.468	***	.371	.749
TSE→TSE5	2.658	.008		
TSE→TSE6	2.262	.024		
CO→CO1				
CO→CO2	4.407	***		
CO→CO3	.363	.716		
CO→CO4	6.238	***		
CO→CO5	6.470	***	.471	.850
CO→CO6	6.650	***		
CO→CO7	6.497	***		
CO→CO8	1.239	.215		
RE→RE1				
RE→RE2	.135	***		
RE→RE3	.134	***		
RE→RE4	.162	***	.537	.852
RE→RE5	.219	.831		
RE→RE6	.140	***		
IN→IN1				
IN→IN2	5.186	***		
IN→IN3	6.470	***	.799	.940
IN→IN4	6.189	***		
CR→CR1				
CR→CR2	6.044	***		
CR→CR3	3.711	***		
CR→CR4	3.919	***	.582	.890
CR→CR5	3.983	***		
CR→CR6	3.749	***		

Table 5 shows the result of 1st validity analysis. In regards to TSE, TSE2 and 6 have lower discriminant validity. Thus, removing both items can improve the validity of the factor. CO3, CO8 have non-significant C.R. values (C.R.< 1.965) so they also have to be removed. RE5 shows a non-significant C.R. value and inappropriate standard coefficient value(< .45). So RE5 also needs to be removed.

After the analysis of the first discriminant of each factors, a total of 5 items – TSE2, TSE6, CO3, CO8, RE5 - were removed to increase the validity of the questionnaires.

Table 6 indicates the result of removing the inappropriate items in the context of validity analysis results. In terms of TSE, removing the TSE2, TSE6 affects increasing the C.R. value which means that significant (C.R. > 1.965). In addition, the AVE value appeared as .466 and construct reliability was increased to .765 which can secure the discriminant validity. In case of CO, elimination of CO3 and CO8 has its effect on securing significance, AVE(=.593) and construct validity(=.895). RE5 was deleted from the RE factor's 6 items. After deleting the RE5 item, eigen value(>.45), AVE(=.691), construct reliability(=.916) were valid.

TABLE6. Result of validity analysis(2nd step)

	C.R.	P	AVE	Construct reliability
TSE→TSE1				
TSE→TSE3	3.786	***		
TSE→TSE4	3.750	***	.466	.765
TSE→TSE5	2.779	.005		
CO→CO1				
CO→CO2	4.031	***		
CO→CO4	5.949	***		
CO→CO5	6.302	***	.593	.895
CO→CO6	6.546	***		
CO→CO7	6.218	***		
RE→RE1				
RE→RE2	7.688	***		
RE→RE3	8.489	***	.691	.916
RE→RE4	6.585	***		
RE→RE6	4.693	***		
IN→IN1				
IN→IN2	5.186	***		
IN→IN3	6.470	***	.799	.940
IN→IN4	6.189	***		
CR→CR1				
CR→CR2	6.044	***		
CR→CR3	3.711	***		
CR→CR4	3.919	***	.582	.890
CR→CR5	3.983	***		
CR→CR6	3.749	***		

Thus, final survey items were identified to analyze the relationship between TSE, CO, RE, IN and CR. The current model suggests relationships with 4 previous technological factors of creativeness to suggest the componential model of creativity relating to educational technology (see Figure 1).

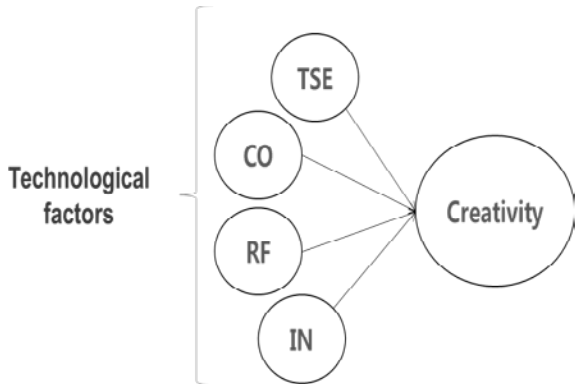

FIGURE1. Componential model of creativity relating educational technology

First, technological self-efficacy (TSE) is a reliable and valid factor that affects creativity. Technological self-efficacy means that a person fulfills technologically related tasks are by themselves. If students have confidence with fulfilling a technology task, creativity revelation can easily take place.

Second, cooperativity(CO) is defined as various kinds of social collaboration, working together to achieve the sharing object. SMART devices can be used to improve students' communication.

Third, resource enriched(RE) means that by using technology accessibility to abundant learning materials can be increased. It is expected that accessing abundant learning materials enhances creativity.

Fourth, interactivity(IN) is defined as interaction of students - students, tutor – tutee and learning materials – students. If students draw a response from their SMART devices, we can conclude that interactivity has occured.

4. Conclusion

Four technological factors affecting creativity are revealed through the study. Reviewing previous research related to technology and creativity creates 4 main factor categories– Technological self-efficacy, Cooperativity, Interactivity, Resource Enriched and Interactivity.

In conclusion, 4 technological factors - technological self-efficacy, cooperativity, resource enriched, interactivity - affecting creativity were revealed. However, the relationship between the 4 technological factors and creativity remains uncertain. Thus, a creativity revelation model in the educational technology environment especially SMART learning needs to be developed through further studies. Moreover, the recent interests of the environmental factors through the perspective of componential theory of creativity give rise to investigate the technological factors as the educational environment changes.

Furthermore, the following research to understand the internal components of creativity in the application of educational technology environment should be examined. The authors are suggesting including 3 components of creativity (domain relevant skill, creativity relevant skill and motivation) into the current model to understand the complex relationship of the effect of educational technology tools of students' creativity.

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