Educational Policy Analysis and Strategic Research

Volume 13, Issue 2 June 2018

epasr.penpublishing.net

ISSN: 1949 -4289 (Print)

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To cite this article

Batdi, V., Semerci, C. & Aslan, A. (2018). A meta-analytic and thematic study concerning the effect of inquiry based instruction on learners' achievement. Educational Policy Analysis and Strategic Research, 13(2), 51-68. doi: 10.29329/epasr.2018.143.3

Published Online	July 23, 2018
Article Views	9 single - 10 cumulative
Article Download	24 single - 33 cumulative
DOI	https://doi.org/10.29329/epasr.2018.143.3

Educational Policy Analysis and Strategic Research, V 13,N 2, 2018

A meta-analytic and thematic study concerning the effect of inquiry based instruction on learners' achievement[i]

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Abstract

This research aims at investigating the effect of Inquiry-Based instruction (IBI) on learners' academic achievement through meta-analytic and thematic approaches. In the meta-analytic study, 27 studies, which were implemented between 2000 and 2016 years, were examined. CMA and MetaWin statistical programs were used to calculate the effect sizes of these studies. The effect size (0.688) of the study indicates that the use of IBI has a positive effect on learners' achievement. To support findings of the meta-analytic study, a thematic study including 36 studies was applied. As a result of the analysis of the latter study, five themes, namely affective, cognitive and social domain themes, learning environment and negative aspects were generated. The former four themes demonstrated that IBI positively affects learners' achievement except the negative aspects theme. The negative theme stresses out that the effectiveness of IBI depends on how well the IBI activities are planned beforehand. If they are planned in detail, learners can know what to do in the activities. So, IBI can be used systematically in learning as an alternative method which can meet students' needs in technological era.

Keywords: *Meta-analysis, Thematic Analysis, Inquiry-Based Instruction, Achievement.*

DOI: 10.29329/epasr.2018.143.3

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[i] This study was presented as an oral paper at the Congress of 3rd International Eurasian Educational Research Congress (EJER) held on 31st May-3rd June 2016 at Muğla Sıtkı Koçman University, Muğla/Turkey.

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Introduction

Knowledge plays a crucial role in promoting countries to develop in technological, educational, socio-economic aspects. This is notable with the changes in technology and in the structure of employment which require citizens to get high level cognitive skills including the perception, interpretation, analyzing and transmission of confused knowledge (OECD, 2012). As a matter of fact, thinking and productive individuals can train these citizens who can meet their countries' needs. In this way, countries can sustain their entities in developed civilizations. Training thinking and productive individuals is possible with quality education systems. There are different approaches for quality issue in education. In other words, there is not a single definition for the quality issue in education and a number of items with regard to this issue can be compiled. To illustrate, learners' being very active and creative, acquiring knowledge through their experiences and reconstructing the knowledge by associating with their previous one (Osborn, 2013), teachers' guidance how to construct learners' knowledge, their encouragement to generate new ideas, their preparation for learning environment where different teaching methods and techniques are used (Eryaman & Bruce 2015; Ranjan & Rahman, 2014; Shaikh & Khoja, 2012), learners' cognitive, creative and affective development with their citizenship attitudes and values (Yıldırım, 2009) can determine the quality issue in education.

It is indicated in a number of studies that the methods used in the education systems are inadequate for the learners in the 21st century who encounter different needs (Alberta Education, 2010; Barron & Darling-Hammond, 2008; Friesen & Scott, 2013). According to Prensky (2001), "Our students have changed radically. Students today are no longer the people our educational system was designed to teach" (p.1). So, he coins them Digital Natives, who are "native speakers" of the digital language of technologies including computer, video game and the Internet. In another study, Gardner and Davis (2013) call today's youth app generation who are different from their previous generations with regard to identity, intimacy and imagination aspects. "App" derives from "application", a software program through which users conduct one or more operations on a mobile device. Applications enable users to access to newspapers, e-mails, games, bank accounts and so forth. At this point, Göka (2017) attracts our attention to the fact that this generation has different mental functions. He clarifies how their mentality works out indicating that "what will we do with schools in future? or are all these answers already on smart phones or will be on them sooner?" (p.118-119). These explanations indicate that today's youth or students do not face any difficulty in accessing knowledge. Knowledge is available for them by touching an app on a smart phone or write search item in search engine and click enter button and they can easily and fast access to knowledge. That is, knowledge is a touch or click away distance. So, it should be taken into account that learners have different learning styles.

When learners' different needs, interests in technological era are concerned, it is seen that teacher centred approach is not an effective method to enable them to acquire higher-level cognitive skills to find jobs in today's employment system. These skills require them to do research, inquiry and solve problems. They should reconstruct their acquired knowledge and come up with ideas to solve problems. As indicated by Serafin, Dostal and Havelka (2015) that the current social needs require an individual with the creative thinking to find the problems and solve them effectively. In this regard, Inquiry-Based Instruction (IBI) method can play a crucial role in ensuring them to develop their cognitive skills. This method is based on John Dewey's philosophy of education and it involves skills such as solving problem in learning process, conducting research and generating solutions (Erdem, 2006). As indicated by Dostal (2015) that "the inquiry-based instruction is an activity of a teacher and a pupil that is focused on the development of the knowledge, skills, and attitudes based on the active and relatively individual cognition of the reality by the pupil who learns on his/her own how to explore and explores." (p.79). This method starts with learners' curiosity on a particular issue with a willingness to do research. In this process, they collect, compile and analyze data with regard to the issue and then come to a conclusion or decision on this issue. In this method, learner is actively involved in exploring and constructing knowledge. That is, student and process of learning are in the core of IBI instruction (Aulls, Magon & Shore, 2015).

This study is concerned with revealing to what extent IBI has an impact on learners' grades in their courses. That is, it focuses on the relationship between the effect of the use of IBI in learning and learners' academic achievement. As a result of the literature review, it was found out that any study involving both meta-analytic and thematic approach has not been encountered to enlighten this relationship. So, the findings of the current study are hypothesized to make a valuable contribution to researchers, teachers, pre-service teachers, academic members responsible for training teachers, learners and designers for curriculum in education.

i. In the current study, questions that follow are answered:

ii. What is the effect size of the use of IBI in learning on learners' academic achievement?

iii. What are the participants' perceptions with regard to the use of IBI in learning?

Method

Research Design

This study mainly deals with investigating the effect of the process of inquiry based instruction (IBI), which can be implemented in every course, on learners' academic achievement. Namely, it identifies to what extent IBI method influences learners' achievement examining the studies conducted with regard to this method in national and international levels. For this purpose, quantitative

and qualitative techniques were applied to reveal more general and comprehensive findings to the related literature.

Data Collection and Analysis

In the quantitative part, meta-analytic method, a statistical technique to incorporate the findings of the separate studies with respect to similar issues (Crombie & Davies, 2009), was implemented. In this regard, a variety of databases including the Higher Education Council of Turkish Republic of National Thesis and Dissertation Centre, Google-Scholar, Ebscohost-Eric, Taylor and Francis Online Journals, ProQuest Dissertations-Theses, Web of Science and ScienceDirect were scanned to reach the studies related with IBI in national and international levels between 2000 and 2016 years. Of the databases, 840 studies were attained. A selection criteria was conducted to determine which studies should be included in the current one. Based on the criteria, the studies involving the effect of IBI on academic achievement and calculating the descriptive data for the effect sizes and those published in Turkish and English were taken into account. As a result of these criteria, 27 studies were included. Comprehensive Meta Analysis (CMA) and MetaWin programs were used to analyze these selected studies. The analysis were conducted according to fixed effects (FEM) and random effects models (REM) taking into account Cohen's (1992) classification level (0.20-0.50 small; 0.50-0.80 medium; over 0.80 large effect size). "Hedges' d" was used to calculate the effect sizes, whereas x^2 Q statistical value was used in the analysis (Higgins, Thompson, Deeks & Altman, 2003). Reliability among Assessors calculation formula [consensus / (consensus + dissensus) x 100] by Miles and Huberman (1994) was conducted to ensure the reliability outcome of the study. As a result of the calculation, it was found out to be 100%.

Thematic analysis was added in the study to support and complement the meta-analytic aspect of the study. As a result of the document review of the related literature, 36 studies with regard to IBI were included. These studies were coded into computer as: (178571-53). The former number (178571) in the parenthesis refers to the number of the thesis in the Higher Education Council of the Republic of Turkey and the latter number (53) indicates the page of the code in the related thesis. In the other codes Thesis (T) and number are used. Then, they were analyzed thematically. The content analysis was used to analyze the obtained data in the studies through Maxqda-11 program. In the analysis process, the expressions were coded and categorized under different themes. The coding of the studies was implemented by two raters. Agreement coefficient values (Cohen Kappa) for each theme were found and these values were taken into account to calculate the agreement among the raters (Viera & Garrett, 2005). Thus, the coefficient value for affective domain was found as .761, for cognitive domain as .789, for social domain as .833 and for IBL in learning process as .802 (App. 1). These values indicated that the coding was reliable.

Findings and Comments

In this section, the quantitative and qualitative findings related to the effect of IBI on learners' academic achievement were presented. In this way, all the findings were integrated with each other and complementary or different points were indicated.

The Quantitative Analysis Results of the Studies With Regard to IBI

Based on the selection criteria, 27 studies were included in the meta-analytic review. In Table 1, the frequency values for categorical independent variables of the studies, namely subject area and grade level, on the effect of IBI on learners' academic achievement were presented. When subject area variable is examined in Table 1, it is seen that most studies were implemented with the science course (n=10), and then science and technology (n=7), chemistry (n=2), physics (n=2), and mathematics (n=2) respectively. If the grade level variable is considered, it will be noticed that most of the studies were carried out with the students in lower-secondary school (n=14), upper-secondary school (n=5), elementary school (n=4), and then university (n=4). It is recognized that the studies with regard to IBI focus on sciences courses with the students in lower-secondary schools. It can be inferred that students are more likely to inquiry, do research, and explore in science courses.

Table 1: Frequency values of the studies regarding the effect of IBI on learners' academic achievement

Variables	(f)	Variables	(f)
Subject Field		*Grade Level*	
Science/ Chemistry/ Social Sciences	10/2/1	Elementary School	4
Physics/ Biology/ Mathematics	2/1/2	Lower-Secondary School	14
Science and Technology/ Visual Arts	7/1	Upper- Secondary School	5
Language and Arts/	1	University	4

When the studies' effect sizes with regard to academic achievement were figured out, according to FEM in Table 2, it was understood that the distribution of the effect sizes was heterogeneous as Q statistical value in homogenous test (131.02) exceeded the critical value (38.885) in 95% significance level from x^2 table with 26 degree of freedom. So, the academic achievement points of the 27 studies were examined through REM and the effect sizes of the points turned out to be 0.688. This value is at moderate level based on the effect size classification. This result indicates that the process of IBI has a positive effect on academic achievement.

Table 2: *The distribution of homogeneous values, average effect sizes and confidence intervals in the meta-analysis according to the effect modes with regard to the effect of IBI on learners' achievement*

Model Type	N	Z	P	Q	ES	95% Confidence Interval	
						Lower limit	Upper limit
FEM	27	15.989	0.000	131.019	0.729	0.640	0.819
REM	27	6.467	0,000	33.118	0.688	0.479	0.896

df:26

In Table 3, the statistical values of the studies based on IBI considering the grade level were given. With regard to *grade level*, four categories were created; primary (n=3), secondary (n=15), high school (*n*=4) and university (*n*=5). There wasn't a significant difference among these categories (Q_B= 3.87, *df*= 3, *p*>0.05). This means that scores of academic achievement do not show a change according to grade levels based on IBI. If the effect of IBI was examined in accordance with the academic achievement regarding grade level, the greatest effect size was in high school category (*ES*=1.02) and the lowest was in the case of university students on the other hand (*ES*=0.41).

Table 3: The Effect of the Studies on IBI Regarding the Grade Level

Mixed Effects Analysis	n	ES	SE	95% Confidence Interval		Test of Mean		Test of heterogeneity in effect size		
				Lower	Upper	Z-value	p-value	Q-value	df(Q)	p-value
Primary	3	0.82	0.24	0.34	1.30	3.36	0.00			
Secondary	15	0.70	0.14	0.42	0.97	4.88	0.00			
High	4	1.02	0.50	0.03	2.00	2.02	0.04			
University	5	0.41	0.14	0.14	0.69	2.94	0.00			
Tot. Betw								3.87	3	0.27
Overall	27	0.60	0.09	0.42	0.78	6.64	0.00			

Another analysis in the process was the IP of studies. When the analyses were carried out, a categorization was made and IP of the studies were grouped into five as 2-4, 5-6, 7-8, 9-18 weeks and unspecified IP. When the effect sizes of the IP groups of studies based on IBI was regarded, the lowest effect size was seen in the case of 9-18 week (ES=0.61), while the highest one in 7-8 week period (ES=1.47). But, there was not seen a statistical significant difference in terms of the groups effect (QB= 2.00, df= 4, p>0.05). This result indicated that effect sizes of the studies do not change according to IP.

Table 4: The Effect of the Studies on Creative Drama Regarding the IP

Mixed Effects Analysis	n	ES	SE	95 Confidence Interval		Test of Mean		Test of heterogeneity in effect size		
				Lower	Upper	Z-value	p-value	Q-value	df(Q)	p-value
2-4	7	0.76	0.19	0.39	1.12	4.09	0.00			
5-6	3	0.65	0.18	0.29	1.00	3.54	0.00			
7-8	6	1.47	0.60	0.30	2.65	2.46	0.01			
9-18	5	0.61	0.39	-0.15	1.37	1.57	0.12			
Unspecified	6	0.84	0.30	0.24	1.44	2.76	0.01			
Tot. Betw								2.00	4	0.73
Overall	27	0.74	0.11	0.52	0.96	6.58	0.00			

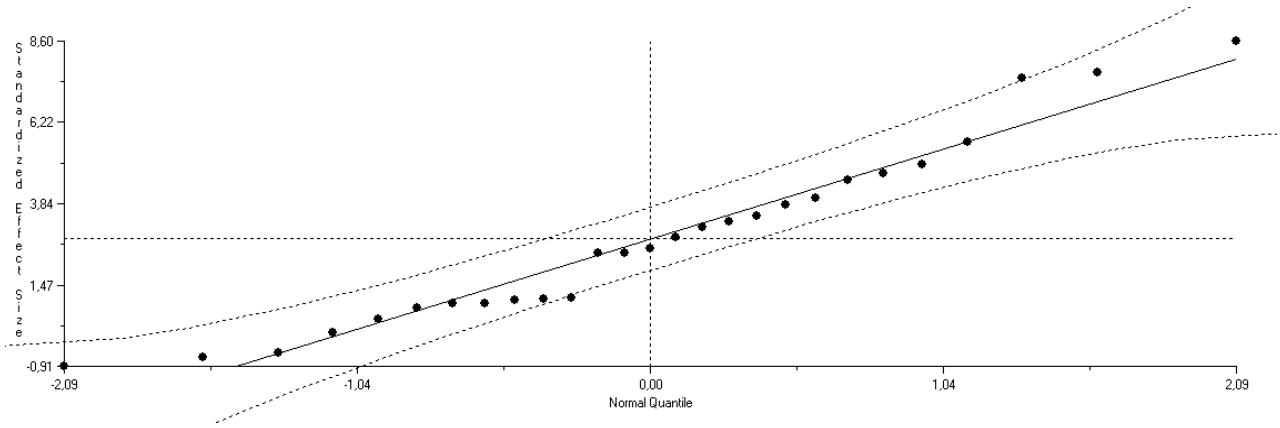

Figure 1: *Normal quantile plot*

The chart of the Normal Quantile Plot was presented in Figure 1 to see if the effect sizes of the studies were suitable for the normal distribution using the MetaWin program. Through the chart control, the reliability of the meta-analysis is tested. In Figure 1, the distribution of effect size indicated a normal process as any large deviations in the effect sizes didn't emerge. Based on the normal distribution of effect sizes, it can be stated that combining the studies in the meta-analytic process is statistically relevant. Moreover, in meta-analysis publication bias can be encountered and Rosenthal (1979) stated herein that if a number of studies which have null effect sizes are added to the analysis, the significant difference of the included studies can be cleared off. This calculated number is called as fail-safe Number (N_{FS}). For this study, the value of N_{FS} test is found as 2109.1. It means that 2109 studies are required to fall the overall effect size down to the level 0.01. Therefore, it can be stated that the related number of studies are highly in excess compared to the studies included and to the studies that can be reached. The results of the analysis are, thus can be expressed to be reliable.

The Qualitative Analysis Results of The Studies With Regard To IBI

In the context with the qualitative research, the participants' perceptions for the use of IBI in learning were studied to reveal what they think about the role of IBI in education. So, their perceptions were examined in different dimensions. As a consequence of the content analysis of the 36 studies in the qualitative research, five themes, namely affective domain, cognitive, social domain, learning environment and negative aspects were obtained. This section dwelled on these five themes and related codes. These codes are based on the participants' self-stated opinions in the studies included in the thematic studies. Furthermore, through the participants' quotations, the themes and codes were supported and enriched.

The participants' perceptions for the affective domain theme on with regard to the use of IBI in the learning process are presented in Figure 2. In terms of this theme, several codes such as different from previous expressions, appealing to a variety of senses, perceiving previous course boring, increasing students' self-confidence and perceiving the method interesting and useful were generated. These codes were formed considering the participants' expressions in the studies. To illustrate, it was quoted from 178571-60 coded study that "*...you can grasp lesson better conducting experiment. You can see subject matter...Instead of hearing, learning by seeing is more effective... learning becomes permanent.*" Another example from 298502-130 coded study is that *"The method is interesting and effective."* From the generated codes, it is understood that the participants' perceptions for the use of IBI method in learning is positive and encouraging.

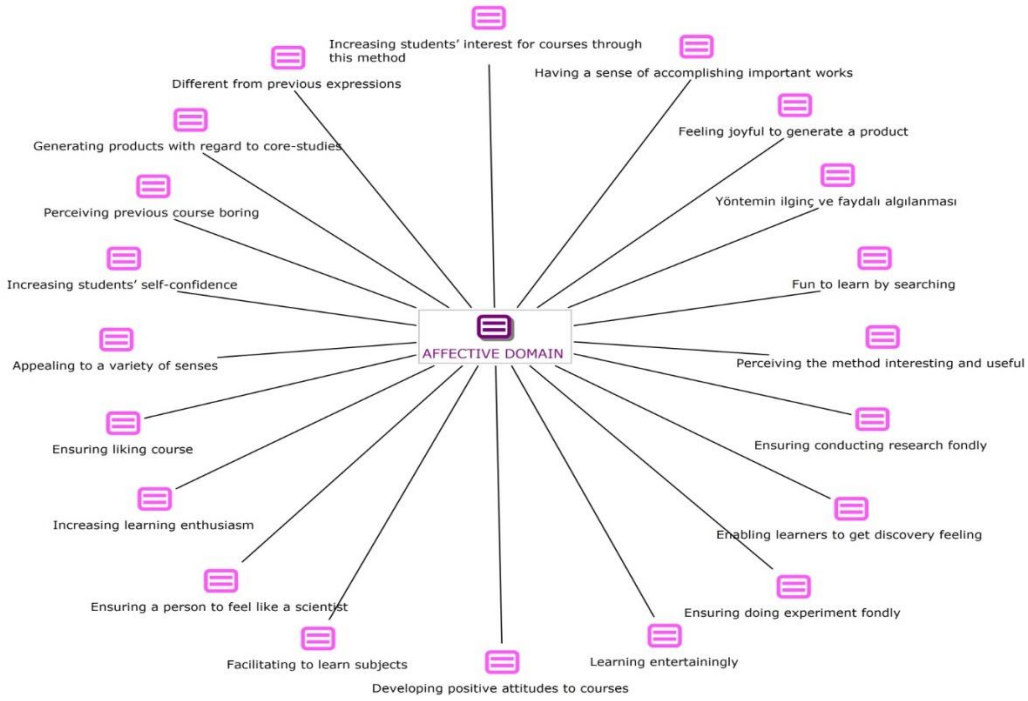

Figure 2: *Participants' perceptions for the affective domain theme with regard to the use of IBI in learning*

In Figure 3, the participants' perceptions for the cognitive domain theme on account of the use of IBI in the process of learning are provided. With regard to this theme, several codes including conducting research individually, exercises, figures and experiences facilitate to understand subjects, learning research methods, increasing comprehension and presenting authentic outputs were formed. For instance, it was cited from 214533-218 coded study that *"First of all, I thought that what a beautiful job we did. I thought how well we learnt. Besides, I have learnt research methods which I will use in future. That is, I thought we, indeed, got valuable acquisitions through the studies we conducted..."* Besides, a male participant stated in Out16-51 coded study that *"...simply attaining knowledge is not an ultimate goal. Rather, scientific way of thinking is more important for them to acquire."* These codes demonstrate that the use of IBI in learning has contributed to developing their cognitive domain when they are involved in learning process.

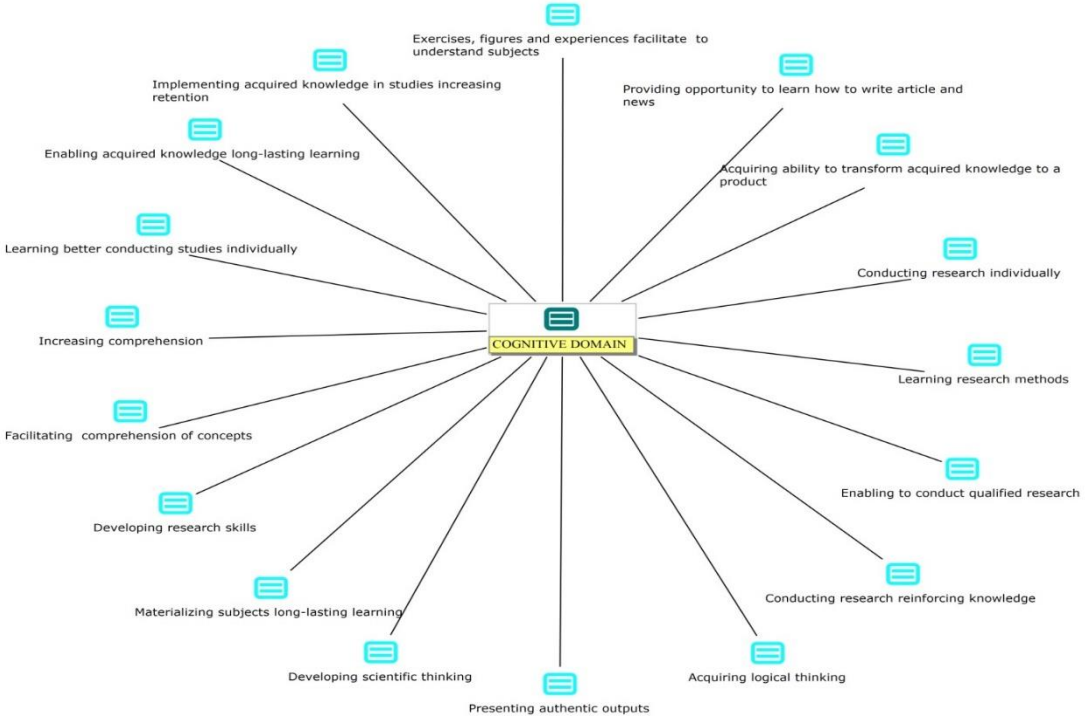

Figure 3: *Participants' perceptions for the cognitive domain theme with regard to the use of IBI in learning*

The participants' perceptions for the social domain theme on account of the use of IBI in the process of learning are displayed in Figure 4. With regard to this theme, several codes such as being happy to share in group works, promoting to acquire the ability to conduct research easily, reinforcing knowledge through activities and encouraging to show respect for others' thoughts were formed. For example, it was quoted from M47-251 coded study that "We are trying to find solutions for the research questions discussing with my friends in group

works." In the light with the generated codes, it can be claimed that the use of IBI is effective to conduct studies in group works, thereby increasing cooperation and collaboration with group members in learning process.

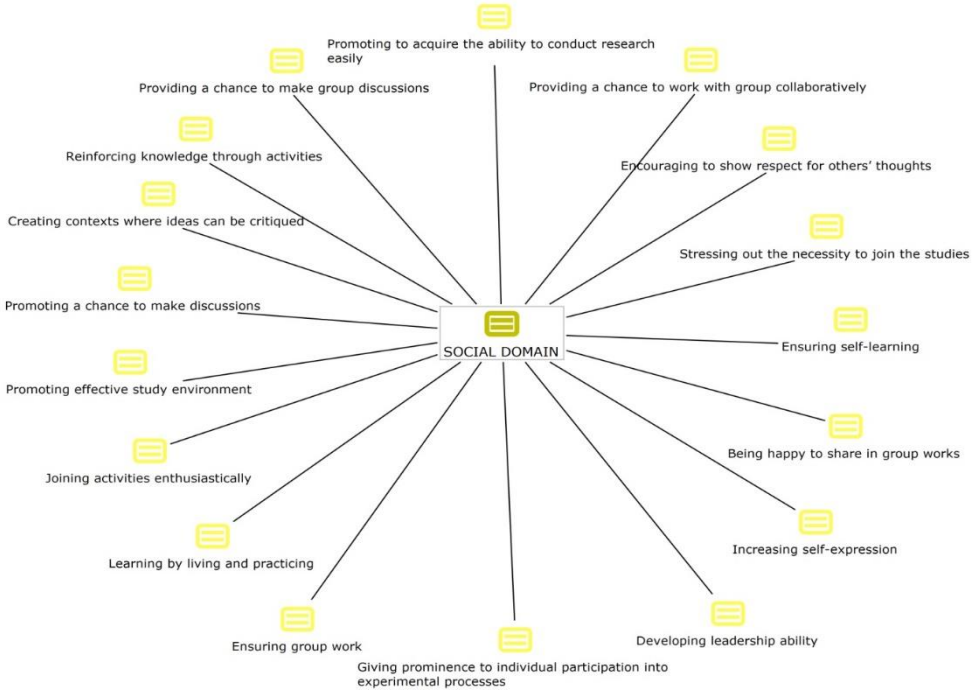

Figure 4: *Participants' perceptions for the social domain theme with regard to the use of IBI in learning*

The participants' perceptions for the learning environment and negative aspects themes and the related codes on account of the use of IBI in the learning process are presented in Figure 5. As for the learning environment theme, a number of codes such as conducting a number of experiments increasing retention, appealing to eyes and ears increasing long-lasting learning, visualization increasing retention and highly qualified experiments increasing learners' participation were formed. A participant from 356691-159 coded study cited that "...*When we peeled an apple, we saw that it got dark five or six minutes later. It was a good experiment."* Another example from 298502-130 coded study that "*It can be grasped easily...".* It can be said that the use of IBI in learning process creates a positive learning environment where learners can reinforce or consolidate what they learn.

Unlike the former themes, the participants point out negative issues in the use of IBI in learning. The formed codes for the negative aspects theme as follows: requiring hard and boring study, inadequate resources at home causing to dislike studying, a number of procedures available, depending on directions and person unavailable to clarify not understood subject matters. To illustrate, it was quoted from 345239-92 coded study that *"I don' like it because there are not enough*

resources at home." Another example from Out15-53 coded study is that "*Doing our own (procedure), we try to make procedures that we already like, have the information on. But, doing your procedures, we might not know...the information on it, so we can actually learn something from doing your procedures instead of making up our own that we already know."* These codes stress out that the effectiveness of IBI depends on how well the IBI activities are planned beforehand. If they are planned in detail, learners can know what to do in the activities.

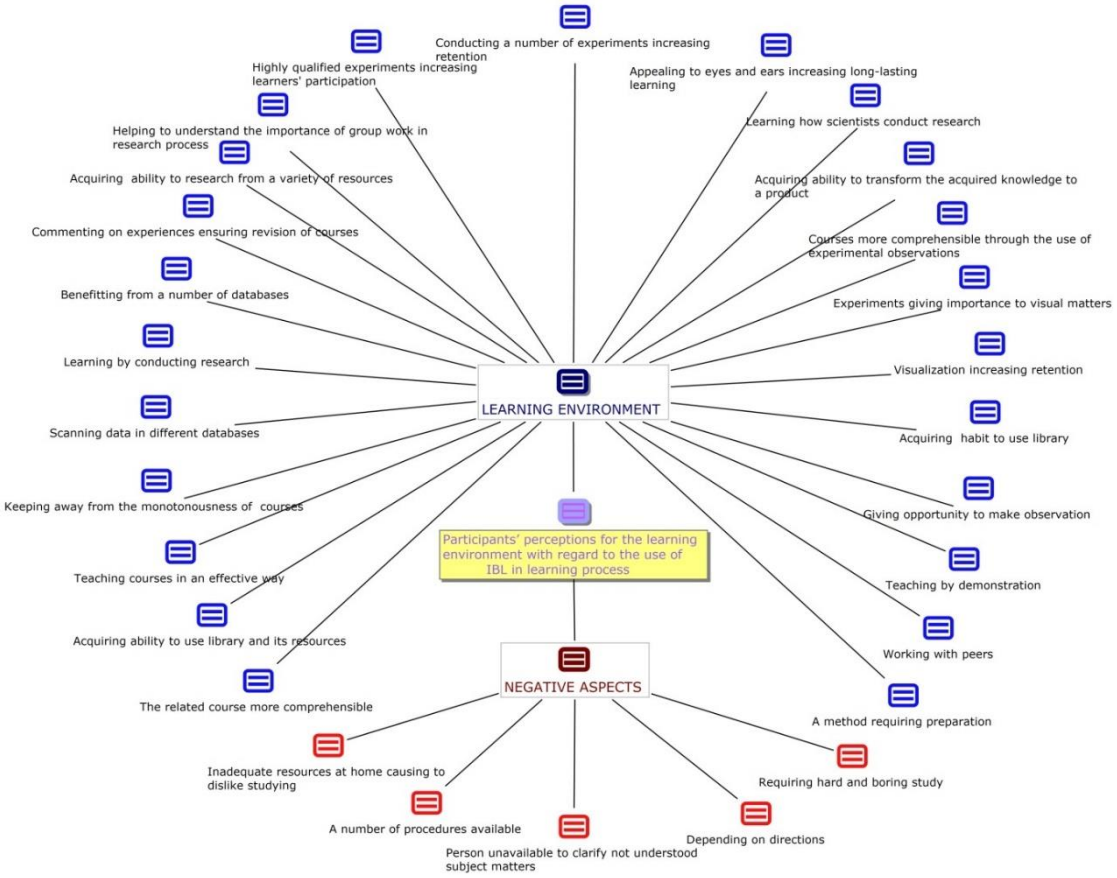

Figure 5: *Participants' perceptions for the learning environment and negative aspects themes with regard to the use of IBI in learning*

Limitations

The related study seemed to have certain limitations. First of all, the sample sizes in the meta-analytic studies are not large enough to generalize the quantitative findings. Second, in some studies the implementation period variable is not specified. More importantly, the contextual information with regard to the selection of experimental and control groups are not dealt in detailed way. To illustrate, where are the studies conducted? In urban or rural part of the country? In this respect, sample sizes of the studies could be increased to generalize the findings, the categorical independent variables such as implementation period could be dealt in detail, the contextual information concerning the selection of

the samples could be provided and more advanced statistical techniques such as multi-level analysis, structural equation modelling could be implemented to ensure more detailed analysis on account of the effect of IBI on learners' achievement in future studies.

Result and Discussion

The purpose of the current study is to understand the effect of IBI in learning process on learners' academic achievement. Meta-analytic and thematic study methods were conducted to evaluate the relationship between the effect of IBI and learners' achievement. As a result of the meta-analytic method, it was revealed that the effect size moderately influences learners' academic achievement. This finding is parallel with the study conducted by Çalışkan (2008) indicating that inquiry-based learning approach in social studies course has a positive impact on students' attitudes towards course, academic achievement and the degree of retention. Likewise, Sever (2012) found out that there is more explicit increase in the mean score of the students' academic achievement where IBI is conducted. So, there is a positive relationship between the use of IBI in learning process and their academic achievement.

As for the qualitative analysis of the thematic study, five themes, namely affective, cognitive and social domain themes, learning environment and negative aspects were formed. In the context with affective domain theme, it was understood that IBI increases learners' eagerness to learn and ensures to display positive attitude by increasing their interests in lesson. So, learners listen to their lessons and participate in their lessons with pleasure thereby increasing their academic achievement. With regard to cognitive domain theme, it can be indicated that IBI develops learners' research skills, increases their perception capacity, enhances their scientific thinking and enables their reasoning styles. At this point, the results of the current research are supported with the ones of the study conducted by Edelson, Gordin and Pea (1999) revealing that IBI makes significant contributions to developing scientific learning skills and combines new knowledge with the current knowledge by keeping motivation at optimum level. In terms of social domain theme, it was revealed that IBI develops learners' ability of expressing, increases their enthusiasm to study in group work, creates discussion and sharing setting and enables them to feel more social and be more active. As far as the learning environment domain theme is concerned, it was stated that the materials appealing to all sense organs, visual items and observation opportunity make leaning more meaningful and enjoyable. Although IBI has a variety of limitations such as requirement of preliminary preparation and involvement of different procedures, it can be suggested that it can be an effective and efficient learning method by overcoming these limitations. Unlike the negative aspects theme, it was revealed that the participants' perceptions for the use of IBI in learning process with regard to the other themes are positive and encouraging. This result is confirmed by Ramnarain (2014) that learners develop experimental skills and find science more enjoyable based on the teachers' perceptions for IBI.

Besides, it was understood in the result of the research conducted by Gormally, Brickman, Hallar and Arnstrong (2009) that students learning their lessons through IBI, have high self-confidence and strive more to participate in their lessons. This result overlaps with the results of the current research in relation to the affective and cognitive domain themes. Duran (2014) revealed in her doctoral dissertation that inquiry-based activities are enjoyable and students are more interested in the lessons involving these activities. Sever also (2012) found out that the students like doing experiments most in the experimental process and suggest that experiments be conducted in Science and Technology course. In the context with the learning environment theme, Poon, Tan and Tan (2009) indicated the impact of IBI on learning environment, which supports the results of the current research. The qualitative findings are seen to support the quantitative ones in the current study. On the other hand, the negative sides on account of the use of IBI in learning process were encountered. The findings show similar points in the study by Dostal (2015) indicating that the tasks concerning inquiry-based approach are frequently time-consuming. Therefore, the guided activities developed based on this approach play a significant effect on the students' academic achievement (Duran, 2014). Guided activities and well planning beforehand are thought to reduce the negative aspects in this approach.

As a result of the analysis of both the quantitative and the qualitative findings, IBI can be used systematically to increase learners' awareness, interests, attitudes and achievements in their courses. Taking into account how well they are competent to use technology, IBI activities supported with technology can be developed to increase their curiosity, thereby enabling them to acquire highly-ordered thinking skills. These activities should be enhanced with guided and well planned directions to decrease the negative sides of IBI in learning process. Academic members, researchers, decision makers, teachers can benefit from the findings of the current study to develop the curriculum for especially digital native learners.

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Appendix 1. Cohen Kappa Values of Themes in the Study

Affective Domain					Cognitive Domain					Social Domain					…IBL in Learning Process				
		K2					K2					K2					K2		
		+	-	Σ			+	-	Σ			+	-	Σ			+	-	Σ
K1	+	20	2	22	K1	+	17	2	19	K1	+	17	1	18	K1	+	28	3	31
	-	3	17	20		-	1	10	11		-	1	8	9		-	2	19	21
	Σ	23	19	42		Σ	18	12	30		Σ	18	9	27		Σ	30	22	52
Kappa: .761			p:.000		Kappa: .789			p:.000		Kappa: .833			p:.000		Kappa:.802			p:.000	