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The Effect of Technology-Aided Project-Based English Learning on Critical Thinking and Problem Solving as Indices of 21st Century Learning

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ABSTRACT

This study sought to explore whether the incorporation of technology and project-based learning into the mainstream English teaching classrooms contributes to the development of critical thinking and problem solving, as two skills essential for 21st century English learning. To accomplish such an objective, 35 Iranian learners of English were assigned to an experimental and a control group in a quasi-experimental study. Along with benefiting from a multi-skill textbook-oriented language instruction, the participants in the experimental group dealt with a variety of short- and large-scale technology-aided projects. The control group's participants, on the other hand, received a multi-skill textbook-oriented language instruction in the absence of any technology-aided projects. The comparative analysis of the control and experimental groups' performance on the critical thinking and problem solving pre- and post-treatment measures revealed a significant impact for the study treatment in improving the participants' critical thinking and problem solving. The findings of the current study may be beneficial to those interested in exploring the contribution of technology to the modern educational system.

Keywords: Critical Thinking, Language Education, Problem Solving, Project-based Learning, Technology-aided

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1. Introduction

Owing to the rapid global swing toward digital literacy in the 21st century, the educational system, and the roles and routines thereof, have undergone a number of drastic changes. To Robinson and Aronica (2015), these changes acquire a special significance given the millennial learners' enthusiasm for taking advantage of today's technological and digital resources to meet the real challenge of learning in the current century. As contended by Dede (2009), the widespread use of computers and technological accessories (i.e., portable digital devices, gaming consoles, smartphones, and so on) has boosted the growing demand for an educational reform so as to prompt educators to adapt their competencies to such innovative and sophisticated system of life.

The educational reform intended to suit the whole range of today's learning needs requires to strike a balance between the ambitions of *digital natives* and the desires of *digital immigrants*. Having used the terms digital natives and digital immigrants to refer to the people born into and grown up in the fast-paced era of technology dominance (at the turn of the 21st century) and those born in the 20th century, respectively, Prensky (2001) contended that digital natives are presumed to be native users of technology language, whereas digital immigrants require to get accustomed to using technology. An instruction conscious of the differing needs of both generations is, therefore, in dire need of paying proper regard for effective techniques of developing world readiness (Takeda, 2016).

World readiness was initially proposed by the American Council on Teaching of Foreign Languages (ACTFL) to refer to a list of standard skills essential for a global language education in the 21st century. Centering around three main concepts called literacy, real world application, and 21st century skills, the world-readiness standards clarify various language learning goals to guide instruction, assessment, and curriculum implementation in the current educational landscape. Accordingly, the educational system intended for 21stcentury learners is supposed to promote a variety of time- and context-relevant competences called 21st century skills. These skills, as enumerated by Fandiño (2013), include creativity, self-direction, collaboration, digital literacy, critical thinking, and problem solving.

Critical thinking and problem solving, both qualified as 21st century skills, are widely accepted as higher-order thinking skills (e.g., Miri et al., 2007; Moseley et al., 2005). To Zhang and Kim (2018), "students must further develop and broaden such higher-order skills as critical thinking together with informed decision making, and real-world problem solving in this digital age" (p. 2). These two skills are proposed to be cultivated going through an independent and self-regulated learning path, entitled project-based learning (PBL), which provides room for social interaction and collaboration (Simpson, 2011). Acting as a means of delivery, accomplishment, and presentation of group-based projects, technology, and its contribution to PBL, are judged to be useful in surmounting the obstacles in the way of PBL such as tight schedules and crowded classrooms. The present research study, therefore, aimed at exploring the impact of applying technology-aided PBL practices on the development of critical thinking and problem solving, as two instances of 21st century skills. To this end, the following questions were addressed:

1. Does the incorporation of technology-aided project-based learning into EFL classrooms influence Iranian EFL learners' critical thinking ability?
2. Does the incorporation of technology-aided project-based learning into EFL classrooms influence Iranian EFL learners' problem solving ability?

2. Literature Review

2.1. Critical Thinking and Problem Solving, as Two Indices of 21st Century Skills

As argued in *Glossary of Education Reform* (2016), the majority of contemporary students and workforce put their academic and occupational success down to the mastery of 21st century skills. 21st century skills encompass the skills, abilities, and competences required to meet the challenges of the contemporary world (Ercikan & Oliveri, 2016). These skills, as elucidated by Sawchuk (2009), are concerned with learners' ability to work collaboratively, use technology, and apply a specific content knowledge. A comprehensive list of these skills, as proposed by Binkley et al. (2012), includes creativity, innovation, social skills, communication, media literacy, collaboration, decision making, cross-cultural skills, civic literacy, ICT literacy, critical thinking, and problem solving.

Serving as an essential means of decision making and problem solving, critical thinking ability plays a central role in tackling real-life problems (Halpern, 2003). The literature that resonates with critical thinking traces its origin back to the early 20thcentury when a special emphasis was placed on reflective learning (Brookhart, 2010). Nonetheless, the use of the term critical thinking in the literature goes back to the mid-twentieth century when it was used to refer to the act of searching for evidence so as to support ideas and assertions (Hughes, 2014). Rainbolt and Dwyer (2012) defined critical thinking as the ability to make sensible decisions based on a sound judgment. A more detailed definition of critical thinking is proposed by

Brown and Keeley (2007) who characterized it as a combination of qualities and abilities including a) critical awareness of various critical questions, b) ability to ask and answer these questions at proper times, and c) enthusiasm for asking these questions.

Problem-solving, on the other hand, owes its origin to the Socratic Method whereby the truth of ideas was examined according to a question/answer system (Doghonadze & Gorgiladze, 2008). The initial endeavor to incorporate problem solving into education goes back to the late 20th century when it was utilized by a number of scientists (e.g., Martinez, 1998; Botti & Myers, 1995) for teaching mathematics and science at schools and universities. Given the conceptual broadness of a problem, problem solving has been classified differently, distinguishing between domain-specific or domain-general problem solving and complex or analytical problem solving (Fischer et al., 2012). Focusing on a general domain, Csapó and Funke (2017) defined problem solving as an ability to logically process relevant information to come up with a solution ideally suited to the goal of a particular problem.

2.2. PBL and its Contribution to 21st Century Skills Cultivation

PBL, generally defined by Thomas (2000) as "a model that organizes learning around projects" (p.1), is viewed by Bell (2010) as a "student-driven, teacher-facilitated approach to learning". Projects, known in Beckett's (2002) words as "long-term activities", are thought by Thomas (2000) as "complex tasks, based on challenging questions or problems, involving students in design, problem-solving, decision making, or investigative activities; giving students the opportunity to work relatively autonomously over extended periods of time; and culminating in realistic products or presentations" (p. 1). As asserted by Debski (2006), PBL is chiefly based on Vygotsky's (1978) sociocultural theory. The theory, as asserted by Jaramillo (1996), assumes that a learner "develops his own interpretative meaning of act while communicating with others" (p. 136).

To Bell (2010), PBL is a multi-phase process; the completion of each phase is in need of a timely manner and a detailed planning. The phases of a PBL process include a) launching a project based on an inquiry question, b) brainstorming the potential procedures for research, c) deciding on a procedure ideally suited to the project's goals, d) going through the selected procedure, e) coming up with an effective solution to the inquiry, and f) presenting the results to the target audience (Bell, 2010). In an earlier attempt, however, Hedge (1993) enumerated the activities (phases) included in PBL as planning, information gathering, discussing information in groups, problem solving, reporting results, and displaying.

The incorporation of PBL in EFL classrooms has been presumed to profit students in varying aspects varying from developing language learning skills and sub-skills (i.e., reading, writing, grammar, vocabulary, etc.) to accelerating personal growth (Thuan, 2018). To Bell (2010), the merits of applying a PBL model are twofold: first, gaining an in-depth discipline-specific knowledge, b) improving in terms of learning motivation, responsibility, independence, and discipline. The other virtue of PBL is regarded by Gültekin (2005) as creating students who are better researchers, problem solvers, and thinkers. Offering a comprehensive list of benefits, Simpson (2011) claimed that the adoption of a PBL approach opens up an ideal opportunity to improve learning motivation, language proficiency, academic achievements, authentic learning, autonomous learning, collaborative learning, and higher-order reasoning skills.

2.3. Technology and its Facilitating Role in PBL

Given the merits enumerated above, PBL is theoretically viewed as a vital alternative or add-on to the conventional teaching/learning methods, albeit with the caveat that there is a need to surmount a number of obstacles such as tight schedules and crowded classrooms. Additionally, as proposed by Black (2009), to foster 21st century skills cultivation along with developing linguistic competence, the current time-limited language learning programs should involve learners in multimodal ICT-assisted activities including digital storytelling, instant messaging, media redesigning, and social networking. By inference, a synthesis of PBL and technology seems very likely to have the potential for simultaneous cultivation of digital literacy, 21st century skills, and language proficiency.

According to Taylor (2017), Technology is a major component which support PBL, profiting students to explore project topics and proceed into creation of website, podcasts, and blogs. Taylor (2017) also added that the use technology allows students to work collaboratively (with teammates and teacher) beyond the classroom. As believed by Darling-Hammond et al. (2017), benefiting from technology, teachers can evaluate students' progress more readily and provide corrective feedback exclusive to every individual student.

The valuable contribution of technology to an effective implementation of PBL is also reflected in Bell's (2010) words that "Technology as a means, not an end, enables students to experiment with different technologies for all aspects of PBL" (p. 42). According to Bell (2010), to effectively assist PBL through technology, a multitude of applications (e.g., web 2.0 tools) can be employed to facilitate the whole process of projects, from research to presentation. Acknowledging that PBL involves learners in a variety of distinctive stages, Pilten et al. (2017) contended that "ICT is especially effective in the steps of communication, accessing, organizing and presenting information" (p. 136).

To conceptualize the ICT tools applicable to language teaching/learning in general and PBL in particular, different frameworks have been proposed to date. Gill (2006), for instance, refers to "Power Point, email exchanges, web based activities, and synchronous and asynchronous communication (through the use of threaded discussion boards, live chat, and virtual communities)" (p. 19) as the technologies essential for language teaching. A more comprehensive list of ICT tools applicable to PBL, as proposed by Sharma and Barrett (2007), includes electronic dictionaries, word and graphic processing tools, interactive whiteboards, instant messaging applications, web browsers, search engines, web quests, blogs, wikis, podcasts, digital portfolios, and social networking applications.

2.4. Empirical Background to the Study

The significance of technology as a supportive means of cultivating 21st century skills such as critical thinking and problem solving has been validated empirically (e.g., Angeli, 2013; Ashraf et al., 2012; Kim & Hannafin, 2011; Kong, 2015; Lee, 2015; Lee et al., 2016; Tewelde & Ghosh, 2018). In addition, there is adequate empirical evidence for the contributory role of PBL in developing higher-order thinking skills (e.g., Lukitasari et al., 2018; Pan & Allison, 2010; Rochmahwati, 2015). Furthermore, there is a plethora of investigations showing the facilitating role of technology in PBL (e.g., Chu et al., 2017; Donnelly, 2003; Marwan, 2015; Taylor, 2017; Zamorshchikova et al., 2011). The contributory role of ICT-aided project-based instruction in the development of 21st century skills essential for language education, however, remains to be uninvestigated.

3. Methods

3.1. Design of the Study

To address the research questions, a quasi-experimental pretest-posttest control group design based on a quantitative analytical approach to data analysis was employed. following such a design, the study sought to explore whether or not adopting a technology-aided PBL approach to language teaching (the independent variable) affects the development of critical thinking and problem solving skills (the dependent variables) among Iranian intermediate EFL learners.

3.2. Participants

Employing convenience sampling method, two intact classes, including 35Iranian learners of English from an accredited language school in Tehran, Iran, were recruited to take part in the study. The homogeneity of the participating individuals was guaranteed choosing intact classes of the same proficiency level and administering the Preliminary English Test (PET). Based on the PET results, all the participants enjoyed an intermediate proficiency level. The study chose to be focused on female learners owing to some practicality concerns.

3.3. Instructional Materials

In accordance with the participants' level of English proficiency (i.e., intermediate), the instructional content of the first four units of the book *Touchstone (*Level 4, second edition) constituted the core content of the study course. In addition to the instructional content of the textbook, the participants in the experimental group worked on a total of 24 short-scale and seven large-scale projects. The projects were designed based on the topics covered by the textbooks (see Appendix A). Since technology was regarded as the means of project implementation, a number of audio/video tutorials, containing comprehensible instructions on the use of the target ICT tools were developed in consultation with an expert in IT. The tutorials' length varied between 10 and 20 min. Furthermore, a 20-minvideo lecture was provided to raise the participants' awareness of the characteristics, principles, and methods of PBL.

3.4. ICT Tools

WhatsApp, a popular and user-friendly instant messaging application, was utilized as the central ICT tool of the study. WhatsApp was preferred to the other mobile social applications because of its accessibility in the local context of the study. The other online tools the participants benefitted from included wikis and blogs, as two instances of Web 2.0 technologies applicable to language teaching/learning. Furthermore, the large-scale projects of the study necessitated utilizing offline word/graphic processors and dictionary applications.

3.5. Instruments

3.5.1. PET

To make sure of the homogeneity of the participants in terms of English proficiency, The PET (Cambridge ESOL examination, 2004), was administered at the outset of the study. The scale evaluated the participants' initial knowledge of English focusing on their proficiency in listening, speaking, reading, and writing. As reported by Cambridge English Quality and Accountability (2016), PET is a reliable (α = .92) measure of overall proficiency in English.

3.5.2. Critical Thinking Questionnaire

The potential impact of the study treatment on the participants' level of critical thinking was gauged through the critical thinking questionnaire developed by Honey (2004). The questionnaire contained 30 questions probing into the participants' ability to analyze, infer, evaluate, and reason. Each of the questions was followed by a five-point Likert scale including Never (1), Rarely (2), Sometimes (3), Often (4), and Always (5). The questionnaire originally developed in English was translated into Persian so as to avoid any ambiguity. To make sure of the translation authenticity, one university professor in the field of translation was consulted while rendering the instrument into Persian. The accuracy of the translation and the validity of the instrument was ensured through expert appraisal; however, the reliability was ensured through pilot testing on 15 EFL learners. The Cronbach's Alpha level estimated based on the pilot data (α = .78) testified to the internal consistency of the instrument.

3.5.3. Problem Solving Inventory (PSI)

The PSI, a widely accepted measure of global problem-solving appraisal, developed by Heppner (1988), was used to evaluate the changes in the participants' problem solving ability as a result of the study treatment. The instrument is a self-report inventory comprised of 35 Likert-type items which measures a three-factor structure including approach-avoidance style (16 items), problem-solving confidence (11 items), and personal control (five items). The Likert scales used in the PSI included strongly agree (1), moderately agree (2), slightly agree (3), slightly disagree (4), moderately disagree (5), and strongly disagree (6). To maximize the authenticity of the responses, the inventory was translated into Persian prior to its administration. The original scale is validated empirically (e.g., Heppner, 1988; Heppner et al., 2004) and, at the same time, is presumed to enjoy a good degree of internal consistency (Heppner & Petersen, 1982; Heppner, 1988). Nonetheless, the Persian version was pilot tested in terms of reliability before the main administration and the estimated reliability coefficient (α = .80) showed an acceptable degree of internal consistency.

3.6. Data Collection Procedure

As the preliminary stage of the data collection process, the participants were asked to complete the two survey instruments of the study so as to be gauged in terms of their initial critical thinking and problem solving abilities. They, subsequently, took part in a semester-long multi-skill English course. The course was held twice a week throughout a full instructional semester (i.e., three months). To maximize the internal validity of the study, the same instructor and instructional content (textbook) were used and the class time in both groups of the study was mainly devoted to teaching the instructional content of the textbook. As the only distinction, the learners in the experimental group were asked to work on a variety of ICT-aided projects, in parallel with receiving the text book-oriented language instruction.

Before implementing the study treatment, the experimental group was virtually split into small groups of three or four learners. The rationale for virtual grouping of the learners, as done through WhatsApp, was to facilitate interactive working on the target projects both inside and beyond the actual setting of the classroom. The experimental group's participants then received an extra technology-assisted instruction on the use of a number of ICT tools as well as the principal features of PBL through the pre-planned video tutorials. Subsequently, the predetermined course-driven (both short- and long-scale) projects were assigned to every virtual group via WhatsApp. Each large-scale project (i.e., developing a local biography of a local celebrity) was scheduled for completion during a period of two weeks, whereas every short-scale project (i.e., framing three interview questions to probe into an interesting life experience) was planned to be accomplished within the span between every two training sessions of the course (see all the projects in Appendix A). While the whole process of working on every short-scale project was handled through WhatsApp, the large-scale projects demanded the use of more instances of ICT tools (i.e., wikis, blogs, etc.).

According to the PBL video tutorial, the members of the experimental group went through a number of successive project-completion processes including a) thinking on the procedure required to tackle the problem, b) making use of their instructor's guidance on the procedure, c) recognizing and brainstorming the task's objectives, d) consulting with their teammates about possible ways to collect relevant materials and information, e) sharing the responsibilities among the group's members, and f) making use of the predetermined ICT tools. Throughout the course, the instructor and the IT expert maintained contact with the learners in order to facilitate their use of various offline and online tools. The instructor was also responsible for facilitating cooperation between the groups' members, providing them with adequate guidance on self-assessment, peer-assessment, and social skills valued for making success in group working. The learners were required to virtually submit a detailed report of their progress to the instructor. Once the learners' cooperation resulted in the completion of the assigned task/tasks, the groups' representatives sent the results via WhatsApp. At the conclusion of the study course, the critical thinking questionnaire and the PSI were administered for a second time to the whole participating sample.

3.7. Data Analysis Procedure

Statistical package for social sciences (SPSS, version 22) was utilized to estimate the descriptive and inferential statistics required to address each of the research questions. In order to compare the experimental and control groups' performance while controlling the impact of any initial between-group differences in terms of their critical thinking and problem solving abilities (covariate variables), analysis of covariance (ANCOVA) was run.

4. Results and Discussion

4.1. Results

Table 1 below depicts the descriptive statistics of the participants' performance on the critical thinking and problem solving measures before and after receiving the treatment.

Table 1

Descriptive Statistics of the Critical Thinking and Problem Solving Levels

Skill	Group	Variable	*N*	Min.	Max.	Mean	*SD*	Skewness	Kurtosis
Critical Thinking	Experimental	Pretest Level	18	68	96	84.00	8.10	-.61	-.34
		Posttest Level	18	70	99	87.56	7.97	-.59	-.24
	Control	Pretest Level	17	71	103	87.53	10.33	-.20	-1.28
		Posttest Level	17	70	102	88.24	10.48	-.37	-1.25
Problem Solving	Experimental	Pretest Level	18	112	138	125.94	7.76	-.42	-.71
		Posttest Level	18	117	140	130.11	6.65	-.18	-.92
	Control	Pretest Level	17	114	140	125.71	7.53	.17	-.91
		Posttest Level	17	116	141	126.76	7.36	.24	-.85

As shown in Table 1, at the commencement of the training, the control group' learners showed higher levels of critical thinking (M = 87.53, SD = 10.33) in comparison with their counterparts in the experimental group (M = 84.00, SD = 8.10). Such initial between-group heterogeneity accentuated the necessity of taking account of the pre-existing differences (as the covariate variable) while analyzing the data inferentially. A pair-wise comparison of the pretest and posttest critical thinking levels in each of the study groups indicated that the experimental group's initial critical thinking levels rose after receiving the treatment (M = 87.56, SD = 7.97), whereas the control group's critical thinking performance on the post-treatment measure (M = 88.24, SD = 10.48) was found quite similar to their pre-treatment performance.

Regarding the problem solving levels, as displayed in Table 1, the two groups' initial performances (Experimental: M = 125.94, SD = 7.76; Control: M = 125.71, SD = 7.53) were found to be rather identical. Additionally, the pair-wise comparison of the pre- and post-treatment problem solving levels testified to an improvement in the final achievements of the experimental group's learners (*M* = 130.11, *SD* = 6.65). On the contrary, the control group's performance on the post-treatment measure (*M* = 126.76, *SD* = 7.36) did not improve remarkably in comparison with their initial problem solving levels.

To address the first question of the study, the significance of the between-group differences in terms of critical thinking was explored running a one-way ANCOVA on the critical thinking levels after conducting the preliminary checks (see Appendix B). Table 2 details the ANCOVA results.

Table 2

Details of the ANCOVA Results in Terms of the Critical Thinking Levels

Source	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.	Partial Eta Squared
Corrected Model	2584.794	2	1292.397	161.079	.000	.910
Intercept	12.854	1	12.854	1.602	.215	.048
Pre-treatment Levels	2580.755	1	2580.755	321.654	.000	.910
Group	61.259	1	61.259	7.635	.009	.193
Error	256.748	32	8.023			
Total	273178.000	35				
Corrected Total	2841.543	34				

As demonstrated in Table 2, a statistically significant difference was observed between the experimental and control groups in terms of critical thinking posttest levels, $F(1, 32) = 7.635$, $p < .01$, $\eta^2 = .193$. The effect size value, shown as partial eta squared(η^2), was found to be small based on Cohen's (1988) interpretation of effect size. The means estimated based on the critical thinking post-treatment levels after detaching the covariate effect (i.e., marginal means), as demonstrated in Table 2, corroborate the significant between-group difference in terms of critical thinking.

To inferentially examine the significance of the between-group differences in terms of problem solving, an analytical procedure similar to that of the critical thinking was followed and the results are summarized in Tables 3 and 4, respectively.

As depicted in Table 3, the differential methods employed to teach the control and experimental groups of the study resulted in a significant between-group difference in terms of the post-treatment problem solving levels after controlling for the initial between-group differences, $F(1, 32) = 4.410$, $p < .05$. Nonetheless, the effect size value ($\eta^2 = .121$) was found to be small. Taking the problem solving marginal means (as demonstrated in

Table 4) into account, those participants who were exposed to the study treatment outperformed their counterparts who received no technology-aided project-based instruction.

Table 3

Details of the ANCOVA Results in Terms of the Problem Solving Levels

Source	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.	Partial Eta Squared
Corrected Model	1064.393	2	532.197	26.595	.000	.624
Intercept	188.711	1	188.711	9.430	.004	.228
Pre-treatment Levels	966.487	1	966.487	48.298	.000	.601
Group	88.256	1	88.256	4.410	.044	.121
Error	640.350	32	20.011			
Total	579505.000	35				
Corrected Total	1704.743	34				

Table 4

Marginal Means of the Post-Treatment Critical Thinking and Problem Solving Levels

Variable	Instruction	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Critical Thinking	ICT-aided PBL	89.196	0.674	87.823	90.569
	Conventional	86.498	0.694	85.085	87.912
Problem Solving	ICT-aided PBL	130.029	1.054	127.881	132.177
	Conventional	126.852	1.085	124.641	129.062

4.2 Discussion

The first question of the study asked whether the incorporation of technology-aided project-based learning into EFL classrooms influences Iranian EFL learners' critical thinking ability to some significant extent. As presented in the preceding section, the inferential statistics estimated based on the post-treatment critical thinking levels indicated that after removing the impact of the initial between-group differences, those learners who were exposed to the technology-aided project-based instruction significantly outperformed their counterparts in the control groups. Such a statistically significant difference lent support to the contributory role of PBL in improving critical thinking skills as reflected in the findings of some previous research (e.g., Lukitasari et al., 2018; Pan & Allison, 2010; Rochmahwati, 2015).

The contributory role of the study treatment in enhancing critical thinking may be attributed to the cumulative effect of both PBL and ICT. The significance of such cumulative effect has been validated previously by Sidman-Taveau's (2005) study whereby a synthesis of technology and PBL was found to be influential in developing higher order thinking abilities. Given the merits of each single component of such combined approach (as argued earlier in this section), it can be easily inferred that an effective integration of these components has the potential to yield even more promising results, inasmuch as one (ICT) facilitates the full administration of the other (PBL), creating an interactive, pleasurable, and readily accessible learning environment. To thoroughly elucidate the cumulative impact of technology and PBL, the subsequent paragraphs elaborate on the potential impacts of each of the two components and the interplay between them.

As far as the specific treatment of the study is concerned, in addition to the tasks and activities assigned to all the participants, the experimental group's participants were engaged in a variety of short- and large-scale course-based projects in a guided and collaborative setting. Since none of the projects entailed a unique predetermined path, the learners were provided with an ideal room to fulfill a variety of functions including discussing the initially-provided materials and personal responsibilities, brainstorming the likely project-completion ideas and scenarios, deciding on the scenarios ideally suited to the needs of every distinctive project, self- and peer-monitoring of the in-process and ultimate products, and synthesizing the individually-provided fragments to form an integrated product. Dealing with such multi-function projects enjoys the potentiality to set the ground for deploying higher-order thinking skills such as reflective and critical thinking. The improvement observed in terms of critical thinking in the present study can be partially explained by brainstorming, self-monitoring, and learner engagement integral to project-based instruction. Empirical data have already demonstrated the impact of brainstorming (e.g., Rezaei et al., 2011), self-monitoring (e.g., Ghandizadeh, 2017), and learner engagement (e.g., Cox, 2014; Gokhale, 2005) on the development of critical thinking abilities.

The assumption that the significant improvement in the critical thinking levels of the experimental group's participants is rooted in the systematic use of ICT tools, is supported by a plethora of studies (e.g., Ashraf et al., 2012; Kong, 2015; Lee, 2015; Lee et al., 2016; Tewelde & Ghosh, 2018). To explain the contributory role of technology in enhancing critical thinking ability, most of the previous studies have made a reference to the merits of the constructive learning environment created by technology which is likely to give rise to collaborative and active learning. Learning in such a stimulating and interactive environment is found to facilitate content mastery along with the cultivation of 21st century skills such as critical thinking, communication, technology literacy, and collaboration (Tewelde & Ghosh, 2018).The significant contribution of technology in critical thinking development is also in accord with Huang, Liang, Su, and Chen's (2012) assertion that the incorporation of ICT tools into classrooms facilitates learners' access to evidential information as well as learner-learner interaction. Benefiting from technological facilities, learners could be collaboratively involved in evidence-based arguments, challenging a multiplicity of ideas proposed by individual team members. This way, the use of technology could yield an eventual enhancement in critical thinking ability.

Collaboration, as a widely-accepted virtue of technology-aided PBL, can admittedly serve as an alternative explanation for improvements in critical thinking (e.g., Boud & Felleti, 1997; Duch et al., 2001). In spite of the fact that learner collaboration, and the changes thereof, were not measured systematically in the current study, based on the instructor's personal observation, higher degrees of peer collaboration was witnessed among the experimental group's learners compared to those in the control group. Acknowledging the positive correlation between peer collaboration and the ability to think critically, as validated by Gokhale (2005), there exists a possibility that the active involvement of the learners in the content-based projects of the study may have helped them take advantage of peer scaffolding to think more critically while going through the distinctive steps involved in the projects.

The second research question was concerned with the impact of technology-aided project-based instruction on Iranian EFL learners' problem solving skill. The quantitative results gained from the comparison of the adjusted means revealed a significant between-group difference in the problem solving levels measured at the conclusion of the study course. This finding makes sense given the fact that PBL entails tackling a number of open-ended problems with no straightforward solutions. Accordingly, integral to any PBL approach to language teaching is the opportunity which fosters training problem-solvers. This claim has already been established by Yadav et al. (2011) who found that PBL does lead to higher levels of problem-solving. The presupposition that learner involvement in projects may lead to problem solving improvement has been made clear by Motallebzade and Kafi (2014) who found that project-based instruction exercised a significant effect on the improvement of Iranian intermediate EFL learners' real world problem solving.

The incorporation of technology into project-based instruction has been reported to function as a shortcut to problem solving (e.g., Angeli, 2013; Kim & Hannafin, 2011; Shield, 1996). Consequently, one reasonable explanation for the effectiveness of the study treatment may lie in the implementation of PBL with the assistance of technology. Phrased differently, the technology-assisted projects of the study have arguably provided the learners with ample opportunity to embark on authentic problem solving. Being required to systematically analyze and tackle these problems, learners in the experimental group were privileged enough to use technology to access the pieces of information required to solve the problems. Additionally, leaving within-group interaction and final-product presentation by virtue of technology with the learners led to their deep engagement in authentic problem-solving situations.

The efficacy of the study treatment in enhancing the participants' problem solving skill could also be attributed to the significant gain in their critical thinking ability, as unveiled in the current study. The literature on higher-order reasoning skills reinforces the notion that critical thinking serves as a prerequisite for problem solving (e.g., Snyder & Snyder, 2008; Thompson, 2011). That is, to develop problem-solving skill, learners are supposed to initially foster some degrees of critical thinking skills. There are some others (e.g., Tan, 2004), however, who portray a reverse direction, referring to the contributory role of problem solving activities in driving critical thinking ability of learners. Irrespective of either this or that of these two 21stcentury skills initiates the functioning of the other one, the majority of the previous studies conducted on PBL in different disciplines (e.g., Chapman, 2002; Weissinger, 2004) revealed that PBL helps learners improve in terms of both skills, involving them in a continuous process of decision-making.

5. Conclusion and Implications

Based on the findings, the incorporation of a technology-aided project-based instruction into a conventional multi-skill EFL program yielded greater levels of critical thinking and problem solving. As determined by Partnership for 21st Century Skills (P21), critical thinking and problem solving together denote the ability to exploit different forms of reasoning, analysis, evaluation, and decision making while encountering learning and real-life problems specific to the 21st century. The findings of the current study, therefore, offered the view that students' engagement in technology-assisted projects would act as a trigger point for the enrichment of their 21st century literacy.

The findings also suggested that by virtue of a variety of ICT tools, there is a real possibility for a departure from teacher-centered EFL teaching methods. Compensating for the lack of time, as the salient excuse for balking at learner-centered approaches, the use of various user-friendly technological tools not only facilitates working on a variety of content-relevant projects, but also lays the foundations for an effective learner-learner/teacher-learner interaction. The probable outcomes of such technology-aided interaction (i.e., learner engagement, collaboration, etc.,) seemed to have the potential for fostering higher-order reasoning skills essential for language learning in contemporary educational systems. Armed with these skills, EFL learners are more likely to autonomously progress toward a full mastery of the target content. Consequently, an effective implementation of a technology-aided project-based instruction may give millennial EFL learners a chance to achieve higher levels of critical thinking and problem solving along with language learning.

Notwithstanding its merits, a technology-aided PBL could place a great burden on teachers unless they enlist IT experts' and syllabus designers' support. By a careful planning of content-relevant projects to incrementally be incorporated into a textbook-oriented instruction, material developers and syllabus designers could honor their full commitment to materials provision. Consulting IT experts and specialists about the ICT tools well suited to the projects' demands, textbook designers could design and develop relevant audio/video tutorials so as to augment their instructional package for technology-assisted PBL.

The findings of the current study are likely to have been affected by several limitations including the limited size of the participant sample, the short period of the instruction, and the impracticality of random selection of the participants. Replication of the study on a large randomly-chosen sample of EFL learners may cast more light on what has been found in the current study. Researchers motivated to expand upon the findings are recommended to take account of teacher and learner attitudes while exploring the efficacy of a technology-aided project-based method of language learning.

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Appendix A: Content-Relevant Projects of the Study

Unit 1

General Title	Function	Small-scale Project	Large-scale Project (LSP)	Presentation Format for LSP
Interesting Lives	**1.** Asking questions to find out about someone's interest and background **2.** Telling interesting stories about your/someone's life	**1.** Free discussion (in groups) to decide on three main areas (e.g., occupation, travels, hobbies or interests, life experiences, etc.) which lead to an interesting life. **2.** Framing three interview questions to probe into an interesting experience of an imaginary interviewee. **3.** Conducting interview in groups using the questions framed in the previous sessions. **4.** Writing a short anecdote using six randomly-assigned verbs chosen from Dan's story. **5.** Developing a conversation similar to Juan and Bryan's about a scary experience. **6.** Discussing in groups about success and the ways people can make success through which.	**1.** Developing a biography of a local celebrity **2.** Conducting a structured interview with a person from your relative or friends accepted by the group to have an interesting life.	**1.** A wiki **2.** A short video created by Windows Movie Maker

Unit 2

General Title	Function	Small-scale Project	Large-scale Project (LSP)	Presentation Format for LSP
Personal Tastes	**1.** Talking about makeovers, style, and fashion **2.** Talking about your tastes in clothes and music	**1.** Giving characters of the lesson a makeover according to the pictures and content. **2.** Practicing *just as ….as* or *not as …. as* structure in groups based on randomly selected nouns related to appearance. **3.** Writing a conversation in which a pair of persons (mother/daughter, wife/husband, etc.) with different tastes are shopping for clothes. **4.** Free discussion in groups about the members' favorite clothes for special occasions using guesswork. **5.** writing a conversation similar to Tracy and Omar's through brainstorming different interests (e.g., sports, clothes, books) for which each group member might buy people gifts. **6.** Conducting a structured interview in groups discussing these questions: Do you think everyone has a personal style? Do you wear clothes similar to those worn by everyone else, or do you try to be different? How would you describe your personal style?	**1.** Conducting a comparative research on the favorable outfits of two celebrated politicians. **2.** Making a visual report of the group's preferred outfits for different occasions	1. A narration-assisted Power Point file 2. A blog

Unit 3

General Title	Function	Small-scale Project	Large-scale Project (LSP)	Presentation Format for LSP
World Culture	**1.** Talking about aspects of someone's culture **2.** Talking about manners, customs, and culturally appropriate behavior.	**1.** Preparing a short talk on a traditional food that a visitor to Iran should not miss. **2.** Free discussion on the places the group members have visited describing the events, monuments, food, and etc. **3.** Writing an argumentative essay about the lists of Dos and Don'ts according to an Iranian culture. **4.** Preparing a list of social behavior have changed today compared to the past. **5.** Writing and presenting a conversation similar to Hilda and David's, beginning with *If I lived abroad ….* **6.** Brainstorming in groups to make a list of reasons for living away from home.	**1.** Making a travel brochure to introduce your city (or any other city) to visitors from other countries. **2.** Making a detailed picture-based report of Iranian costumes throughout recent 100 years	**1.** Electronic brochure (e-brochure in Microsoft Word). **2.** A narration-assisted Power-point file

Unit 4

General Title	Function	Small-scale Project	Large-scale Project (LSP)	Presentation Format for LSP
Socializing	**1.** Talking about things you are supposed to do, things you were supposed to do, and things that are supposed to happen **2.** Talking about going out and socializing	**1.** Telling anecdotes about activities or events that each of the group members were supposed to take part in at some time in the past (e.g., childhood, high school, more recent past) and then did not. **2.** Searching for extra vocabulary for inseparable phrasal verbs with *get* (i.e., get along with someone, get back from a place), using Longman dictionaries (either print or online version). **3.** Writing a short conversation similar to that of the lesson, using as many as inseparable verbs with get which have already been found by the group members. **4.** Preparing an anecdote about a surprising party that one of the group's member has organized for someone else recently. **5.** Writing and discussing five questions on the topic of birthdays (e.g., Do *you always do something special for your birthday?*). **6.** Free discussion about the group members' reactions to a situation in which they just got some really great news. (e.g., They won a lot of money)	Conducting a research on social life of a historical figure and creating a video biography of that person. The video is intended to be accompanied by narration.	**7.** A short video created by Windows Movie Maker

Appendix B: Assumptions Checked for Running ANCOVA

Table B1

Results of Normality Testing for Unstandardized Residuals of the Posttest Scores

Variable	Kolmogorov-Smirnov[a]		
	Statistic	*df*	Sig.
Residuals for Critical Thinking Scores	.128	34	.057
Residuals for Problem Solving Scores	.065	34	.200

Table B2

Results of Levene's Test on the Posttest Scores

Variable	*F*	*df1*	*df2*	*Sig.*
Critical Thinking Scores	.951	1	33	.421
Problem Solving Scores	1.044	1	33	.379

Figure B1

Line chart representing the linear relationship between the CT pretest and posttest scores

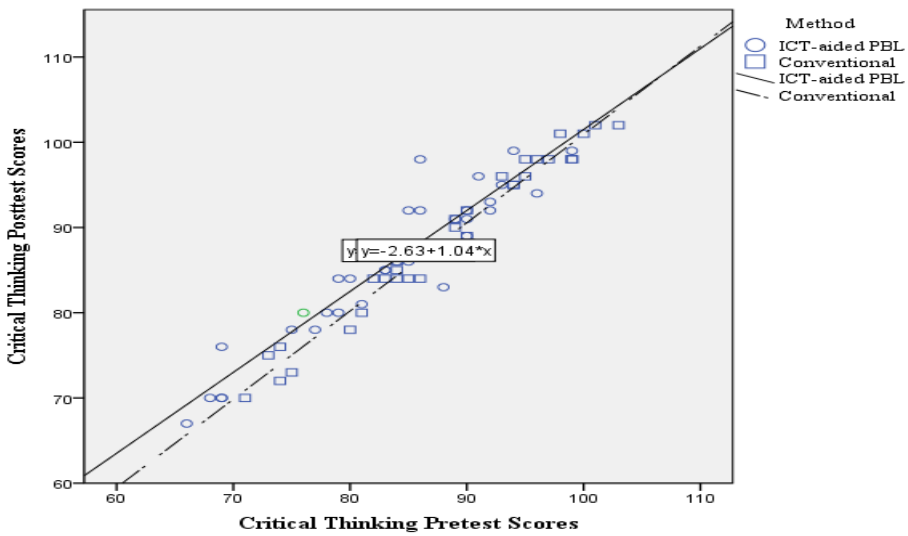

Figure B2

Line chart representing the linear relationship between the PS pretest and posttest scores

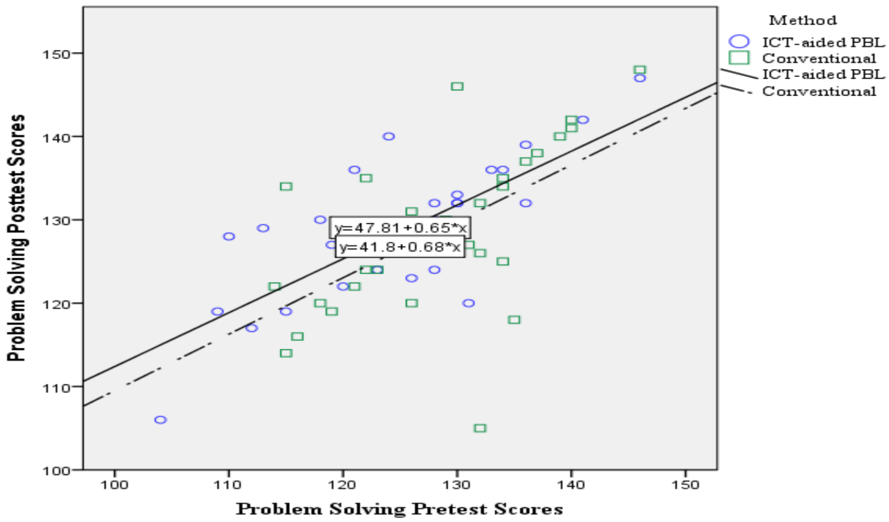

Table B3

ANCOVA Results for the Homogeneity of the Regression Slopes based on the CT Scores

Source	Type III Sum of Squares	*df*	Mean Square	F	Sig.
Corrected Model	2587.987	2	1289.493	157.162	.000
Intercept	12.274	1	12.274	1.496	.230
CT Pretest Scores * Method	34.075	2	17.037	2.293	.087
Error	262.556	32	8.205		
Total	273178.000	35			
Corrected Total	2841.543	34			

Table B4

ANCOVA Results for the Homogeneity of the Regression Slopes based on the PS Scores

Source	Type III Sum of Squares	*df*	Mean Square	F	Sig.
Corrected Model	1052.671	2	526.335	25.83	.000
Intercept	189.262	1	189.262	9.288	.005
PS Pretest Scores * Method	15.599	2	7.799	.715	.401
Error	652.072	32	20.377		
Total	579505	35			
Corrected Total	1704.743	4			