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Interplay of Design Thinking & Technology Integration: A Project-Based Learning Design

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Abstract

Design Thinking (DT) and Project-based Learning (PBL) are innovative pedagogical approaches that are gaining popularity in modern education systems due to their potential to develop the knowledge, skills, and attitudes (KSAs) required for successful participation in the competitive global environment. However, limited resources and fixed mindsets of stakeholders have hindered the adoption of these approaches in the higher education system of Pakistan. To address this, a course was designed and implemented in the STEM department of a public university in Pakistan, which focused on the interplay of PBL, Design Thinking, and technology integration. Constructive alignment was incorporated within standard academic requirements throughout the course, and the results demonstrated visible improvements in critical thinking, collaboration, communication, and creativity (4Cs) among students. This successful implementation of PBL can serve as a model for improving higher education in Pakistan, especially in STEM fields, by promoting growth mindsets and effective technology integration to enhance student learning. This research highlights the importance of shifting from teacher-centred to student-centred inductive teaching methods, from on-campus to online collaborative spaces, and from traditional to ongoing and continuous improvement through PBL. The findings can be useful for policymakers, curriculum developers, teacher education institutions, and educational researchers seeking to improve education in Pakistan and beyond.

Keywords: Design Thinking, Project-Based Learning (PBL), Technology Integration, Gold standard PBL, SDG4, KSAs, 21st-century skills, Inductive pedagogical method, STEM

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Design Thinking (DT)

Design thinking (DT) is a problem-solving strategy that focuses on human-centred design to identify and solve complex problems (Razzouk & Shute, 2012). This approach involves thinking both analytically and creatively, as well as iterating through prototyping and feedback from the targeted audience. Design thinking has been applied in a variety of settings, including industry and commerce, where it has shown potential for promoting organizational innovation (Grots & Creuznacher, 2016). In today's highly competitive environment, design thinking is considered an essential skill for individuals to participate effectively in the 21st century (Razzouk & Shute, 2012). While traditionally used in industrial and commercial activities, design thinking is also gaining popularity in education (Kulick, 2017; Tsai et al., 2013). By engaging in design challenges, teachers and students alike can develop 21st-century learning skills, including higher-order thinking skills (HOTS), metacognitive skills, and technological literacy (Koh et al., 2015). Unlike traditional teaching methods, design thinking requires students to take an active role in constructing knowledge through interdisciplinary learning and thinking beyond the limited requirements of everyday lessons (Panke, 2019). This approach has the potential to cultivate a range of creative possibilities and potentials for identifying problems and finding solution paths. Summarily, design thinking is a valuable problem-solving strategy that has the potential to enable individuals to think creatively and innovatively, making it an essential skill in today's world.

Project-based Learning (PBL)

Project-based learning (PBL) is a student-centred teaching method rooted in the constructivist theory of learning (Kokotsaki et al., 2016; Michael & Richard, 2006). This approach involves contextualizing learning within real-life problems and authentic questions(Al-Balushi & Al-Aamri, 2014), providing learners with meaningful experiences that enhance their competencies and skills critical for success in the 21st century (Holmes, 2012; Satari & Ismail, 2015). PBL also aligns with deeper learning competencies, including cognitive, intrapersonal, and interpersonal

domains, as suggested by many research studies in this field (Hixson et al., 2012; Pellegrino & Hilton, 2012).

The three main principles of constructivism, context-specificity of learning, active learning process, and social and interactive learning, form the foundation of PBL (Kokotsaki et al., 2016; Thomas, 2000). Additionally, PBL includes critical and reflective thinking, hypothetico-deductive reasoning, metacognition, collaborative learning, scaffolding, and knowledge building through prior knowledge and authentic (real-world) problems (Cervantes, 2013). Compared to traditional teaching methods, PBL provides students with opportunities to develop competencies such as critical thinking, creativity, collaboration, communication (Ark & Schneider, 2014), and academic mindsets (Limna et al., 2022; Sohaya, 2020). PBL encourages learners to grasp the core academic content while also promoting the development of these competencies through authentic problem-solving experiences.

Statement of the Problem

Past research claimed that necessary modifications in classroom curriculum and a transition in pedagogical methods along with effective technology integration are required for improving the quality of education within the context of the 21st century (Hur et al., 2016; Limna et al., 2022; Niu et al., 2021; Sohaya, 2020). However, in Pakistan, there has been limited research on the effectiveness of inductive pedagogical methods e.g. PBL in comparison to traditional methods. Likewise, a very limited place has been given to design education or design-related courses in the field of education (Akram et al., 2020). Moreover, effective technology integration for the successful implementation of inductive pedagogies and design thinking strategies has not been widely practised in Pakistan. Since design education and project-based learning are highly stressed to develop intrinsic skills for solving authentic problems and for learning the required skills of the 21st century (Condliffe et al., 2017; Koh et al., 2015; Kwietniewski, 2017; Razzouk & Shute, 2012), the need for teaching design thinking to prospective teachers and educational researchers within a technology-integrated PBL environment was highly felt.

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Research Objectives

Keeping in view the above considerations, the objectives of this research project were:

- To design and implement a technology-integrated course that could clearly manifest all the recommended enactment procedures of PBL to teach design thinking.
- To provide evidence of the effectiveness of the PBL method for improving the 4Cs of 21st-century skills among the learners.

This particular course was designed and implemented in the STEM Department of a public university in Pakistan. Participants of the course and research project were 146 prospective teachers and educational researchers (61 undergraduates, 20 graduates and 66 post-graduate) who were enrolled as full-time learners during the academic semester Fall 2021-22.

Course Designing Process

This particular PBL course was designed on the "Project-Designer" which was a platform of PBLWorks (Buck Institute for Education). The Project designer (https://my.pblworks.org/project-designer) of PBLWorks gives a ready-to-use template for designing and implementing high-quality PBL in classrooms. For the designing of this course, specific labels and titles provided by PBLWorks were used. The details of this course can be seen in Project Companion Portal (To visit the Project Companion Portal, follow the link https://sites.google.com/view/project-companion-portal). Project Companion Portal was developed to provide guidance according to the needs of students and other stakeholders. Students needed proper guidance for all activities of PBL as they were for the first time put in such an environment. In this portal, all important details about the project are presented. These include objectives of the course (Educational Technology) for which PBL was adopted, objectives of the project with specific reference to the "Driving Question" of PBL and "Design Thinking", desired learning outcomes as well as considerations. In addition, various educational resources including relevant books, tutorials, videos useful links, rubrics and samples of end products can also be found there.

The design of this course was influenced by the contributions of project-based learning, design thinking and technology integration in education for visible learning and preparing students

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for the highly competitive and technological world. Figure 1 shows the inter-relation of design thinking, technology integration and PBL for improving much needed 21st-century skills to support visible learning.

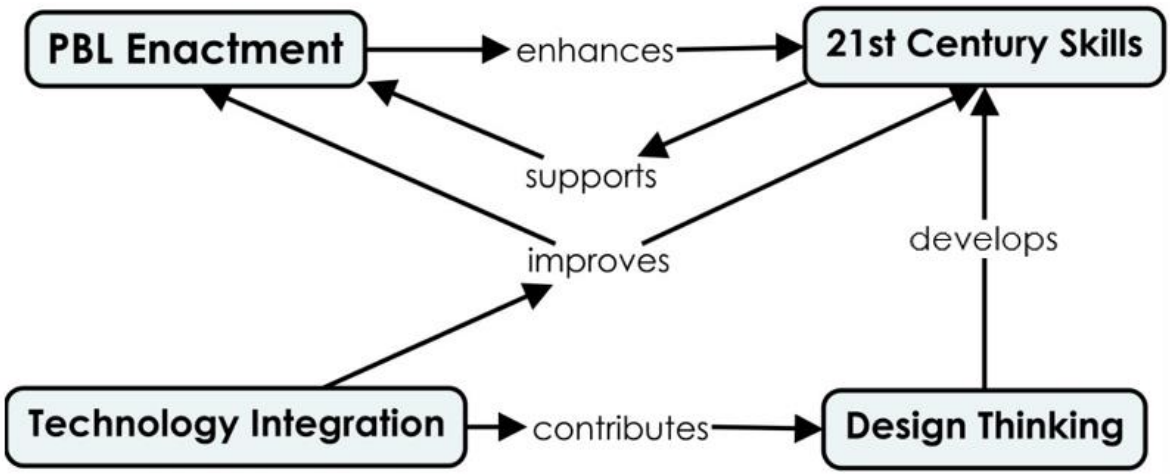

Figure 1. *Interrelation of Design Thinking, Technology Integration, PBL and 21st-Century Skills*

Driving Question for PBL

Many experts in the field of PBL stressed a well-defined open-ended question for the whole activity of PBL (Condliffe et al., 2017; Guo et al., 2020; Larmer et al., 2015; Thomas, 2000). The driving question of this project was based on "Improving the quality of Education". The statement of the question was "*How can technology integration improve the "quality of education?"*. This driving question was consistent with Sustainable Development Goal 4 (SDG4: *"Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all").* While seeking an answer to this question, students learnt such skills (4Cs and problem-solving) which are much needed in the 21st century's various competitive environments that ensured many life-long opportunities for the students.

Course Setting

An existing technology-related course was redesigned and implemented where a project-based learning method has been used with the intent to make it innovative and beneficial for

developing 21st-century skills among the students. Those skills especially include problem-solving and the 4Cs (collaboration, communication, critical thinking, creativity). In this PBL course, teaching, learning and assessment had been aligned with the learning objectives to ensure constructive alignment. This alignment helps in developing KSAs in students required for academic, personal and workplace environments. Collaboration was another much-focused element for knowledge construction, social learning, scaffolding and culture building within the classrooms (Hadwin et al., 2017; Järvelä & Järvenoja, 2011). The teams of students were formed using the CATME application by Purdue University for better collaboration to complete the project's tasks and requirements. Students' team compositions encouraged them to learn efficient, productive and responsible team-working skills. Teams were well-informed and guided about the PBL environment, assignments, artefacts, and assessment strategies. All necessary and relevant communications and actions of participating students performed during the collaborative learning environment were recorded and analyzed to understand the deeper learning processes taking place during the PBL environment.

While seeking answers to the driving question, students were required to identify authentic and real-life problems in teaching-learning practices and find solutions using Design Thinking. These problems were required to be relevant to the driving question (*How can technology integration improve the "quality of education)* Purposeful use of technology integration models, reflective and constructive feedback and peer evaluation was also an essential part of the process. Being in teams, students needed to suggest some technological tool or app for the solution of the identified problem as their end product. They publicly elaborated their suggested technology-integrated solution with all necessary details and learning strategies through various online multimedia presentations. They were also encouraged to make their learning visible by sharing their project processes and products within a community of practice.

PBL Enactment Process

The researcher ensured the successful enactment and implementation of the PBL model (by PBLWorks of BIE) through the interplay of the Design Thinking model (by IDEO) and ASSURE model of technology integration *(Figure 2)*. Design thinking generally involves five

stages which are *1) Empathize, 2) Define, 3) Ideate, 4) Prototype,* and *5) Test.* For this particular study, Design Thinking for Educators by IDEO *(Figure 2)* was introduced to the participants as they all were basically studying in the field of education and hoping to pursue careers in education systems. Design Thinking for Educators also involves similar stages called 1) *Discovery, 2) Interpretation, 3) Ideation, 4) Experimentation,* and *5) Evolution.* The model starts with an additional preparation stage termed *'Getting Started'.*

For careful planning of technology integration during the process of PBL implementation, ASSURE model was utilized. ASSURE model of technology integration is a typical example of the ADDIE model that comprises six sequential steps: 1) *Analyze learners, 2) State standards and objectives, 3) Select strategies, technology, media, and materials, 4) Utilize technology, media, and material, 5) Require learner participation,* and *6) Evaluate and revise.* ASUURE model is specifically designed for guiding teachers in the technology integration process. It helps them to plan lessons following the sequential steps of ASSURE. However, iterative cycles of design, redesign and reflective practice which are the main elements of a teacher's lesson planning (Laurillard, 2013) may not be well-reflected in it (Koh et al., 2015). Therefore, for this present study, we adapted ASSURE model in such a way that made it a useful guide for both teachers and students.

First, two steps of ASSURE (*Analyze learners, State standards and objectives)* were part of Designing & Planning and Aligning to standards (*Figure 4:* Project-based teaching practices) and thus considered before launching the project by the instructors. Since the students were prospective teachers and educational researchers, these two steps were followed by the students during the initial phases of Design Thinking when they were analyzing their learners (stakeholders, end users) and identifying their goals and objectives for their projects. The third step of ASSURE (*Select strategies, technology, media, and materials*) was followed in the *Ideation* stage of Design Thinking; whereas the fourth and fifth steps (*Utilize technology, media, and material, Require learner participation*) covered the *Experimentation* stage *(Figure 2).* The last step of ASSURE model (*Evaluate and revise*) was part of the *Evolution* of Design Thinking. Since design thinking is an iterative process which requires the designer's involvement throughout the course of

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designing, it requires learners' participation in all the phases from start to end. Even after reaching the next stages, the previous stages can be revisited again. Therefore, critical and reflective thinking entailed the whole design process within PBL enactment and thus, utilization of technology, materials and resources, analysis, evaluation and revision were actually the requirement of each stage of Design Thinking during the enactment process.

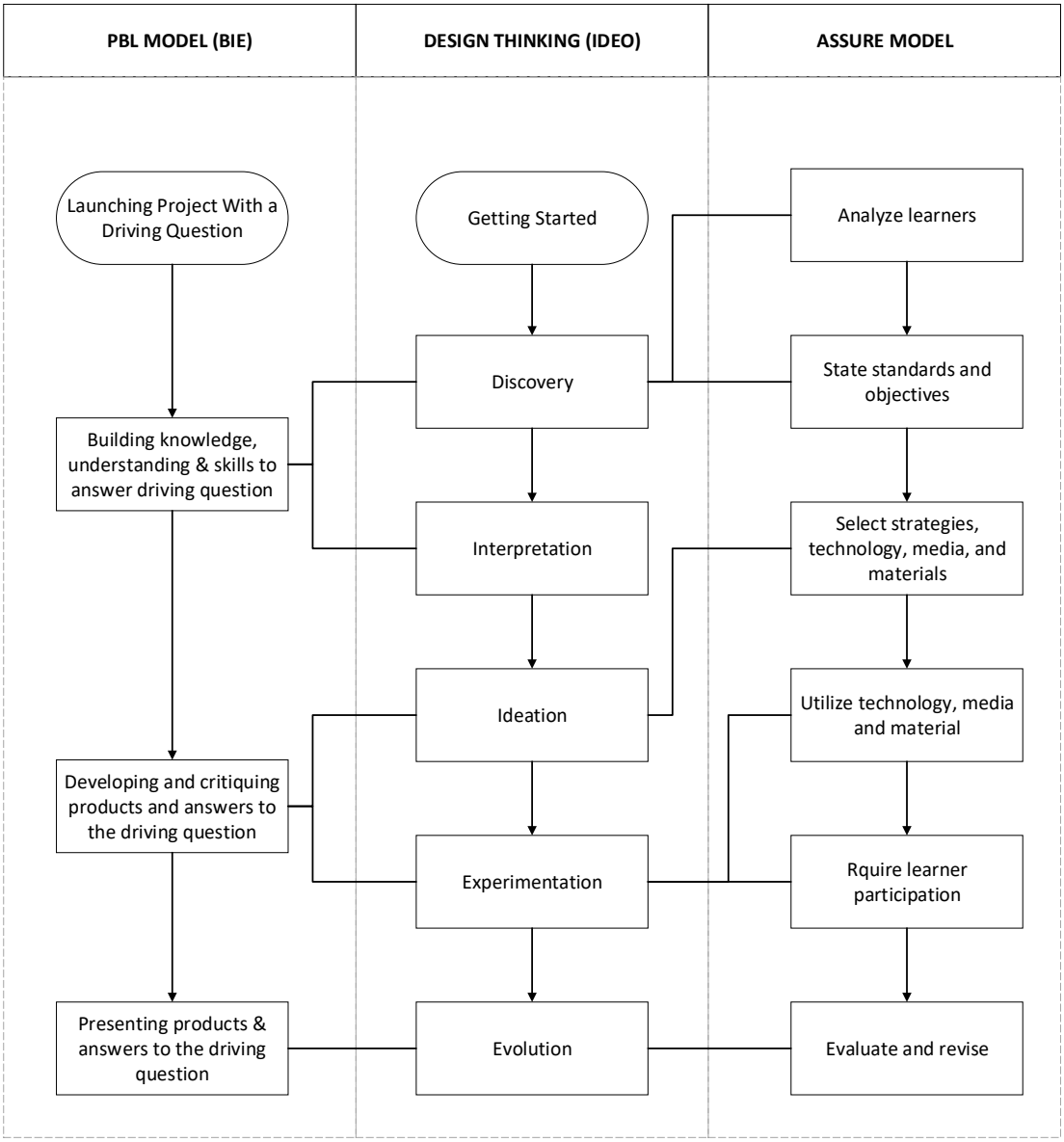

Figure 2. *Interplay of Design Thinking and ASSURE Model Within PBL Environment*

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Table 1

Components of PBL Enactment Process

*Stages of Design Thinking (Milestones)	**PBL Enactment Phases	Key Student Questions (KSQs)	Students' Activities	Instructors' Practices
0 - Getting Started (Define a Challenge and Prepare Before You Start)	Launching the project with a Driving Question	Driving Question (DQ): How can technology integration be used for "improving the quality of education"? KSQ: What is your initial understanding and planning to answer the driving question?	Students introduced themselves on the Padlet; performed CATME Team-making survey; got familiar with their teammates, decided a catchy name and chose a team-leader for the team; shared their individual thoughts on the workbook and with the team regarding the DQ; listed some actionable problems to be solved; discussed the stakeholders, goals, success indicators and constraints on Padlet; wrote down their tentative project plan, team name, team members, their roles on the assigned Google form collaboratively; shared their reflections on a reflection form (adapted from Gibbs, 1988)	Instructors delivered an introductory presentation on the project's Driving Question; formed teams through CATME application (Team-making Survey); designed a Project Companion Portal and Padlet; shared project calendar, portal and other resources with students; discussed major projects and activities of the project
Milestone 1 – Discovery 1-1 Understand the Challenge 1-2 Prepare Research 1-3 Gather Inspiration	Building Knowledge, Understanding, and Skills to answer driving question	What is an authentic educational problem that you have identified to solve through technology integration? How did you choose that particular problem? Why do you think that it can be solved through technology integration?	Students chose and reframed the most accessible and solvable educational problem from the list of actionable educational experiences/complaints/wishes of themselves or the people around; shared prior and new knowledge about their project; assigned roles and provided feedback to their teammates; made a list of concerned people for meeting; made a list of activities for the meetings; prepared the team for the field work; got an evidence of the fieldwork and meetings; shared the evidence/scenario of the identified/self-selected problem; shared the whole process of "Discovery" on Padlet, Google form and on their workbooks; performed self and peer evaluation on CATME	Assessed teams' and their project plans; provided scaffolding for students' learning and research; answered students' generated questions; ensured students' engagement and healthy culture and collaboration during the phase; assessed and visited students' tasks and Padlet space; gave individual and group-wise feedback
Milestone 2 - Interpretation 2-1 Tell Stories 2-2 Search for Meaning 2-3 Frame Opportunities	Above phase continued	How do you define the problem at hand (chosen in "Discovery") and what are some actionable opportunities for the solution of that problem?	Shared a summary of team-meetings on Padlet; organized their whole fieldwork/research on the project; identified and defined themes in the project work through discussions on the assigned spaces; presented their fieldwork/research on the project through a journey map; performed self and peer evaluation on CATME; shared reflections	Above practices continued as well as presentations of the work done in previous milestones were taken

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Table 1. ***(Continued)***

*Stages of Design Thinking (Milestones)	**PBL Enactment Phases	Key Student Questions (KSQs)	Students' Activities	Instructors' Practices
Milestone 3 – Ideation 3-1 Generate Ideas 3-2 Refine Ideas	Developing, Critiquing, and Revising Products and answers to the driving question	How to address the needs of stakeholder(s) of your self-selected/formulated problem through technology integration? How would you choose from a range of educational technologies/tools/apps? Share 8-10 technologies/tools/apps?	Searched various solution paths for finding digital solutions (tools/apps/technologies) of self-selected problems; generated and refined useful ideas through discussion; chose a clear, most appropriate idea for solving problem in hand; shared a summary of meetings (on brainstorming) on all assigned spaces; performed self and peer evaluation on CATME; shared reflections	Shuffled students within teams where required; ensured students' engagement and collaboration; assessed and visited students' tasks and Padlet space
Milestone 4 - Experimentation 4-1 Make Prototypes 4-2 Get Feedback	Above phase continued	How would you build digital prototypes for the particular stakeholder(s) facing the problem? How would you learn and teach the chosen educational technology? How do you integrate it to solve the problem in hand?	Created digital prototypes in various formats for the solution; discussed their prototypes within teams; shared a summary of team-meetings on Padlet; got feedback from peers, experts and end users; recorded the feedback and its integration (if done); performed self and peer evaluation on CATME; shared reflections	Above practices continued; students' shortlisted digital solutions with reference to the problems were evaluated and feedback on students' prototypes was provided
Milestone 5 - Evolution 5-1 Track Learnings 5-2 Move Forward	Presenting Products and answers to the driving question	How would you justify your chosen digital solution (educational technology/tool/app) for the problem and define its success? How would you share the finalized technology-related solution for the problem with others?	Tracked and revised their learning on the project; shared it on Padlet; recorded the experiences of the end users after experimentation of given solutions; recorded the whole process through e-posters, journey maps and slides; developed their teams' project-portfolios to share their projects with a broader audience; performed self and peer evaluation on CATME; shared reflections on the whole project	Provided a platform to students for building an active community of practice; assessed students' tasks and Padlet space and ensured students' engagement and healthy culture and collaboration
Final Presentation & Assessment (Present the whole exercise of problem solving; Accept results and feedback; Learn new ways for making learning visible; Scrutinize decisions and skills for future)	Exit phase: Evaluating the whole exercise of PBL with reference to the driving question	How can you display your solution, conclusions and artifacts for making your learning visible and learning through constructive feedback in future?	Added a tagline or motto for the display of their final products (individual & team work); prepared a group summary to document all the work they had done to give a detailed rationale about the technology-integrated solution of the concerned problem; performed self and peer evaluation along with an exit survey; shared their future plans and recommendations regarding PBL projects.	Took final presentations of students' efforts with reference to the project during PBL; compiled results for students' grading and research work; gave and got feedback and recommendations; evaluated scrutinized decisions; planned for future iterations

*Stages of Design Thinking presented by IDEO have been adapted as PBL Milestones in this course; **PBL Phases are described by Larmer and colleagues in their book "*Setting The Standard for Project-Based Learning: A Proven Approach to Rigorous Classroom Instruction*" (BIE).

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Experts of PBL from Buck Institute for Education, Larmer and colleagues (2015) explained the four phases of PBL model which are as follows:

a. *launching project with a driving question,*
b. *building knowledge, understanding & skills to answer the driving question,*
c. *developing and critiquing products and answers to the driving question,* and
d. *presenting products & answers to the driving question.*

Design thinking accompanied PBL phases (Figure 2, Table 1) from 'Getting Started' (launching a project with a driving question) and then covered all three milestones by taking five steps (Discovery, Interpretation, Ideation, Experimentation and Evolution).

Table 1 presents an overview of all activities and practices of students and teachers carried out during the phases of PBL enactment along with the stages of Design thinking to answer the Driving Question and key student questions (sub-questions). In this course, the implementation of BIE's PBL model started with the launch of the project with an open-ended driving question to guide the process of inquiry. In this entry phase, students prepared a well-elaborated plan for their projects (Getting Started). From the second phase, i.e. building knowledge, understanding & skills, the journey really began. To cover this milestone, students identified and defined their projects (Discovery and Interpretation) with the help of independent investigation and teacher-provided resources. They identified authentic educational problems that could be solved through technology integration. They also met experts, stakeholders and mentors to deeply understand their projects and to achieve the required skills. In phase three, students applied higher-order skills to answer the driving question. They generated multiple questions and ideas for brainstorming (Ideation) about the solutions and possibilities for their self-selected educational problems as well as they selected relevant technologies, apps and digital tools for the solution of the problems at hand. Moreover, they also developed digital prototypes (Experimentation) in various media formats (e.g. text audio, video etc.) Students sought feedback on these prototypes and initial drafts from their peers, mentors, teachers or stakeholders and decided to iterate or revise the process. Then came the final phase of PBL where students were required to compile their work, upload on

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teams' project portfolios and present the whole process before a broader audience (Evolution). During the whole journey, students were motivated for self and peer-evaluation by the instructors to ensure a healthy culture among the students. Moreover, all project-based teaching practices *(Figure 4)* noted by Larmer and colleagues (2015) in Gold Standard PBL model of Buck Institute for Education were also consistently practiced by the instructors *(Table 1).*

Alignment of the Course with Gold Standard PBL

Gold Standard PBL is a comprehensive and research based model for PBL published by Buck Institute for Education to help PBL practitioners and researchers. Gold Standard PBL comprises three parts which are student learning goals, essential project design elements, and project based teaching practices (Larmer et al., 2015).

Figure 3. *Design Elements of Gold Standard PBL (Adapted from BIE)*

Larmer and his colleagues (2015) explained that student learning goals are related to *key knowledge, understanding & success skills* while project design elements include *challenging*

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problem or question, sustained inquiry, authenticity, student voice & choice, reflection, critique and revision and public product (Figure 3). In Gold Standard PBL, project based teaching practices involve *design & plan, align to standards, engage & coach, build the culture, manage activities, scaffold student learning* and *assess student learning (Figure 4).*

Figure 4. *Gold Standard Project Based Teaching Practices (Adapted from BIE)*

Gold Standard PBL model demonstrates effective alignment of learning outcomes and pedagogical strategies as it facilitates in content coverage, contributes in visible and deeper learning (Ark & Schneider, 2014; Pellegrino & Hilton, 2012) and improves the success skills required in the complex environments of 21st century.

In *Table 2*, some prominent features of this particular course are discussed to showcase how the design and implementation process is consistent with the Gold Standard PBL (Larmer et al., 2015) presented on the website of Buck Institute for Education. Past researchers noted the lack

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of consensus on essentials of PBL and stated the difficulties faced by PBL practitioners and researchers (Condliffe et al., 2017; Ravitz, 2010; Tamim & Grant, 2013; Thomas, 2000). However, in the present study, the researcher tried to be consistent with the design elements of Gold Standard PBL (Buck Institute for Education) along with the course objectives in order to achieve desired learning outcomes *(Table 2).*

Table 2

Course Alignment with Design Elements of Gold Standard PBL (BIE)

Gold Standard PBL (BIE)	Course Alignment with Design Elements of Gold Standard PBL
Challenging Problem or Question	The driving question was open-ended and consistent with SDG4. Key student questions (sub-questions) were challenging that demanded students' deep cognitive, inter-personal and intra-personal skills.
Sustained Inquiry	Over the course of whole semester: Students remained engaged in multiple assignments which were precisely related to the driving question and sub-question of the working phase. Students made iterations and revisions in their work with the help of self, peer and teachers' reflections and with various information resources.
Authenticity	The driving question and sub-questions were geographically contextualized with the real-life and authentic educational problems of actual stakeholders or with students' own identities, interests and concerns.
Student Voice & Choice	Students were allowed to autonomously select an authentic educational problem for their projects. Students were encouraged to take control of the project processes, self-direct their learning, provide input on their roles within teams, and discuss questions, resources and end products.
Reflection	Students reflected on their learning informally and formally (through assigned tasks designed to collect their reflections). Students were given time to reflect on their project to justify and evaluate their projects' relevance with the answer to the driving question.
Critique and Revision	Students were provided peer-to-peer and expert feedback during and after each milestone for quality work. Based on feedback, students revised their work and artifacts to meet the needs of concerned stakeholders.
Public Product	Students developed project portfolios and uploaded their end products there for making learning visible. Students presented their projects before other students and instructors as well as shared their portfolios with detailed whole semester exercise to a larger learning community to actually meet authenticity criterion.
Key Knowledge, Understanding & Success skills	Key project standards and learning outcomes were aligned with the learning objectives of Educational Technology (a subject in which PBL design was embedded). Application of knowledge of academic content and fundamental concepts of the subject was taught to students to enable them to solve authentic educational problems and to answer the driving question. Design education through technology integration enabled students learn success skills of 21st century. (For more details, visit https://sites.google.com/view/project-companion-portal)

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There was a little more emphasis on some design elements relative to others, e.g. authenticity was considered more important than students' choice. It implied that authenticity of students' self-selected educational problem for their projects was checked by the facilitators of PBL in the initial milestones of PBL implementation and then those educational problems were allowed to be worked on further. Provided the unique nature of academic content and learning processes in the PBL environment, assessment is pointed out as another concern for PBL educators. This issue was successfully handled in this study by using analytic rubrics provided by PBLWorks to evaluate the constructs and activities of students during the process. Evaluations of artefacts were made more convenient by requiring students to present their projects in the form of project-portfolio as their final products. These portfolios provided not only solutions to authentic problems but also showcased students' design thinking processes carried out from start to end.

Conclusion and Implications

The course design, setting, and implementation process of Project-Based Learning (PBL) aligns with the Gold standard PBL framework developed by the Buck Institute for Education to varying degrees of emphasis. Based on a comprehensive examination of all practices and procedures, including their justifications and evaluations, it can be concluded that modern inductive and student-centred instructional methods, such as PBL, can be successfully integrated with technology and the 21st-century learning model, significantly improving students' problem-solving, critical thinking, creativity, collaboration, and communication skills. This study's course design is of great significance to all education system stakeholders concerned with their students' success skills and content comprehension. Educators, curriculum developers, and policymakers who may be hesitant to adopt PBL due to its apparent uncertain nature can replicate the design and implementation of PBL discussed in this study with ease. This evidence-based research project confirms that PBL is accessible to all and can be implemented using traditional tools and resources with low-stakes structures. PBL encourages students to be confident in using technology and sharing their knowledge publicly, making it a powerful tool for our education system to develop individuals into critical and creative thinkers, communicators, collaborators, and problem-solvers, allowing them to thrive in the competitive environment of the 21st century.

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