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Design for the real world: a problem-based learning approach

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Abstract

Problem-based Learning is an established learner-centred pedagogical approach for developing skills and competencies. This paper presents the evolutionary development of a Massive Open Online Course, titled "Design for the Real World: A Problem-based Learning Approach", with the aim to empower learners to independently pursue problem-based inquiry using design methods and tools, thereby fostering creativity and life-long learning.

Keywords: digital learning, lifelong design education, problem solving, problem-based learning

1. Introduction

In today's time of rampant disruptions in the job market, the World Economic Forum, 'Future of Jobs Report 2023' states that a foreseeable "*23% of job change*" is predicted and that upto "*44% of worker's core skill are expected to change the next five years*". It further reports that 81% of Organisations are enroute to adopting the strategy of *'**investing in learning and training on the job**'* to upskill and re-skill the workforce. The report also enlists the top 10 skills on the rise for 2023-27, of which the non-technological skills are; Analytical thinking, Creative thinking, Leadership and social influence, Curiosity and life-long learning, etc. Thus, directing the need to develop these skills and competences for being future-ready, beyond formal education. Problem-based Learning (PBL) is one such pedagogy that enables the development of various competences, i.e. knowledge, skills, behaviours and attitudes, through a learner-centred approach, and has been leveraged to build capacity across several beneficiary South Asian institutes of Higher Education over the tenure of the Erasmus+ Capacity Building in Higher Education (CBHE) project titled, "PBL SA - *Strengthening Problem-based learning in South Asian Universities*" (Acharya, et al., 2021 a, b; Acharya, et al. 2023; Jurelionis, et al., 2023). Along with several capacity-building, experiential activities that were conducted, various supplementary resources were also co-created to support the learners and to inculcate PBL through dissemination to other benefactors. However, it was realised that the benefit could only be accessed by a limited audience and that the true value addition to the needs of future-readiness maybe effective by a flip to this conventional top-down perspective to imbibe skills and knowledge.

This paper presents the evolutionary development of a MOOC (Massive Open Online Course) titled "*Design for the Real world: A Problem-based Learning Approach* " available for free access on the SWAYAM platform, that promotes "*the complete realization and liberation of the self*" through development of not only "*cognitive capacities, such as, critical thinking and problem solving – but also social, ethical, and emotional capacities and dispositions*" (National Education Policy, NEP 2020).

2. Inculcating Problem-based Learning (PBL) for future-readiness

A survey of the beneficiary South Asian Universities revealed the need to develop hard and soft skills essential for employability and industry-readiness in their graduates (Acharya, et al., 2021a,b), and PBL was found as a viable approach to do so upon several evidentiary indications in. With the primary focus on capacity-building, the implementation required, both, theoretical development of pedagogy and planning of practicalities, which in turn lead to development of several resources (as in Figure 2), with the vision that the outcomes of the project's capacity-building endeavour would not only develop industry-readiness in graduates but also support future capacity-building in an iterative manner.

2.1. Theoretical underpinning

PBL was formally modelled and identified to have six core characteristics (Barrows,1996). Savery and Duffy (1995) further developed it into an "*instructional (and curricular)*" approach, where it is noted that the 'problem' is either discovered or adopted by learners, in spite of no pre-specified objectives being presented to them. These real-life, messy, 'wicked problems' do not have a singular correct solution and so, an experiential problem-solving process ensues that encourages learners to research, apply theoretical knowledge and hone practical skills to conceptualise viable solutions (Torp and Sage, 2002; Hmelo-Silver, 2004; Savery 2015). Through the PBL approach, the learner actively constructs knowledge (Gijselaers, 1996). It is empirically found to enhance *conceptual understanding and critical thinking*, promote *self-directed learning*, improve *problem-solving skills* (Williams, 1999; Denton, et al., 2000; Rideout and Carpio, 2001; Torp and Sage, 2002; Yadav, 2011), as well as increase *motivation and engagement* (Albanese and Mitchell, 1993; Vernon and Blake,1993; Dolomons, 2016; Caswell 2017). In fact, Duch, et al. (2001) reports that it is due to the motivation and engagement, *collaboration, and communication*, that the various skills, such as, complex problem-solving, critical thinking, and self-learning develop. While PBL can be implemented in many ways, it is essentially characterised by two phases: ***collaborative learning phase*** and ***self-directed learning phase***, as one type of learning alone cannot sufficiently impact one's overall learning (Schmidt, et al., 2009). The learning also requires Teacher scaffolding to ensure that misconceptions are addressed. Therefore, the role of the Teacher/tutor shifts from lecturer/instructor to that of facilitator who helps direct metacognitive activities through 'triggers', and mentor who mitigates conflict and enables constructive discussions. As a process, it is rooted in constructivism and the overarching approach has been collated into12 steps (as in Figure 1).

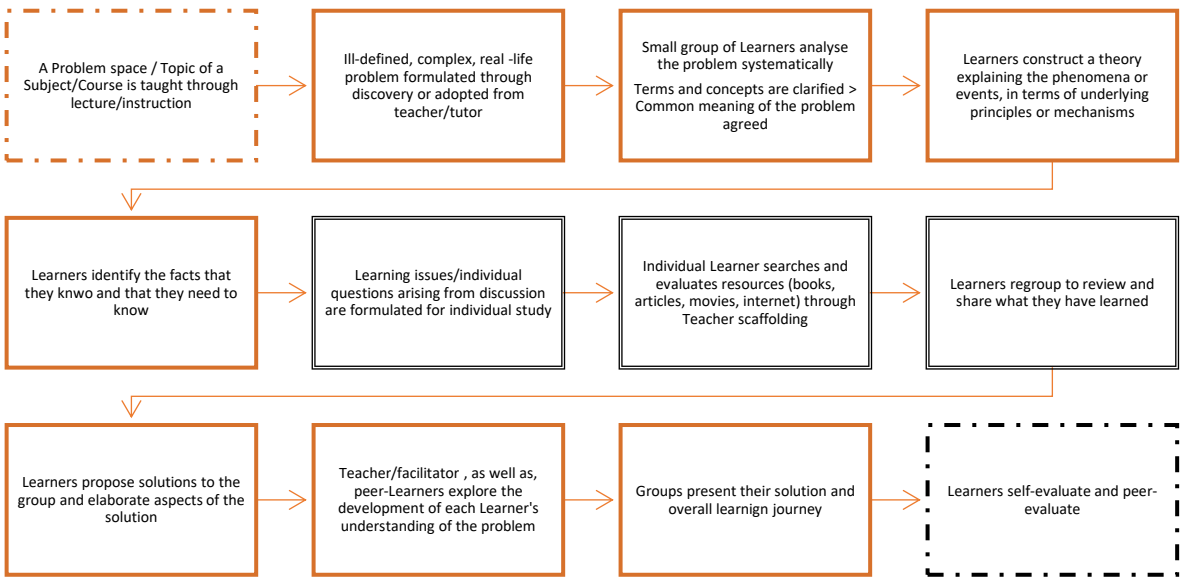

Figure 1. A generic PBL process

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2.2. Practical implementation

Mills and Treagust (2003) states that, in traditional engineering education, the critical but common issues are : (a) ***Students*** lack communication and collaboration skills, as well as, awareness of social, economic, environmental and legal factors; (b) ***Faculty members/Teachers/Mentors*** lack the practical experience of adequately relating theory to practice, and lean on outdated teaching-learning strategies; and (c) ***the Program/Course***, developed by the Administrative members for curriculum of the institute, are content-driven and do not have adequate avenues for incorporating practical experience. This was found consistent with the findings of a survey of faculty from the five beneficiary South Asian partner institutes of the PBL South Asia project, who offer undergraduate courses in engineering (Acharya, et al., 2021a). Acharya, et al. (2021a) highlights that the top constraints with respect to the context are; heavy syllabi as per University-directed lesson plans that restricts time for practicals and less number of co-instructors to help guide practicals. In addition, it was found that these faculty members and administrators were unfamiliar with PBL pedagogy and how to imbibe the same into their respective subjects/courses, and therefore, a two-pronged solution was devised to empower them with Capacity and Resources, as articulated below in (Figure 2).

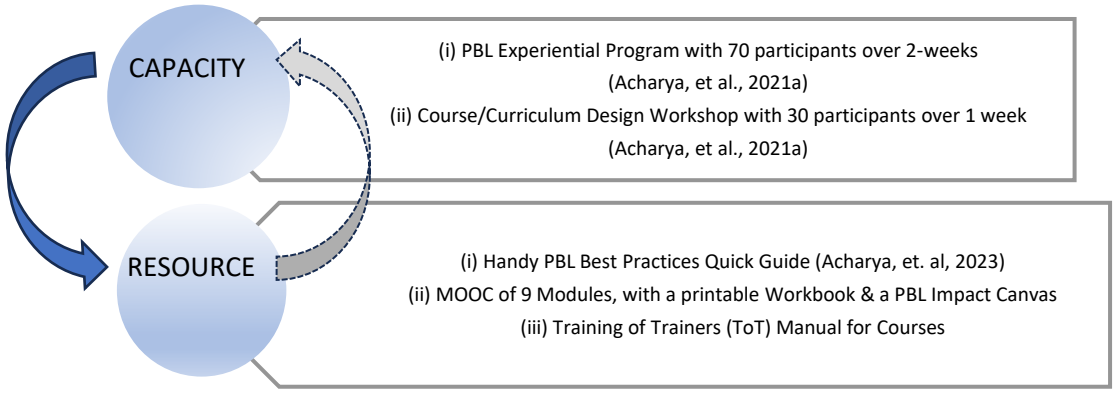

Figure 2. PBLSA project methodology to imbibe PBL and outcomes

- First, **Capacity** was developed in the Teachers/Mentors and the Administrative members responsible for curriculum/course design, some of whom were also senior Faculty members. The immersion into the PBL methodology was inculcated through Design Thinking and led to the development of a 'PBL schema' that entailed the stages of exploration/identification to identify the 'right problem', followed by conceptualisation/ideation, consolidation of solution and selection of final concept for Presentation. To do so, the following two capacity-building exercises were undertaken:
  - ***Experiential Program*** comprising of case studies and workshops | August 2019 : A two-week long program of 70 participants across 10 universities, aimed to introduce the concepts of PBL and familiarise with the practical aspects of conducting field study for problem-solving (Acharya, et. al, 2021a) ;
  - ***Course/curriculum Design Workshop*** | October 2019: A weeklong workshop of 30 participants, comprising of additional theoretical training and mentored course plan creation (Acharya, et. al, 2021b).
- Then, **Resources** were developed to aid the trained faculty members in PBL practice at home institutes. The methodology for resource creation further garnered the PBL approach to;
  - compile (i) a handy ***PBL Best Practices Quick Guide*** (Acharya, et. al, 2023), that glosses over the Definitions, Characteristics and Learning Principles, Measures and Metrices of effectiveness, Role of the tutor/teacher, and general Guidelines for problem formulation and the importance of the 'right problem'. Further, the handbook introduces a 'PBL schema' developed from the collated PBL process, and provides a template to aid course design.

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- co-create (ii) ***online learning modules**** akin to that of a MOOC, each consisting of short videos of 3-10 minutes on lesson lectures and demonstration of tools. These are supported with a printable *Workbook* to track the process and develop the solution, and a *'PBL Impact Canvas'*, a step-by-step guiding framework to engage in discussions, to identify and evaluate the impacts considered by the students in the project.
- In hindsight, (iii) a *ToT (Training of Trainers) manual* was also compiled to help the PBL practicing Teacher/Mentors to 'Develop' the course through identifying the learning objectives, 'Engage' students through time-tested ways, 'Supervise' through motivation and effective feedback, and 'Assess' through formative and summative approaches, based on an assessment plan.

* *All resources developed are open access and available on YouTube.*

2.3. Impact on learners, insights & reflections

To assess the impact of the PBL course/curriculum implementations in the five beneficiary institutes, pre- and post- surveys were conducted by Jurelionis, et al. (2023). The questionnaires were designed to evaluate the perception of distinct competencies or learning outcomes by two major stakeholder groups - *Students* and *Faculty/Teachers/Mentors*, as well as map the expectations regarding which learning outcomes the faculty anticipated achieving and whether students indeed attained them. The number of respondents for each stakeholder group were 75 students pre-Course and 55 post-Course, and 15 Teacher/Mentors pre-Course and 14 post-Course, and the responses were visualised with respect to the appearance of selected keywords. The keywords, in turn, corresponded to the four out of five top skills for industry-readiness as identified by World Economic Forum (2016), namely, *Critical Thinking, Problem Solving, Collaboration or Teamwork, and Communication*. In addition, *'problem identification'* was also assessed as its importance forms the central premise of the proposed 'PBL schema'. The surveys also delved into the PBL practices, encompassing the methods employed in courses, the structuring of the teaching/learning process, logistical considerations, and related aspects. The survey revealed change in perception before and after the PBL course, and the positive impact in the development of the skills.

In parallel, key insights and takeaways from the project implementations were ; PBL courses are best suited for projects that inherently require teamwork and have an inter-disciplinary flavour. It is suited for slightly matured, self-directed students, such as those in their final years who already possess the fundamental knowledge of their domain as introducing PBL approach for core/fundamental topics were found difficult and required meticulous design. Teachers/mentors too required more training to be able to apply PBL generically across wider possibilities and create future course materials, as the trade-off between core subject matter and experience of its real world applications were difficult to negotiate. Despite several dissemination events undertaken to spread awareness on PBL as a pedagogical approach and its rewards, and open availability of resources there has been little to no traction on the further application of PBL at other institutes in South Asia since. The project members reflected and collectively opined that the developed resources were supplementary to the actual mentorship received, which offered hand-holding and immersion to build capacity, and are limited in their ability to support self-learning and course development by individuals who were not part of the project. The most profound takeaway from the project experience was that in spite of the evident success in imbibing industry-readiness and the top skills for employability in students, and availability of a number of resources to implement and develop more PBL courses, the same did not take place sporadically as was envisioned indicating a lack in translation of the training to foster creativity and lifelong learning.

2.4. Evaluation and need for iteration

Evaluation of the project by experts at Academic Section in premier institute of Higher Education in India, comprising of course administrators, educators, senior Faculty members/Teachers, while appreciative of the two-pronged methodology used to inculcate PBL, critiqued that the resources were mere conceptual snippets and not capable of imparting competence to learners. They further

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recommended that more content - in depth and rigor, and mentorship is required to disseminate subject knowledge, and develop skills and abilities in individuals in a subject or domain .
However, they noted that this type of course/training would immensely benefit working professionals engaged in mentor roles and help them upskill. This prompted a hair-pin turn to the approach met so far in imbibing PBL approach through subjects and led to an iteration to flip the focus bottom-up on to the skills intended to be developed with the intent to foster creativity, wider applicability and lifelong learning. Thus, culminating into a comprehensive training program which is presently under production.

3. Development of a PBL massive open online course/training

Open Online Courses and Training has gained much popularity over the past years, more so after the pandemic. While it is an excellent medium to disseminate knowledge and train skills, it may lack the personalised care and mentorship as required by each individual learner or maybe overwhelming for both instructor and leaner, to communicate over a virtual platform amidst several unfamiliar people. In addition, the large number of such courses claiming fame and assured results, lack credibility and proper recognition. While there are several dedicated platforms, be it operated from universities or by Edtech start-ups, there is also the added concern of expense on part of the learner. In contrast, free platforms such as, YouTube, as was used to host the video resources of the PBLSA project, maybe used but as found was not very effective. However, the promise of the Massive Open Online format is great as its reach is mindboggling and has the capability of bringing the best quality education home.

3.1. The 'SWAYAM' initiative

The Government of India has initiated a programme called "SWAYAM", which in Sanskrit implies "*by one's own self*", to offer the best teaching resources to all and leverage digital education based on the three principles of the National Education Policy (2020), i.e, access, equity and quality. The platform, developed under the aegis of Ministry of Education and the National Programme on Technology Enhanced Learning (NPTEL), facilitates various interactive courses, from the level of Class 9 till Post-graduate across diverse disciplines, free of cost or offering certification against proctored examinations at designated centres. The initiative has 9 National Coordinators, 203 Partnering Institutes, over 37 million student enrolments and approximately10,000+ courses for school education to Technical, Non-technical, Management, as well as Teacher training courses.

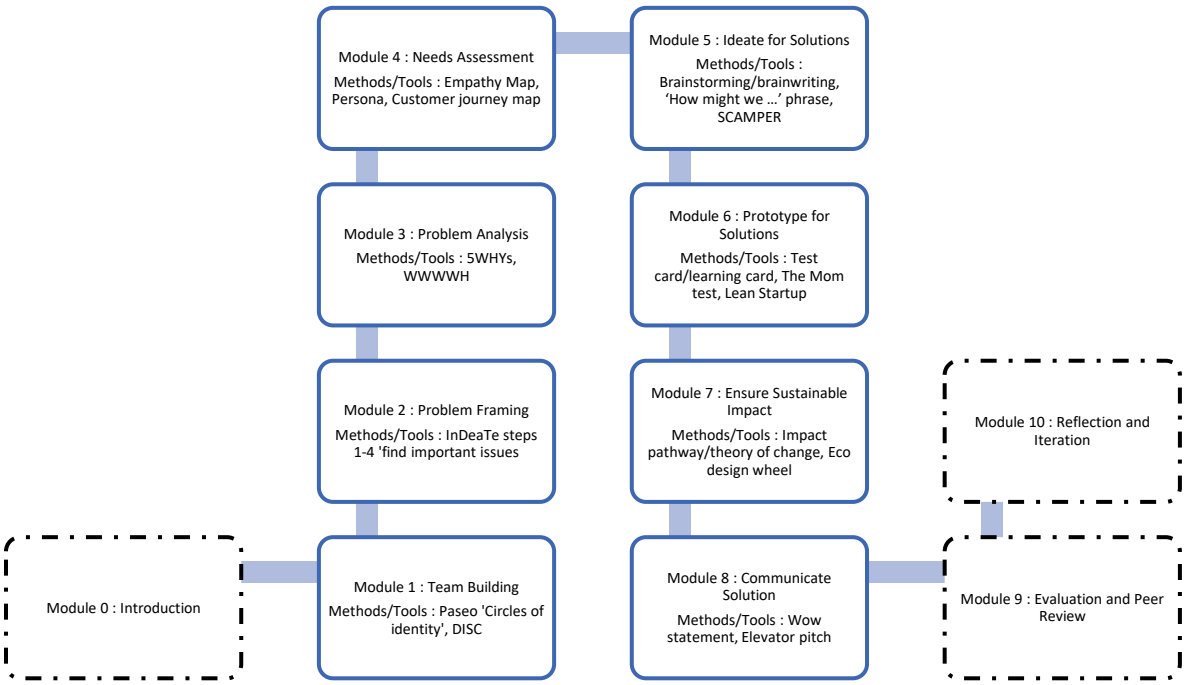

Figure 3. SWAYAM course structure & methods/tools

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Courses are designed to have four facets: (1) *video lectures*, (2) specifically *curated reading materials* available for download/print, (3) *self-assessment tests*, comprising various test and quizzes, and (4) an *online discussion forum*, to address queries and doubts. Presently, credit-transfer to academic record of students are being mitigated through UGC (University Grants Commission) and AICTE (All India council for Technical education for non-technical post-graduate education, and for self-paced and international courses, respectively. The primary motivation, however, is to meet the needs of life-long learning.

3.2. Design of course

The objective of the proposed SWAYAM course, titled "*Design for the Real world: A Problem-based Learning Approach*", is to equip the learner with a selection of theories, practical tools and real-world case examples to develop their problem-solving competence and creative confidence, framed by the Problem-based Learning methodology. It can be widely used to support several domains, and is especially empowering for students and faculty of Engineering and Design, to imbibe creativity and competence through a guided pedagogical approach. It further supports Teachers/tutors/mentors, from secondary school level up to PG, in line with the NEP 2020 that stresses on experiential learning from an early age in India.

Owing to its intended audience, who are primarily under-graduates or post-graduates in a technical domain, the proposed 10 module course is structured into 3 sub-sections; *Introduction* (Module 0 | 2 hrs); *PBL Schema* (Acharya, et al., 2023).*: 'Learning by doing'* (Modules 1-8 | 16 hrs), and *Strategies for PBL Facilitator/Mentor* (Modules 9-10 | 4 hrs), as in (Figure 3). The earlier and latter modules (in dotted boxes, Figure 3) are oriented towards Teachers/tutors/mentors who wish to build capacity, gain a deep understanding of the pedagogy, and develop confidence to implement PBL courses or activities. Whereas the core PBL for upskilling, which is domain agnostic, is offered through the *'PBL Schema - Learning by doing'* subsection, that is furthered from the version proposed during the PBLSA project (as in Figure 3). It is bolstered with richer content, and thorough demonstration of various design methods and tools, which are known to foster creativity (Acharya, et al., 2019).

3.3. Course content: methods/tools to support PBL

The proposed course titled "*Design for the Real world: A Problem-based Learning Approach*" spans over 20 hours of video lectures and method/tool application demonstrations, with 10 modules of 2 hours each. A large component of the modules, particularly those within the *PBL Schema* sub-section, emphasises on the proper use of design methods and tools with the intent to develop the said-skills through *'Learning by doing'*. The appropriate methods and tools are selected from the 'Innovation Design database and Template', i.e., InDeaTe Tool (Chakrabarti, et al., 2017). InDeaTe v.3.0 (Acharya, et al., 2018) is a web-tool that supports Design for Sustainability and foster creativity. It guides designers/learners through a systematic process with its Template and aids the appropriate selection of methods and tools from its Database to undertake design activities.

The following selected methods and tools have been incorporated into the course*, in;

- Module 1 | Building Teams/ Multi-disciplinary Collaboration
  - ***Paseo or Circle of identities*** (Laidley, et al., 2001) tool is useful for initiating dialogue in groups to better understand the issues of identity, diversity, beliefs, and values, and how that shapes one's decisions, through a web of circles. This enables Team members to better understand each other.
  - ***DiSC*** is a personal assessment tool that helps categorise people into 4 major personalities. This understanding further helps communicate and resolve conflict.
- Module 2 | Framing the 'right' Problem
  - ***InDeaTe Tool*** (Chakrabarti, et al., 2017) prescribes steps 1-4 which entails; Select system boundary; Analyse the current situation to identify issues - Systems, Lifecycles and major issues; Select Sustainability Definitions, Goals and Indicators; and Evaluate to 'find important issues'

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- Module 3 | Problem Analysis
  - ***5WHYs*** (Toyoda, 1930s) is a root cause analysis technique, through iterative interrogation, to arrive upon the causal relationships underlying a problem.
  - ***WWWWH*** (Who, Where, Why, When, How) is a simple means to do a stakeholder identification and to better understand the problem space.

Table 1. Detailed online course plan

Module No.	Title / Topics	Exercises	Lecture Hours
0	***Introduction to Problem-based Learning (PBL)*** • Definition and characteristics of PBL • Differences from project-based and case-based learning • Top 5 skills that PBL approach imbibes – Creative problem solving, Critical Thinking, Communication, Collaboration and Self Learning • 'Wicked' problems and importance of identifying 'right' problem • PBL through Design Thinking - A PBL schema	*MCQ (Quiz)*	2
	PBL SCHEMA: 'Learning by doing'		
1	***Building Teams/ Multi-disciplinary Collaboration*** • Understanding teamwork (roles, responsibilities) • How to build a team [Paseo 'Circles of identity', DISC]	*Apply Tools*	2
2	***Framing the 'right' Problem*** • Understanding global challenges, Sustainability and Lifecycle view, and Sustainable Development Goals (SDGs) and Indicators • Frame a Global Challenge [InDeaTe steps 1-4 'find important issues]	*Frame a recent, regional issue*	2
3	***Problem Analysis*** • What is Problem Analysis? • How to do problem analysis? [5WHYs, WWWWH]	*Apply Tools*	2
4	***Needs Assessment*** • What are Needs? • How is Needs Assessment conducted? [Empathy Map, Persona, Customer journey map]	*Apply Tools*	2
5	***Designing Solutions: Ideation*** • What is Ideation? • How to ideate [Brainstorming/brainwriting, 'How might we …']	*Apply Tools*	2
6	***Designing Solutions: Prototyping*** • What is prototyping? How to prototype? • How to test/ validate your solution? [Test card/learning card, The Mom test, Lean Startup]	*Apply Tools*	2
7	***Ensure Sustainable Impact*** • What is sustainable impact and how can you measure it? [Impact pathway/theory of change, Eco design wheel]	*Apply Tools*	2
8	***Communicate the Solution*** • How to communicate effectively [Wow statement, Elevator pitch]	*Make a Presentation*	2
	Strategies for PBL Facilitator/Mentor		
9	***Evaluation and Peer Review*** • What are Learning Objectives and Outcomes? Bloom's taxonomy? • How to offer critical review and develop evaluation plan	*Develop an Assessment Plan*	2
10	***Reflection and Iteration*** • How to improve the process / course? - Reflect • Improve the process / course - Iterate	*Iterate and Present final solution*	2

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- Module 4 | Needs Assessment
  - ***Empathy Map*** is a visual reflection of stakeholders persona, that captures behaviours through four quadrants of 'Says', 'Feels', 'Does', 'Thinks', and aids designers to assess their needs.
  - ***Customer journey map*** is a graphical representation of an individual or stakeholder-type's experience and interactions with 'touchpoints' to identify 'actions'.
- Module 5 | Designing Solutions: Ideation
  - ***Brainstorming/brainwriting*** are ideation techniques to generate piecemeal ideas on various needs identified, collectively, either by verbalising and listing ideas, or by building on a potential idea one by one. It does not give rise to a holistic solution but gives an array of possibilities.
  - ***'How might we …'*** is a popular conceptualisation method to propel 'out of the box' solutions.
- Module 6 | Designing Solutions: Prototyping
  - ***Test card/learning card*** (Osterwalder, et al., 2014) are cards that help in focussed validation of specific hypothesis and learn how to resolve one by one, and can be used throughout the design process.
  - ***The Mom test*** (Fitzpatrick, 2019) is a strategy of getting insights from potential users.
  - ***Lean Startup*** is a product development methodology focussed on market fit and uses " multiple rounds of customer interview and data analysis are used for iterative formulation and testing of hypotheses" (Karia et al., 2022).
- Module 7 | Ensure Sustainable Impact
  - ***Impact pathway*** is a simplified causal chain of events that are of interest and maps the immediate output, intermediate 'outcome' and the overall 'impact'. This is based on the Theory of Change.
  - ***Ecodesign Startegy*** wheel (Brezet and van Hamel,1997) is a checklist to prompt and guide sustainability considerations with respect to the lifecycle of a solution and its impact.
- Module 8 | Communicate Solution
  - ***WOW! Statement*** is a new age sales strategy to use simple language and few sentences that conveys the essence of the solution, and creates interest and connect with the potential users.
  - ***Elevator pitch*** is also a sales strategy where one has only 30-60 seconds to present the most salient features or Unique Selling Point of the solution, that set it apart from the competition.

*Modules 0, 9 and 10 are primarily Lecture-based, discussing various examples and promoting the use of several of the above taught methods/tools to assess, review, reflect and iterate. Hence, explicitly not mentioned.

4. Summary, discussions and future work

This paper presents the theoretical and practical background that evolutionarily led to the development of a Massive Open Online Course on India's largest, free Digital Educational portal - SWAYAM, to develop top skills and competences in under-graduates and post-graduates in industry and academia. The proposed course, titled "*Design for the Real world: A Problem-based Learning Approach*", leverages the learner-centred pedagogical approach of Problem-based Learning (PBL) which is known to stimulate deep learning (Dolomons, et al., 2016), recognised by the Bologna Declaration (1999) as an indicator of "*successful learning*". The Process further identifies the key challenges of *'shortage of skills in critical areas'* and *'employability of graduates'* as a measure of quality of higher education, and to address the same, the Erasmus+ Capacity Building in Higher Education (CBHE) project, "*Strengthening Problem-based learning in South Asian Universities*" (PBL South Asia) was conceptualised. The project entailed; Capacity-building activities based on a proposed 'PBL schema' that imbibed PBL through Design Thinking, and development of several open access Resources to support learners, who were primarily either Teacher/mentors or students. However, upon culmination of the project, reflections revealed that while the project outputs and outcomes are the cornerstone to inculcate PBL, further development of some course-like resource can add the much-required value to those in the job-market or actively involved in teaching/mentoring but do not have the opportunity to

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re-skill or upskill through hand holding or immersive capacity building activities as in the case of PBL SA. More importantly, it was arrived that this course would be best served through massive, open online access with a self-paced learning modality, as offered by SWAYAM. Therefore, the proposed course built further on the 'PBL Schema' and developed 10 modules of 2 hours each, covering three main sub-sections, namely; the Introductory (Module 0) which is primarily knowledge intensive and lecture based; the 'PBL Schema : Learning by doing' (Modules 1-8) which is the crux of the Problem-based Learning, through demonstration of aptly selected design methods and tools known for fostering creativity from an established repository; and 'Strategies for PBL Facilitator/Mentor' (Modules 9 & 10) which is designed to enable Teacher/mentors to develop PBL courses and projects, and engage, supervise and assess the team through the process. The core contribution of the course would be to enable learners to follow problem-based inquiry independently, with the aid of the taught methods and tools, and practice self-learning.

PBL courses and curriculum have been adopted, in part or as a whole, across various domains, such as, schools of business, education, social work, law, architecture, engineering, and at varying levels, such as, graduate and undergraduate programs, high school, etc. (Savery and Duffy, 1995) but upon experiencing implementation, it has been noted that the true value of PBL pedagogy is in offering exposure to real-life applications and augmenting subject learning. To translate the learnings from a PBL approach and expand its positive effects in nurturing the hard and soft skills, the proposed self-directed MOOC has been conceptualised for a wider and more mature audience, i.e., graduate and above, where the focus is on the approach rather than a subject of interest. While in tune with the original project intent, it is the outcome arrived upon to address the lacunae in the initially developed resources and its mode of delivery, and the challenges faced in ensuring longevity of the envisioned impact of the project. This paper presents almost a hair-pin bend in the conventional strategy to imbibe a pedagogical approach by flipping to a bottom-up focus on the skills intended to be developed rather than skilling through a subject.

Presently, the course is under production and future work includes formalising it into a certification course with proctored exams and further live discussions and demonstrations. Further enriching of the list of design methods and tools and expanding the knowledge to other design process guidance maybe introduced, as design is inherently a problem-based learning pursuit.

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References

Acharya, S., Bhatt, A.N., and Chakrabarti, A., (2023), "Problem based Learning through Design Thinking to strengthen education in South Asia", In Proceedings of the Design Society: International Conference on Engineering and Product Design Education (E&PDE23), Spain.

Acharya, S., Bhatt, A.N., Chakrabarti, A., Delhi, V.S.K., Diehl, J.C., Mota, N.J., Jurelionis, A., and Subra, R. (2021a), "Design Thinking as a strategy to inculcate Problem-based Learning (PBL) in undergraduate education across South Asian Universities". In Proceedings of International Conference on Research into Design. Springer, Singapore.

Acharya, S., Bhatt, A.N., Chakrabarti, A., Delhi, V.S.K., Diehl, J.C., van Andel, E., Jurelionis, A., Stasiuliene, L., De Jussilainen Costa, L., and Subra, R. (2021b), "Problem-based Learning (PBL) in undergraduate education : Design Thinking to Re-design Courses", In Proceedings of International Conference on Research into Design. Springer, Singapore.

Acharya, S., Bhatt, A. N., Chakrabarti, A., & Nagai, Y. (2019). Fostering creativity in design-An empirical study on improvement of requirement-satisfaction with introduction of InDeaTe tool. In Proceedings of the Design Society: International Conference on Engineering Design (Vol. 1, No. 1, pp. 3631-3640). Cambridge University Press.https://dx.doi.org/10.1017/dsi.2019.370

https://doi.org/10.1017/pds.2024.281 Published online by Cambridge University Press

Acharya, S., Chatty, T., Ranjan, B. S. C., Ghadge, K., Bharath, P. A., & Chakrabarti, A. (2018). InDeaTe 3.0: An Ontology based, generic design process guidance web-tool. In DS 92: Proceedings of the DESIGN 2018 15th International Design Conference (pp. 137-148).
Albanese, Mark A., and Susan Mitchell (1993) Problem-based learning: A review of literature on its outcomes and implementation issues. Academic Medicine- Philadelphia- 68, pp. 52-52.
Barrows, Howard S (1996) What Your Tutor May Never Tell You: A Medical Student's Guide to Problem-based Learning (PBL). Southern Illinois University School of Medicine, 1996.
Birgegård, G., & Lindquist, U. (1998). Change in student attitudes to medical school after the introduction of problem-based learning in spite of low ratings. Medical education, 32(1), 46-49.
Caswell, C. A. (2017). Design and facilitation of problem-based learning in graduate teacher education: An MATESOL case. Interdisciplinary Journal of Problem-based Learning, 11(1).
Chakrabarti, A., Acharya, S., Ranjan, B. S. C., Devadula, S., Ghadge, K., Madhusudanan, N., ... & Rachuri, S. (2017). InDeaTe—A Computer-Based Platform with a Systematic Design Template and a Database of Methods and Tools. In International Conference on Research into Design (pp. 277-289). Springer, Singapore.
Declaration, Bologna (2009) The European Higher Education Area, Joint Declaration of the European Ministers of Education, convened in Bologna, 19 June 1999. Retrieved November 8 (1999).
Denton, Betty G., Cara C. Adams, Phillip J. Blatt, and Christopher D. Lorish, (2000) "Does the introduction of problem-based learning change graduate performance outcomes in a professional curriculum." Journal on Excellence in College Teaching 11, no. 2-3: 147-162.
Dolmans, D. H., Loyens, S. M., Marcq, H., & Gijbels, D. (2016). Deep and surface learning in problem-based learning: a review of the literature. Advances in health sciences education, 21(5), 1087-1112.
Duch, Barbara J., Susan E. Groh, and Deborah E. Allen (2001) The power of problem- based learning: a practical" how to" for teaching undergraduate courses in any discipline. Stylus Publishing, LLC..
Gijselaers, W. H. (1996). Connecting problem-based practices with educational theory. New directions forteaching and learning, 13-22.
Hmelo-Silver, Cindy E (2004) Problem-based learning: What and how do students learn? Educational psychology review 16, no. 3, pp. 235-266.
Jurelionis, A., Stankeviciute, G., Dhital, A., van Andel, E., Sundman, J., Stasiuliene, L., Acharya, S., Subra, R., (2023), "Exploring the impact of Problem-based learning on student learning outcomes: Findings from the PBL South Asia project", In Proceedings of SEFI Annual Conference 2023 on Engineering Education for Sustainability, Dublin.
Karia, D., Shah, K., Venkatesh, K., Acharya, S. and Arora, M., (2022). A Comparative Analysis of the Engineering Design and Lean Start-Up Innovation Methodologies. In Proceedings of the Design Society: International Conference on Engineering Design, (Vol. 2, pp.31-40). https://dx.doi.org/10.1017/pds.2022.4
Mills, Julie E., and David F. Treagust (2003) Engineering education—Is problem-based or project-based learning the answer." Australasian journal of engineering education 3, no. 2, pp. 2-16.
Rideout, Elizabeth, and Barbara Carpio (2001) Learning Model of Nursing Education." Transforming nursing education through problem-based learning. pp. 21.
Savery, John R (2015) Overview of problem-based learning: Definitions and distinctions. Essential readings in problem-based learning: Exploring and extending the legacy of Howard S. Barrows 9 pp.5-15.
Savery, J. R., & Duffy, T. M. (1995). Problem based learning: An instructional model and its constructivist framework. Educational technology, 35(5), 31-38.
Schmidt, Henk G., Henk T. Van der Molen, Wilco WR Te Winkel, and Wynand HFW Wijnen (2009) Constructivist, problem-based learning does work: A meta-analysis of curricular comparisons involving a single medical school." Educational psychologist 44, no. 4, pp. 227-249.
Torp, Linda, and Sara Sage (2002) Problems as Possibilities: Problem-Based Learning for K-16 Education
Vernon, David T., and Robert L. Blake (1993) Does problem-based learning work? A meta-analysis of evaluative research. Academic medicine .
Williams, A., Williams, P.J., Ostwald, M. and Kingsland, A., 1994. Problem based learning: An approach to teaching technology. Research and development in problem- based learning, 2, pp.355-367.
Yadav, Aman, Dipendra Subedi, Mary A. Lundeberg, and Charles F. Bunting (2011) Problem-based learning: Influence on students' learning in an electrical engineering course. Journal of Engineering Education 100, no. 2, pp. 253-280.

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