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Design alignment between transformative actions and epistemic agency for physics postgraduate PBL course

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Abstract. There is a broad consensus on the benefit of problem-based learning (PBL) in teaching and learning. While the methodology has its specific focus on transforming students' epistemic consciousness into 'learning to know', its assertions on the transition are often directed towards changing the long-held habit of the behaviour of 'learning to do'. This paper presents an instructional design strategy designed for transformative action and epistemic agency. The curriculum design aims to provide students with emancipation. The philosophy in critical pedagogy is incorporated as a strategic move in PBL during The Philosophical Issues in Science, Mathematics, and Technology course designed for the STEM education of postgraduate students. This study aims to illustrate a curriculum design that can shape the circumstances identified in the PBL process. The PBL activities were designed to enable the students to critically review competing values and practices and empower them to make decisions and act for change. The assessment stage showed that their transformative acts were expressed through thinking and values. During reconstruction, the students were able to reflect and reframe the current practice in teaching and learning using the alternative teaching paradigm. Following the proposed framework, the PBL approach was modified to tap into epistemic dissonance that often explains *the way things are*.

1. Introduction

High-quality professional development today could inflict a tension between the identity and perceived identity of science teachers. Many contextual factors could shape a teacher's identity, including his/her continuing to study for professional development. With the advent of Industry 4.0, physics education for postgraduate programmes has been shaped by new teaching and learning approaches, including the stereotypes rooted in the approaches. Like undergraduate learners, postgraduate learners are exposed to knowledge and thinking and professional skill sets, such as communication and team-working, aimed at twenty-first-century learners. The Global Competitiveness Report 2016 – 2017 published by the World Economic Forum [1] enlists a host of critical professional skills that graduates should possess. Such is in line with the current requirements by graduate faculty members in Malaysia that begin to realign the program learning outcomes with the standard required from postgraduates.

Problem-based learning (PBL) is a teaching approach that uses problems to build new knowledge. PBL is widely known for its application among university students to harness their collaboration, communication, and sophisticated thinking skills [2]. The approaches in PBL follow the current

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educational paradigm or learning theory, which posits that knowledge is actively constructed by the learners and not passively received from the teachers [3]. This educational philosophy—constructivism—is not new to Malaysians as it has been documented since 2003. However, the philosophy is challenging for those who are used to predominantly learn under a philosophy that focuses on content transmission, resulting in conflicting beliefs [4]. Several studies have seen such transition as challenging to PBL instructors because the learning turned out to be overly prescriptive [5] and monetized as a meaningful learning outcome.

Unlike undergraduate students who might experience social or academic adjustment, postgraduate students are exposed to the status quo between new knowledge and existing practices as teachers. Therefore, the design and planning of PBL for postgraduate courses require course designers to be cautious about the over privilege of students' mastery progress that PBL practitioners often do. PBL advocates transformation because the existing habitus was discovered to harden as students embarked on learning [6]. The purpose of this study was to integrate a new theoretical perspective into learning outcomes as described in the curriculum, including communication skills, and to illustrate the role of critical pedagogy as strategic execution for PBL.

The author of this paper is the course designer of postgraduate courses offered in chemistry, mathematics, and physics education programmes. This paper is presented as a continuous quality improvement (CQI) measure of the philosophical issues in Science, Mathematics, and Technology course outcomes. During her three years of teaching this course, the author has conducted design development research to map the alignment between students' habitus, disciplinary culture, action transformation, and teaching approach. This paper discusses only the development of a critical pedagogy framework in problem-oriented lessons.

2. Critical pedagogy for postgraduate student

PBL practitioners place 'problem' at the centre; it is a standpoint that promotes a conception of knowing as learning to do. Students are usually placed in a situation requiring them to exhibit actions like collaborating to achieve the agreed objectives. Habermas [7] describes this as normative in which learning is oriented to shared values and a normative sense of entitlement (members of the group are entitled to expect particular behaviour). However, such a notion is limiting because mature learners' agentic moves tend to exercise control over their meaning-making, which shows high collectively. Various professional backgrounds characterise students undertaking this course; they are either experienced, intermediate, or novice teachers. They could have invested themselves in the well-accepted norms of thought and action in teaching.

Though the characterisation of PBL as practice recognises individual and social structure, what is largely missing from this implementation is the role of a modest example of infusing PBL with critical pedagogy.

Under the banner for transformative education, Freire [8] introduced critical pedagogy, which proposes that learning must overcome oppression. Through critical pedagogy, teaching is directed to attend to learners' consciousness, thus enabling emancipation. Such implies that learning is designed to introduce alternative norms to learners' practices from their profession. Many studies have attempted to define authentic learning mentioned by Freire [8] in materialising critical pedagogy into practice. To science educators, such "authenticity" resonates with the discussion of STEM teachers' identity. "Authenticity" is translated not only as of the self-views of science teachers but also as socialisation into the norm and discourse of scientific practices [9]. Others in Malaysia have risen to the challenge with the influence of Vygotsky because occupying critical pedagogy does not come with a manual on how social transformation can be mapped as an instructional strategy.

Sociologists define agency as the formation of self, and the definition remains a reference point for explaining the learning ecosystem in a PBL class. To sustain interest to assist postgraduate students in developing new proficiency, PBL must navigate the learning impact based on their experiences as teachers. Davidson Jaber and Southerland [10] point out that teachers rarely engage with the experience drawn from refining prior understanding. The limited access to continuously engage with

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their existing practice has caused teaching postgraduates via PBL to become relevant for this study. This study aims to share how the PBL approach can be expanded as a lifelong learning experience for continuous professional development among teachers. This rationale is based on Ivmark and Ambrose's [6] remarks about the mismatch between dominant disposition from learning and students' habitus. In this context, the implementation of PBL must be targeted towards transforming the existing habitus set in place by teaching and learning experiences in the past. Studies on PBL focus on the likely knowledge production from the PBL approach. Nevertheless, as postgraduate students display different attributes as mature learners, more explanation is required on the interplay of epistemic agency to shape transformative action during knowledge development. PBL implementors have designed PBL to enable an epistemic agency for transformative action considering this habitus. Teaching teachers who choose to continue learning at graduate school have an opportunity to dethrone and upgrade the existing practices. This account can be understood by designing a condition for learning with an epistemic agency as their account for reasoning. Hence, PBL is redesigned in this study where epistemic agency and transformative action are conjointly used to determine students' trajectories to reshape their practice.

3. Method: Instructional design using critical pedagogy in PBL

It is not clear from previous studies how critical pedagogy was dissolved in practice, particularly PBL. However, previous studies have made clear the assumptions that lie within this pedagogy. It is crucial to identify what characterises the outcomes, roles, sequence, continuity, and integration of this course at the early stage. The biggest fear in designing this course is to conceptualise the pedagogical practices for transformation actions. The course was designed using the PBL approach but targeting the structural condition as the problem to be acted upon to draw a bridge between students' consciousness and action. Rather than claiming that introducing real-life problems is an effective way to fill the gaps in students' knowledge, critical pedagogy is at the forefront of PBL to works with diverse manifestations about subjugated teaching practices in science education.

3.1. Step 1 Articulating critical pedagogy into PBL

First, critical pedagogy requires revisiting institutional discourse [9]. Teaching the argumentative movement for science education aims at the narration surrounding the argumentation views, models, and disagreements. It requires learners to understand the normative consensus and its role. Second, critical pedagogy seeks learning that enables learners to act upon the disposition and act on by a new disposition [11]. Students will continuously deconstruct, construct, and reconstruct new meanings about the topic discussed in this scenario. Third, critical pedagogy requires facilitation to focus on reflexive deliberation and be used later for learners to pursue the planned course of actions stated [12]. While this takes action, teaching requires students to identify cultural assumptions that constrain them to see, act, or feel the way science teaching must be orchestrated. Last, the transformation only occurs within the self, and sustaining the transformation is a cumulative process [13]. The sequence of learning thereby must assess before, during, and after the process of transformation. Instructors must focus on the density of the discourse during this period to facilitate the shifting perspective held by students. Students eventually have to infer from the changing representation to their perspective as their goals for learning.

This present study seeks to apply and adapt critical pedagogy in PBL to develop its capacity to be reflexive on the teaching practices among postgraduate students. Presumably, the more consistently emancipation is presented in lessons, the stronger the transformative action will be delivered by the epistemic agent. Thereby, by adopting the basic PBL features below by Peterson and Treagust [14], the following steps are used with modifications:

1. Define and frame the problem to identify learning needs
2. Allow students to plan for their course of action to investigate the needs.
3. Independent and group investigation
4. Develop and present artefacts
5. Analyse and evaluate the problem-solving process

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3.2. Step 2 Identify types of knowledge and direction for transformative action

The process begins with identifying the knowledge of the subject to be used as the common goal in learning. About the common goals, no proclaim that they are the standard that learners must achieve; neither direct the course of the activities. The focus of the postgraduate courses in this study was to provide conditions that enable postgraduate students to develop the knowledge base for teaching science with philosophy and make reasoned judgements on their existing teaching practice, referred to as an emancipation opportunity.

PBL usually comes from a problem-centred design curriculum; critical pedagogy, on the other hand, is under the radical design camp. Bridging these two for this course requires PBL not only to assist students' problem-solving skills but be extended to avoid them from accepting and prolonging the status quo of the problem addressed in PBL. Mezirow and Associates [13] enlist the following types of transformation: (i) learning through elaborating existing frames of reference, (ii) learning new frames of reference, (iii) learning through transforming habits of the mind, and (iv) learning through transforming points of view.

In the view mentioned above, the learning need is a coin when students become critically aware of how and why the identified circumstances constraint the way they understand scientific knowledge, science discourse, and ways of knowing in science lessons. The acquisition account that binds students' actions must envision transformative actions with goal-oriented movement. It was started with identifying the outcomes of an epistemic agency that can be resourceful for transformative actions. Table 1 summarises the role of the instructor, students, and instructions meant to be the sources for change. The instructor for this lesson plays a role as an awareness maker, particularly by identifying, projecting, and positioning emancipation opportunities to students. The instructor relies heavily on the discourse associated with what do you want in this situation instead of what the problem wants you to do, like in a typical PBL class. Students are allowed to critique knowledge starting from their self-knowledge.

Table 1. Alignment between agencies, epistemic agency, and planning.

Agencies	**Epistemic agency**	**Plan took by the instructor when designing alignment**
Instructor	Provide windows for emancipation in every phase of lessons	Problem is introduced in the form of assumptions. These assumptions are later examined for their content, premise, and process of being. The instructor is responsible for creating a dialogic environment by forming and reforming students' assumptions about their self-knowledge. Students' epistemic agency is guided to respond to the 1. conscious joint purpose of science norms in school. 2. demand presented by science education scholars, practitioners, and policymakers.
Students	Identify actor in the discussion, manipulate the previous stage of thinking and behaving as the problem that needs to be solved	Explore the process of change by documenting the process into a portfolio.
Instructions	Provide students with the competencies needed to correct that the issues students identified	Equip students with two skills as the tool during activities for them to plan their discourse and actions. 1. Argumentative 2. Self-reflexivity

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3.3. Step 3 Implementation design framework

The implementation framework (Figure 1) illustrates the course's ecosystem established in Step 1 and Step 2. The concept's development in the course is limited to the subject matter and the learning that is made personal to them. The figure illustrates how critical pedagogy informs the PBL process. The subject matter was developed with argumentation and reflexivity as the backbone of the concept's growth, shown in Figure 1.

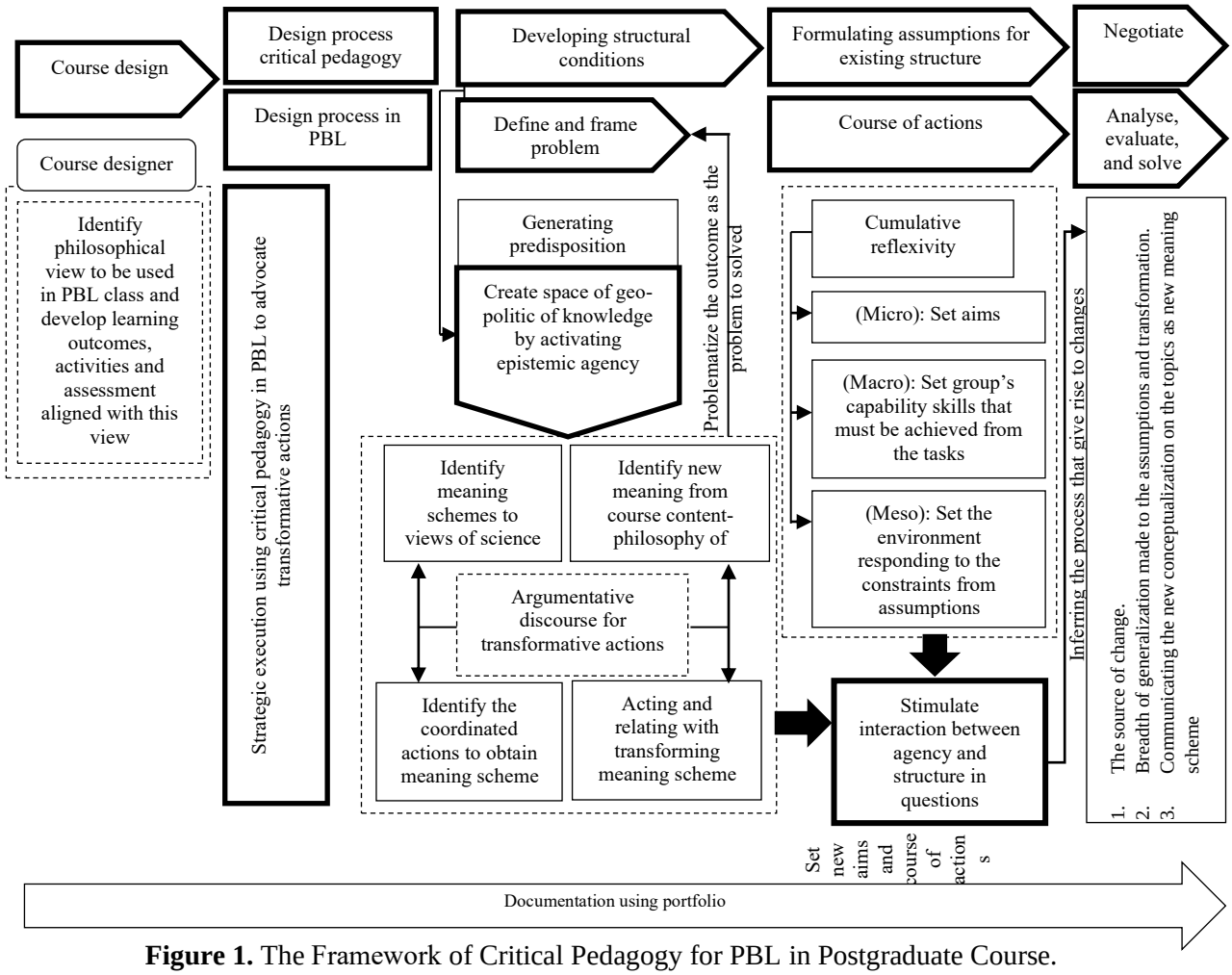

Figure 1. The Framework of Critical Pedagogy for PBL in Postgraduate Course.

Structural condition refers to students' experience in teaching. The structure was conceptualised as students synthesizing the interaction of different agencies (e.g., curriculum developer, administrator, teachers, and so on). Findings from the synthesis are presented as the existing structure for teaching science as emerged from the interaction. Here, every activity employs a student's epistemic agency. Often students at this phase recognise themselves as not having a say in the structural forming like I am just teaching, or I just follow what our ministry wants. It is known as simply living in the social environment; the scenario is often reported as resistance to change [15]. The meaning they have towards their practice later is diagnosed with different activities, resulting in opportunities for emancipation. In the PBL tradition, problems are constructed by the instructor and reduced to students but ("problems" here refer to the emergence of students' interaction with self-knowledge).

Accordingly, students learn how they would respond to the structural form of how science must be delivered in teaching. They begin to identify how they would react to changes in science teaching and improve themselves by coordinating their course for actions to match the standard. Some may not

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subscribe to any set of actions. The analysis addresses the micro, mezzo, and macro parts of their experience in teaching. The instructor at this phase must guide the students to see how their aim and actions coordinate and match expectations. Contrast is made when the students are introduced to the subject matter of the courses (like the philosophy of science, nature of science, science discourse, and others), which scholars have collectively presented to impact scientific knowledge development. The students' self-knowledge is continuously argued to reflect its consequence when examining their coordinated actions.

The discussion held in previous activities will eventually lead students to recognise the need for change. The instructor is responsible for building the students' collectivism to solve problems in their teaching culture, particularly by setting new aims and courses of action. The students must now seek information that can be resourceful to explain the process of change. In the last phase of learning, the students are directed to solve problems within the existing practice and expand the solution to yield new structural conditions. They can be required to formulate a new rule for predicting educational outcomes for science learning to replace the current way to frame outcomes. Table 2 shows how the lesson was carried out with the expected outcomes that rely primarily on emancipatory knowledge towards declarative knowledge (topics).

Table 2. Alignment between instruction and class activities.

Instructions, given to students	**14 weeks for a semester**	**Topics**	**Activities**	**Expected outcomes**
Reflection on who we are, what we have, what we want to go, why we want to go	Week 1-2	Ontology, epistemology, and axiology •Learning theories and philosophy •Brief introduction on Nature of science (NoS)	Paradigm analysis, constant comparative analysis between practices and design, self-reflexivity	Diagnostic evaluation on self-knowledge
Critical analysis on the habit of mind and chosen curriculum approaches	Week 3-4	Type of knowledge •Nature of science (NoS), mechanistic reasoning, and other •Instructional design	Lesson plan and classroom talks analysis, self-reflexivity	Deconstruct self-knowledge
Gathering resources, creating ideas, and constructing new meaning	Week 5-7	Science education outcomes for STEM •Mapping using CA	Curriculum analysis in comparison with a political movement in science education, self-reflexivity	Develop shared awareness on the topics and establish clarity about the nature of science through developing lesson plans using underpinning philosophy
Integration of newly constructed knowledge	Week 9-10	Argumentation •Conceptual change •Developing a lesson using the philosophy of science	Instructional design teaching with the philosophy of science, self-reflexivity	Reconstructing new lessons with an initial plan for changes in instructional design and ideas development

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Carrying out reconstructed knowledge	Week 11-13	Science communication-culture and language in science education	Developing a storyboard that explains the reconstruction lesson	Instructional design for dialogic discourse
Reflection on the impact created by new aims and course of actions on personal development as teachers	Week 14	Role of reflexivity and reflection for continuous professional development	Revisit self-reflexivity from construction until implementation	Re-examination on the micro changes and conceptual development on topics

4. Discussion

Previous works suggested the various ways of implementing PBL for postgraduate students, such as by integrating new skills like creativity, refining the steps taken to conduct PBL [15], and varying the ways problems can be formulated for students [12]. In this course, the tradition of PBL was modified to suit learning practitioners and comply with the learning outcomes targeting professional development. Problems related to practitioners in science education, particularly in Malaysia, include the lack of opportunity to grow professionally within the discipline. Teachers of science education are put in a position that requires them to adapt to the changing demands of the subject matter. Hence, it needs a transformation of practice. As a local scholar in this field, the researcher has been involved with several projects targeting introducing PBL and inquiry-based learning (IBSE) to teachers. The biggest struggle among the teachers is their lack of emancipation despite the opportunity given for a change. Such a dilemma has become one of the factors that necessitate a critical pedagogy.

Indeed, the idea of critical pedagogy is not new to PBL practitioners who understand that learning is culturally mediated. The critical pedagogy introduced in this paper can help to expand the scaffolding and facilitation process in PBL that locates epistemic agency within the participants. Following Habermess' definition of the meaning scheme [2], the course pays attention to students' reflexivity in each phase and their struggle to deliver their sense of self as practitioners in teaching. Table 3 illustrates how the framework is broadened by instilling critical pedagogy. The mechanism of the framework has yet to be evaluated, but it follows the fact that PBL is often conceptualised as a problem-solving process. The selection of cognitive interest is emancipatory; the course instructor focuses on self-knowledge and social expectation as the problem that must be deconstructed, constructed, and reconstructed. All the talks that take place during lessons are subject to these conditions. Such circumstance is helpful to create a context and identify circumstances by allowing students to search for missing pieces in the existing practices. The mapping below shows how instilling the critical pedagogy allows the instructor to identify and intervene in changing behaviour and thinking.

Table 3. Mapping the critical pedagogy to the PBL approach.

	PBL	**Critical pedagogy**
Phase	*Define and frame problem*	*Developing structural condition*
Action	Read problem, identify learning issues	Self-examine and formulating assumptions towards self by identifying premises to self-knowledge
Phase	*Course of actions*	*Formulating assumptions for existing structures* *Stimulate interaction between agency and structure in questions*
Action	Identify what will the students need to do to gather	Identify existing solutions taken by themselves and the process of change that led

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	information.	to issues. The planning of actions focuses more on what has been done rather than what needs to be done.
Phase	*Analyse, evaluate, and solve*	*Negotiate*
Action	Identify new ideas and facts that they have in hand and a possible action plan to integrate both. Students will be evaluating the performance of the solution too.	In this mode, similar to PBL tradition, they need to offer a solution to the problem. Students must enact the problem instead of act on the problem. In this sense, students must renegotiate between self-knowledge and action delivered. Those processes are validated through argumentation.

The opportunity of this framework to facilitate teaching for postgraduate students helps create conditions that are the most conducive for a transformative act to occur. Since this approach was still preliminary, a limitation was seen as the lack of specific parameters to oversee the transition. At the moment, the suggested assessment for this course was a portfolio through which students recorded all the reflectivity and analyzed their transition and knowledge growth. The idea is to assess whether the framework could influence navigating an epistemic agency in the transformative act. The students were guided to do self-scaffolding, and the instructor must have had the capacity to understand the changing discourse behaviour. In each section, the discussion was preceded and followed by an attempt for coherent concept development. The progression in the actual classroom was challenging because of the interplay between declarative and emancipatory knowledge. With the standard practice in PBL, instructors would understand that students differ in terms of the amount and type of declarative knowledge. However, in this course, the framework considers students to be complex agents; the idea targets only declarative knowledge, which may confine the agency as it only promotes the course's values. The successful use of this framework comes from the gradual process of internalisation. Many instructors face a significant challenge in guiding the growth of reflexivity in learning.

Within this study, the implication of empowering agency was affording students to build agentic perspectives to initiate change within their own's existing practices. The framework offered here exposed students to reflexive deliberation [16] by leveraging artefacts and resources most familiar with: personal reasoning. In addition, the framework allows the researcher as an instructor to examine a real-world problem which often stigmatized as problematic and challenging development in a PBL course. The portfolio employed as part of the formative assessment allows this study to obtain a clear intersection of the dilemma and act of individual agency when making a move responding to changes in curriculum. It remarks a vital aspect for new instructors of postgraduate studies. The structure provided by the framework is needed to avoid presenting factual information to adult learners with works experience.

5. Conclusion

The work presents the interrelationship between critical pedagogy and PBL approach through a framework designed based on the recommendations by several prominent scholars in the field, such as Mezirow, Habermas, Freire, and Archer. When designing the curricular alignment, it is crucial to identify areas for innovation that allow the learning to have a breadth of learning outcomes. The framework's conceptual principle is the use of the epistemic agency as the area of potential for self-scaffolding without rejecting the collaborative process for meaning making. Thus, in this PBL, self-reflexivity and emancipatory can be achieved when (i) learning is promoted as a process and (ii) communication is the medium manipulated to achieve the outcomes. Similar to PBL, this framework manipulates learning issues to develop criticality and possibility for discussion among students. Expanding the standard practice through critical pedagogy allows students to act on the learning issues and understand how they affect themselves. The experiences obtained from designing the alignment

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can help a designer consider all characteristics that interplay with the growth of knowledge. Since this framework is still preliminary, further testing and evaluation are needed, particularly for an assessment that requires mapping for knowledge growth.

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