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H-CUP: Increasing Higher Order Thinking Skills Levels through a Framework Based on Cognitive Apprenticeship, Universal Design and Project Based Learning

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Abstract

The current 4th Industrial Revolution (4IR) has brought about the need for workers who not only possess technical skills but also have the necessary Higher Order Thinking Skills (HOTS) to be able to apply this knowledge. The new mandate for educators is to produce these workers by transforming from the traditional instructor-centric teaching model to a student-centric one that prepares students to be life-long learners who not only acquired technical knowledge but also possess the ability to use and apply this knowledge. This paper proposed a pedagogical framework based on a merger of Project-Based Learning (PBL), the Universal Design Learning (UDL) framework, and Cognitive Apprenticeship (CA) Model with the aim of increasing the expertise and HOTS level of students, no matter their learning style. The framework has been implemented for the past 2 years and analysis of results has shown, despite the changing of delivery mode due to the COVID-19 pandemic, that students were able to: 1) acquire and increase their domain knowledge, 2) acquire procedural and process knowledge while solving problems, in given scenarios, as they utilized different methods, procedures, algorithms and techniques, and 3) increase their HOTS competencies.

Keywords

Project-Based Learning, Higher Order Thinking Skills, Universal Design Learning Framework, Cognitive Apprenticeship, Pedagogy

1. Introduction

The digital revolution of the 20th century has ushered in the current 4th Industrial

Revolution (sometimes called the 4IR or Industry 4.0) that has disrupted and changed the way we live, work and relate to one another. The speed, scale, breadth and depth of this revolution are forcing us to rethink how countries develop, how organizations create value and even what it means to be human. Breakthroughs are imminent which will and are changing the look of the workforce. This can be seen in the Institute for the Future (IFIF) 2018 report which stated that 85% of the jobs that today's students will do in 2030 do not exist yet (Dell, 2018). Filling these jobs could prove difficult as they might require skills that potential employees haven't even thought of, or developed yet. For over seven years, the top skills desired in employees are creativity and originality, problem solving, communication and collaboration, critical thinking and analysis, analytical thinking and innovation (NACE, 2021; WEF, 2020; LinkedIn, 2019; NACE Staff, 2019)—all considered Higher Order Thinking Skills (HOTS). Although these skills are not prerequisites to making a job transition, the long-term productivity of employees is determined by their mastery of these competencies.

4IR has however produced a generation of employees who tend to research, learn, find solutions and make decisions mainly depending on search engines. This learning and thinking behavior in the workplace is caused by the absence of work experience as well as a deficiency in soft skills such as critical thinking skills (Qiu, Xu, & Omojokun, 2020; LinkedIn, 2019). Employer surveys (NACE, 2021; LinkedIn, 2019; NACE Staff, 2019; Wiley, 2019) support this finding showing that college graduates consistently fall below the desired proficiency level for the desired soft skills. There is now a need to produce the necessary qualified workforce to fill the increasing gap between supply and demand (WEF 2020). The problem according to employers however is that education has "done little or nothing to address the skill shortage" (Wilkie, 2019). Colleges tend to teach graduates about content and not how to teach, use or understand its importance (Wilkie, 2019). They are struggling to prepare students who have these desired soft skills and as such the IFIF reports that this demand "seriously challenges traditional [learning] establishments" (Dell, 2018).

Employers are demanding employees who have the ability to be fluid in skill sets as well as the ability to apply their knowledge in unknown and evolving circumstances (OECD, 2018) thus the problem of graduates possessing technical skills but poor soft skills must be addressed (Schooley, 2017). Higher Education institutions must now find multifaceted approaches that allow for the teaching of content while embedding the soft skills with the aim of moving students from regurgitation of facts to the application and critical evaluation of knowledge in real life scenarios. No longer can educators draw only from their own learning experiences to inform their instruction—they must now prepare students to perform things that are outside their own learning experience. This now shifts attention from what students know or submit for a grade to how they learn or the processes of learning. Educators must now teach students how to teach themselves to survive this ever-evolving workplace.

This paper seeks to address this problem by proposing a pedagogical framework that is designed to increase students' soft (HOTS) skills while increasing their expertise, thus producing graduates who meet the needs of the employers, having both technical and soft skills. Its implementation has been, for the last two years, in an undergraduate Computer Science course in a Historically Black University (HBCU) in the State of Virginia, USA. Section 2 will discuss what is considered to be HOTS competencies while section 3 examines the teaching strategies that influence the proposed development. Section 4 seeks to introduce the proposed framework with some qualitative evidence showing effectiveness introduced in Section 5. Sections 6 and 7 provide a summary, conclusion and future plans.

2. Higher Order Thinking Skills (HOTS)

Soft Skills called 21st Century Skills is a combination of 12 knowledge, life and career skills, habits and traits that are critical to a person's success in today's world especially in college and the workforce as they contribute primarily to interpersonal relationships (Dogara, Saud, Kamin, & Nordin, 2020). These skills are placed into 3 categories of which the Learning skills category focuses on the mental processes required to allow adaptation and improvement in the workforce. This category contains the 4 Cs—collaboration (ability to work in a team to solve problems), communication (ability to organize thoughts, data and findings and share effectively through different media), creativity (ability to generate and refine solutions to complex problems and present them in a new and original way) and critical thinking (ability to analyze, evaluate and investigate complex problems and draw appropriate conclusions) (Stauffer, 2020; P21, 2019). Merged with problem-solving skills (ability to define and determine the cause of a problem and select and implement appropriate solution), decision-making (ability to choose the best solution from a group) and metacognitive thinking (ability to organize, guide and control one's thinking, actions and learning processes) the Bloom's HOTS set is introduced (Miterianifa, Shadi, Saputro, & Suciati, 2020). Together these skills enhance the construction of deeper conceptually-driven understanding, allowing persons to be able to "analyze and evaluate complex information, categorize, manipulate and connect facts, troubleshoot for solutions, understand concepts, connections and big-picture thinking, problem solve, ideate and develop insightful reasoning" (Top Hat, 2021).

HOTS is simply defined as "the thought processes that help someone connect information in meaningful ways and use those connections to solve problems" (Indeed Team, 2021). It can be divided into four main areas: 1) Creative thinking skills; 2) Critical thinking skills; 3) Problem-solving skills and 4) Metacognitive skills. **Figure 1** shows activities associated with each area. These areas show that HOTS expand the use of the mind to the point where students are able to relate their learning to elements beyond those they are taught to associate with. One research states that HOTS is an important element in education because of

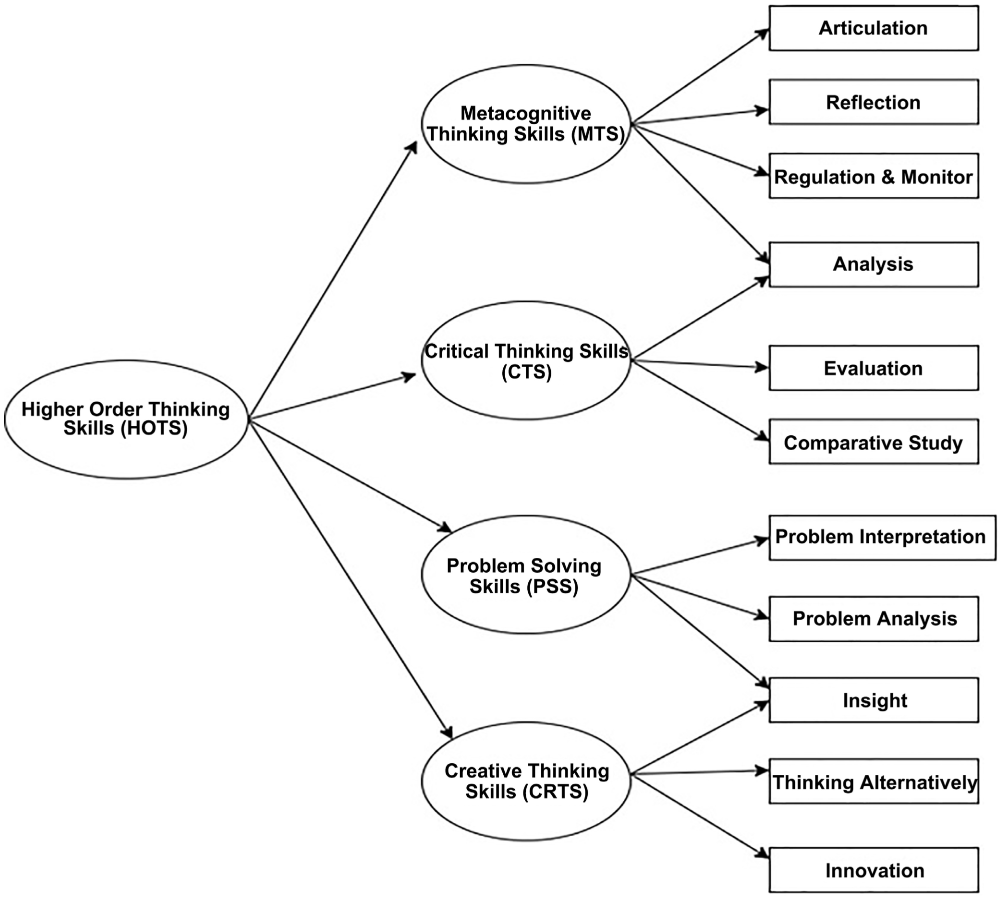

Figure 1. Higher order thinking skills components (Anwar, Jalinus, & Pardjono, 2017).

its benefits in improving students' learning performance, reducing weakness, interpreting, synthesizing, solving problems, and controlling information, ideas and day-to-day activities (Ahmad, Prahmana, Kenedi, Helsa, Arianil & Zainil, 2021). The curriculum should therefore include information and activities that explicitly emphasizes learning how to use one's mind well, to synthesize and analyze skillfully and less on the mastery of information measured by a recall-based assessment.

3. Literature Review

A 2011 research showed that a major factor to the growth of HOTS is a student-centered classroom that supports open expression of ideas, provides active modelling of thinking process, develops thinking skills and motivates students to learn (Suban Garak & Dao Samo, 2020). Numerous researchers have found that Project Based Learning (PBL), an innovative approach to learning is highly successful in creating such a classroom. PBL is great because it is student-driven and teacher facilitated (Baird, 2019; Da Silva et al., 2018) and allows students while taking the lead in the learning process to gain content knowledge and skills by working for an extended period of time to investigate and provide an answer to an authentic, engaging and complex real-world scenario, question, problem or challenge (Baird, 2019). In short, "it empowers students to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem" (Savery, 2017). In so doing allow students to be more independent in building their own understanding while integrating learning with training (Pasha, 2016). It also provides students with opportunities to analyze, categorize and develop the expertise and skills required to address realistic scenarios (Aldabbus, 2018), while enhancing leadership abilities, listening skills, coordination and strategic thinking skills (Musa et al., 2012). Other researches reveal that PBL is also very effective in teaching HOT skills (Dogara et al., 2020; Billah, Khasanah, & Widorento, 2019; Pasha, 2016; Schaller & Hadgraf, 2013; Musa et al., 2012; Ravitz et al., 2012).

Apart from being active thinkers with HOTS skills, to survive in this ever-changing workplace students are required to have some level of expertise in their area. The accumulation of content knowledge does not automatically equal having expertise. This is because along with content knowledge students will need the ability and skills to organize this knowledge, add new knowledge as well as analyze new contexts to fit into and increase this knowledge. Once this is done student experts will be able to use their knowledge to interpret information, analyze situations, and develop solutions to problems. As such, educators must design courses so that students who are novices can be taken on a journey to this level of expertise. The Cognitive Apprenticeship (CA) model, developed by Brown, Collins, and Newman provides the vehicle for this journey. It is designed to help students acquire the cognitive skills that are concerned with the cognitive processes of analysis, interpretation and decision-making—the processes required by experts (de Bruin, 2019). The model supports the three stages of skill acquisition described in expertise literature: the cognitive stage where the student develops their knowledge, the associative stage where any mistakes and misinterpretations learned are corrected while critical elements involved in the skill are strengthened, and the autonomous stage where the skills are fine-tuned to expert level (Edmondson, 2021). CA accomplishes this goal by teaching Content (domain, procedural & process knowledge) based on different teaching methods (*Instructional Mode*—modelling, coaching, scaffolding and *Learning Model*—articulation, reflection, exploration) using different degrees of complexity while fixing into the students' learning environment.

The learning of technical and soft skills is not the same for each student as they are all different and with that comes variation in the ways they learn best. According to the Association for Psychological Science, educators and students have been hearing for over 30 years that most people are either visual or auditory students. This has guided the mode of delivery in schools. Research has however shown that there are at least 4 major learning styles (Malvik, 2020; Flavin, 2019) and the 21st century has transformed education from the traditional teacher-centered to a personalized student-centered environment thus demanding that there be consideration of this diversity. Educators must now deliver their courses using different strategies and methods and removing the barriers to learning. This use of a variety of ways to present knowledge to a diverse population is what the Universal Design for Learning (UDL) framework caters for. Based on 3 principles (Taylor, 2016), which are aligned with the three networks in the brain that are involved in the learning process UDL provides a blueprint for creating instructional goals, methods, materials and assessments that work for everyone—not a single, one-size-fits-all solution, but rather flexible approaches that can be customized and adjusted for individual needs (TEAL, 2010). These principles allow UDL to activate different areas of the brain so students can access the material, build on it, and internalize the content thus it therefore provides ways to improve the learning experience for all students by ensuring that learning is multi-sensory, multi-dimensional, satisfying, meaningful and exacting (Brand & Dalton, 2012). Its purpose is not simply to help students master a specific body of knowledge or a specific set of skills, but to help them master learning itself through flexible goals, methods, materials, and assessments that empower educators to meet these varied needs. As a result, students become expert students, who can assess their own learning needs, monitor their own progress, and regulate and sustain their interests, effort, and persistence during learning tasks (Danielson Group, 2018). In doing so, UDL is designed to provide flexibility that allows teaching and learning to adjust to every person's strengths, weaknesses, challenges, aptitudes, talents, and aspirations by creating varied methods of delivery.

Although research has shown a positive relationship between CA and UDL as well as PBL and CA there has been no research showing the connection with all three. Research has also shown the implementation of a Problem-based Learning and CA merger (Powell & Stansell, 2014), but no research shows the implementation of the merger of PBL, CA and UDL. The proposed framework will therefore seek to create this merger to create a pedagogy called H-CUP (HOTS through a CA, UDL and PBL merger) that will seek to increase students' HOTS skills and expertise level regardless of their learning style.

Justification for Merger

CA and UDL

The central aim of CA is the concept in which experienced people assist less-skilled one to increase their level of cognitive expertise; UDL has the goal of developing expert students. In both cases the aim is to increase students' level of expertise. These new experts tend to be goal-directed, purposeful, resourceful, knowledgeable, resourceful and strategic in their planning—all required in the work-place. Although there is presently no known research that discussed this merger it should result in a teaching approach that enhance or accelerate learning; requiring the instructor to perform task(s) for the students or facilitate them as they work while applying different ways to represent the material so as to consider the different learning styles. In short UDL's Principle 1 (Multiple Means of Representation (Recognition Network)) allows for the use of different teaching methods such as coaching and interaction to guide exploration and new concepts, scaffolding while allowing the instructor to use a variety of strategies, instructional tools, and methods to present information and content to anticipate student needs and preferences (CA Instructional model). It also allows for the use of authentic tools and a variety of practice and experts (peers & teachers). Principle 2 (Multiple Means of Action and Expression (Strategic Network) allows CA to offer the use of the Learning Model where the student can articulate their ideas through presentations, self-reflections, and collaborations to solve problems as well as to demonstrate new understandings (articulate, explore). Principle 3 (Multiple Means of Engagement (Affective Network)) allows the student to utilize collaboration while using a variety of problem-solving methods as they promote their ability to monitor their own learning.

UDL and PBL

UDL is a framework that allows students' choice of action/expression, representation, and engagement (Taylor, 2016); however, Dr. Barbara Hong, a learning specialist stated that all students have one fundamental commonality—every student is most likely to understand by actual experience (Flavin, 2019). PBL by nature meets that demand. Students learn by connecting lessons to real situations/context and in so doing create a sort of self-structuring environment that distributes power to the students while considering each student's characteristics, performance support strategies, technologies, and outcomes. In so doing the classroom environment changes to one that fits the UDL environment demand that eliminates the centrality of the instructor but creates a mentor and a resource, facilitating teamwork and communication. It can then be said that PBL by nature is how students experience learning while UDL is how teachers meet the needs of all students, especially those furthest from opportunity. From **Figure 2**, assessment is inherent to PBL which is inherently aligned with the UDL principles. As Edyburn (2010) stated "UDL outcome measurement needs to focus on the benefits that result from access and sustained engagement: expertise and expert performance". PBL is "expert" in nature particularly within a genuinely PBL-centered course where the client/team interaction and the project delivery serve as true measures of "expert performance".

UDL's Principle 1 (Multiple Means of Representation (Recognition Network)) demands that there be flexibility in the way information is presented. This occurs in PBL as each authentic situation provides its own unique information presented in a variety of media, presentation, slides and notes (printed and electronic). Students' learning is activity-based as well as inter-disciplinary while using exemplary practice when the PBL method is utilized, creating a UDL fit that reduces barriers in instruction, provide appropriate accommodations, supports, and challenges, while maintaining high achievement expectations for all students (Principle 3—Multiple Means of Engagement (Affective Network)). In doing this, students have different ways to respond or demonstrate their new knowledge and skills (Principle 2—Multiple Means of Action and Expression (Strategic Network)).

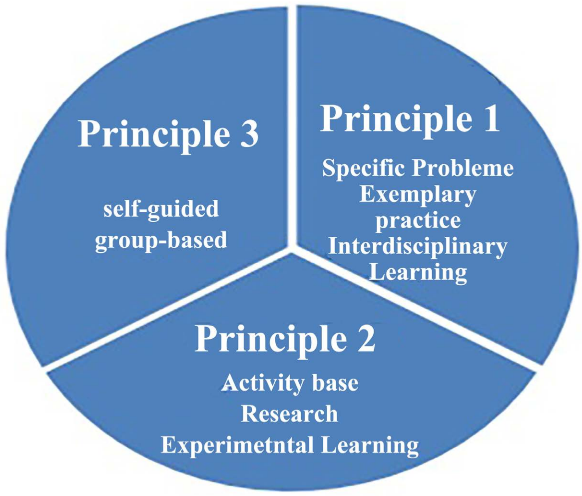

Figure 2. Connection of PBL charateristics with UDL principles.

PBL and CA

There is a gap between formal learning and real-life application as the school is outside the workplace thus students lose the chance to learn through experience where their action and reflections can result in new ones. This is what both CA and PBL offer. The combination is an advanced instructional model that goes beyond the basic transfer of content but fosters critical thinking and problem-solving skills typically found in expert practice (Powell & Stansell, 2014). Studies have shown that the combination results in an increase in students' understanding of the concept of the subject matter (Ibrahim, Ayub, & Yunus, 2020). CA is based on the theory of situated learning where knowledge is acquired and contextually tied to the settings and situations in which it is learnt and PBL has been shown to increase expertise level by providing an authentic experience through projects. For CA, students receive assistance from instructors (experts) through structures and examples which are provided by PBL. Using the real-world examples offered by PBL instructors demonstrate and explain necessary skills and knowledge required for expertise (modelling) for students to understand. Students practice these observed methods and skills on real-world problems increasing in complexity (explore), with guidance from instructor (scaffolding, coaching), articulate their own thinking (articulate) as well as compare it to peers and instructor (reflection). In so doing the combination of CA and PBL creates a custom environment that scaffolds to mastery or real skills directly applicable to the student (Powell & Stansell, 2014).

4. Proposed Framework

In this project-based world, there is the need for not only schools of the future but also pedagogies of the future that teach necessary expertise and skills to help students adapt and grow meet to the challenges of the future. The proposed framework is designed on a unique combination of student-centered approaches that are proven as effective methods for learning core discipline skills. In this framework the practice of PBL (assessment, and real-world exercises) is grounded in CA (teaching methods that increase students' expertise) and UDL (methods addressing diversity) with the aim of increasing HOTS and content expertise. It is guided by the William and Flora Hewlett Foundation (2010) concepts of "deeper learning" and "student-centered pedagogies" that includes "models of teaching and learning that are project-based and collaborative that foster knowledge building, [PBL] while requiring self-regulation and assessment [CA], and both personalized (allowing for student choice and relevance to the individual student) and individualized (allowing students to work at their own pace and according to their particular learning needs) [UDL]" (Ravitz et al., 2012).

This pedagogical framework encourages experiential learning and in so doing allows the synthesis of information through enhanced retention and intentional learning strategies that incorporate collaboration, feedback, modelling, scaffolding, reflection and problem-solving (QCAA, 2021). Full implementation should use the backwards design instructional process and incorporate the following five steps.

1) Student Outcomes—Establish a clear understanding of the goal(s) of the lesson and specific student outcomes

2) Anticipate Student Variability—barriers (e.g., physical, social, cultural, or ability-level) that could limit the accessibility to instruction and instructional materials.

3) Create Measurable Outcomes and Assessment Plan—prior to planning the instructional experience, establish how learning is going to be measured

4) Instructional Experience—establish the instructional sequence of events

5) Reflection and New Understandings—establish checkpoints for both student and teacher reflection and new understanding (NSF, 2012).

Influenced by these steps, the H-CUP framework (**Figure 3**) consists of four elements that must all effectively interact with each other to bring about desired learning outcomes. The first element specifies the measurable learning outcomes of the course along with the HOTS skills to be learnt. The second specifies how the performance in the course will be assessed while the third element provides detail on the instructional methods use to deliver the course. The fourth element specifies the learning environment of the course.

4.1. Societal Environment

For students for survive in the present working world, they cannot be taught in a vacuum. The classroom must now mirror the social nature of real world where acquired knowledge will be applied. In this framework therefore, teachers create a classroom that looks at the specific and general context of the teaching/learning i.e., they not only look at the class size and the delivery mode but also the school's and community's expectation. To create the appropriate environment the teacher must take into consideration the characteristics and learning styles of all students. This will influence how the course will operate as well as the delivery

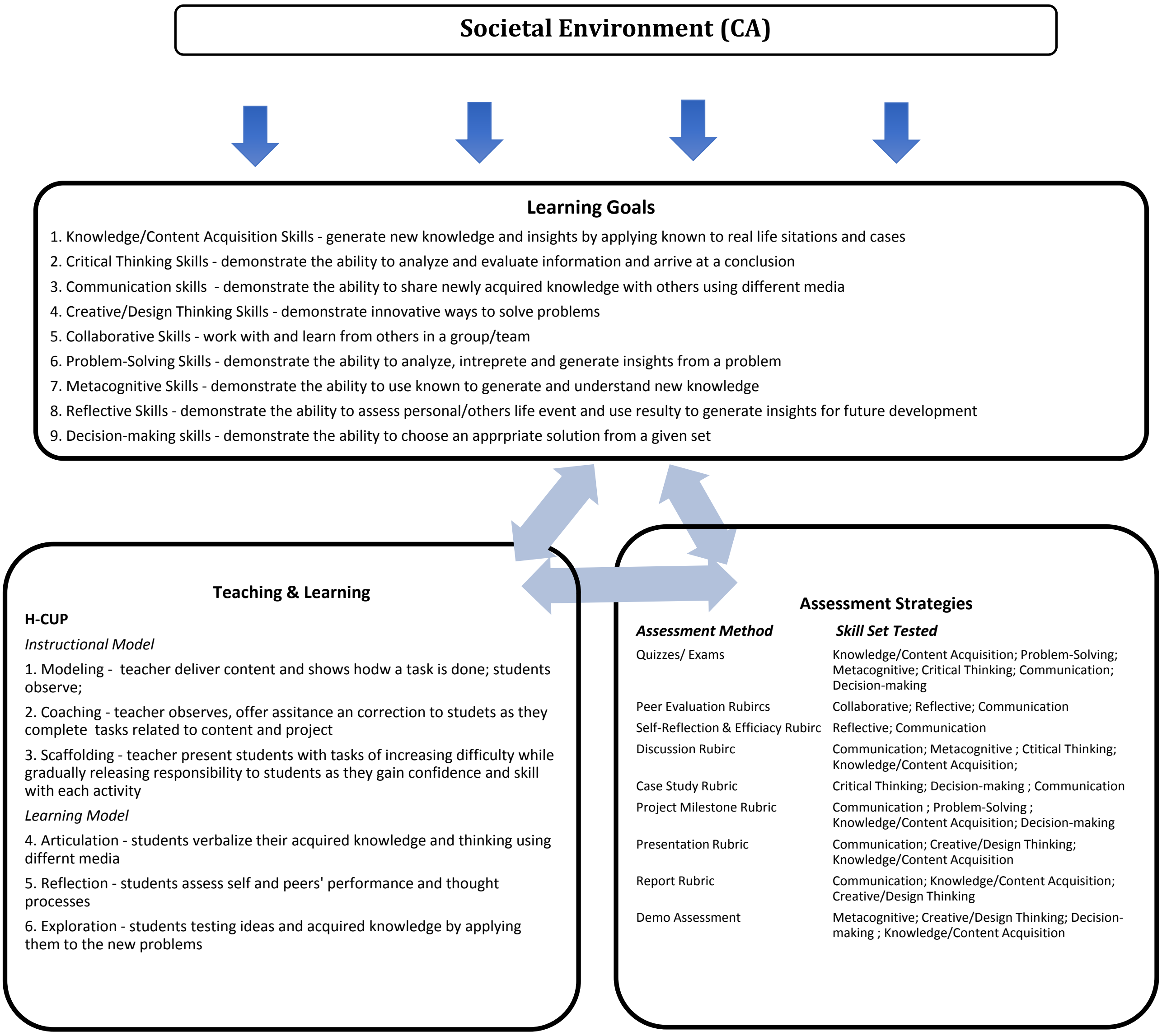

Figure 3. H-CUP pedagogical framework.

mode so as to produce a successful community of students. The environment created should encourage students to communicate and collaborate as well as positive peer reinforcement creation.

For this pedagogy, it is recommended that there be an alignment of all four learning environments to have an optimal learning environment—the HPL Framework where all of the important factors that influence how people learn are present and in balance for learning (Iris, 2021). Alignment between knowledge-centered and assessment-centered is imperative, as assessments must be designed to evaluate student's growth in knowledge and skills. Likewise, getting to understand students through a student-centered perspective is important when considering the content being taught and the way the assessments are designed. These perspectives combined are arranged among the values and learning goals of the community in which the learning takes place (community-centered).

4.2. Learning Outcomes

Once the environment in which the students are to learn is understood, the next step is to determine what the students should be achieving at the end of the course. These learning outcomes look at what content is essential for the students to know as well as what should they be able to do after the course—what students need to know and could make powerful use of to enhance their lives and more effectively contribute to society. For this pedagogy these outcomes should reflect the skills necessary for the desired expertise as well as focus on increasing students' competency in HOTS.

4.3. Learning Assessments

Assessment tells students what is valued and what they need to achieve to be successful in their studies; it captures their attention and directs their behavior; it may act as both a spur and/or deterrent in their studies; it informs them of their progress, which in turn, impacts on how they see themselves as individuals, and future professionals; and, following from these results, it may provide satisfaction or discouragement (UBCO, 2021). For this framework, traditional assessment strategies alone are not appropriate for gauging the learning outcomes of the course, instead authentic assessments are employed. These assessments challenge students to express their own interpretations of the material learnt in the course while assessing the acquired knowledge and evaluating the accuracy with which they are able to execute different functions within a given real-world content-related scenario. Assessment, in the framework, is an ongoing process as it is being conducted continually in various forms (formative & summative), providing a "picture album" of a student's ability instead of the random and more isolated "snapshot" of the student's knowledge provided by traditional testing. Influenced by UDL and PBL, there are six assessment methods that evaluate students' progress with respect to pre-requisite learning outcomes; these are:

1) Examinations—continuous evaluation through quizzes, labs and tests which assess students understanding of course concepts, and their real-world applications in order to optimize learning. Final examinations examine students' ability to apply course concepts to different scenarios.

2) Peer Evaluation—qualitative and quantitative. This is one of the important components of assessments in PBL. Biweekly each team member shares he/her views about peer team members. The purpose is to inform these members about team members' opinion of their performance with the aim of helping them to improve. The qualitative feedback is taken at the end of the semester where each team member assesses the group including self. In this method students assign marks to each member based on a Likert-like scale for different categories such as team-members contribution. Each team member's final grade is an overall average of all group members' assessment.

3) Self-Reflection Evaluation—This is a qualitative feedback where each team

member assesses his/her individual performance and level of learning.

4) Project Milestones—Each team completes different aspect of the project throughout the course timeline and produce specific reports and deliverables which are evaluated on the basis of correctness (non-existence of errors), clarity (properly written, clear diagrams…), adaption (fulfilment of rules, simplicity of solution…) understanding and usage of course concepts related to each deliverable.

5) Project Evaluation—At the end of the course, each team show cases and explains their project solution in detail with its relevance to theory concepts to be assessed. The teamwork process during this showcase is also assessed along with the submitted project report and solution demo.

6) Case Studies—These assessments are optional and evaluate students' opinions in relation to theory as well their analysis of simple theory-related real-world problem scenarios.

7) Discussion—These assessments are optional and seeks to create a community of students.

4.4. Teaching & Learning

The mode of delivery is an important consideration when designing learning activities that will support students to develop the skills, knowledge and understandings required achieving the intended learning outcomes, as measured by assessments. The most appropriate mode of delivery would be selected based on the activities planned that would best support student development of the skills, knowledge and understandings students are expected to achieve. In terms of the model of delivery this pedagogical framework can be implemented using:

1) Face to Face (f2f) where both students and instructor are in a permanent physical environment and students are involved in spontaneous verbal communication. This is the traditional mode of delivery

2) Blended Learning which is a mixture of f2f and online technology mediated instruction. Students have a permanent environment but this is accompanied by online material and activities (can be an LMS such as Blackboard) which supplement and build the content discussed f2f.

3) Remote Learning which is similar to f2f but instead of a permanent physical environment there is a virtual environment.

4) Flipped Learning where students learn material before class through reading, labs, videos etc., and the class time is used to deepen understanding through discussions with peers and problem-solving activities facilitated by instructor.

Since this pedagogy utilizes PBL, teaching & learning will incorporate course-long real-world projects that seek to teach necessary skills and content. Students at the start of the course receive the project problems and placed in teams as expected in the workplace. Using similar problems, the teacher then demonstrates the desired knowledge and skill (modelling). Throughout the course these are reinforced as the teacher increases the complexity of the tasks (scaffolding). Students during classroom as well as their project are then allowed to copy the teacher's actions. The teacher then observes, and provides support and feedback to improve students' learning (coaching). For each new content, students provide the teacher with information on their learning level through teacher, peer and self-observations (reflection, articulate). Finally, students are expected to provide a solution for their assigned project. Table 1 shows how the pedagogy will teach and increase students' HOTS levels.

5. Implementation of Pedagogy

This pedagogical framework, has been implemented over the last 2 academic years (Spring semester), employing an exploratory case study approach to investigate its impact on students' knowledge and skills in an undergraduate Database Management Systems (DBMS) course in a HBCU university. The primary objective of the course was to prepare students with the necessary basic theoretical knowledge and skills in database design, and development. It consisted of 45

Table 1. H-CUP action to resulting in HOTS increase.

CA Actions	UDL Actions	PBL Actions	HOTS Learnt
Modeling	Customize the display of information Illustrate through multiple media Alternative for auditory and visual information	Brain storming Planning Investigation & Inquiring	Analysis (MTS, CRTS, PSS, CTS) Interpretation (PSS) Insight (CRTS, PSS)
Coaching	Individualized feedback Teacher observe as student demonstrate skills Formative Assessments	Critique of possible solutions Solution Designing & Development	Analysis (MTS, CRTS, PSS, CTS) Collaboration (MTS) Insight (CRTS, PSS) Innovation (CRTS) Evaluation (CTS) Interpretation (PSS)
Scaffolding	Simulations & Scenarios Conceptual Model & Algorithm development Discussions	Solution Designing & Development	Analysis (MTS, CRTS, PSS, CTS) Collaboration (MTS) Insight (CRTS, PSS) Innovation (CRTS) Evaluation (CTS) Interpretation (PSS)
Articulation	Use multimedia for communication Oral presentations Demonstrations Summative assessments	Solution Demonstration Project Report Oral & Digital presentation	Communication (MTS) Analysis (MTS, CRTS, PSS, CTS) Innovation (CRTS) Insight (CRTS, PSS)
Reflection	Self-Reflection Formal & informal discussions	Self-reflection Peer evaluation	Reflection (MTS) Analysis (MTS, CRTS, PSS, CTS) Communication (MTS) Evaluation (CTS)
Exploration	New Projects/problems		Communication (MTS) Analysis (MTS, CRTS, PSS, CTS) Innovation (CRTS) Insight (CRTS, PSS)

hours of teaching, assignments, examinations and hands-on labs all supported by a prescribed text distributed over a 15-weeks period. In 2020 the course was delivered firstly in a blended learning mode however due to COVID-19, midway delivery moved to remote. The 2021 cohort was taught solely by remote.

To complete the DBMS course students must have a solid ground in the domain knowledge receiving specific concepts, facts, and procedures that they will then utilize with different applicable techniques for accomplishing given assignments and the PBL project (heuristic knowledge), procedures to help them find solutions (control strategies) and knowledge on how to acquire new facts, concepts and procedures (learning strategies). To achieve these goals, throughout the semester, the researcher employed the different teaching methods of CA for each topic delivered (**Table 2**) while considering students' learning styles by delivering knowledge using different media such as video & PowerPoint (UDL Principle 1—Multiple Means of Representation (Recognition Network)). As such, students learnt by watching for example how to write SQL code or a Relational Algebra or Relational Calculus solution (Modeling) then practicing these techniques and tasks in the class work and assignments provided. During these the researcher observed the students and provided feedback and help when necessary (coaching). Students are also given the PBL project in which they could verbalize their knowledge and thinking (articulation), compare and evaluate themselves and their peers (reflection) while they propose and develop a solution to given real-world problem scenarios (exploration). Throughout the semester the researcher provided help and guidance (scaffolding) for the PBL project while increasing the complexity and diversity of assessments.

Table 2. Course schedule for database course.

Week	Course Topics	PBL Project Deliverables	Other Assessment
1	Introduction to Database Concepts		
2	Introduction to RDBMS	Introduction to Project/Team Launching	Discussion 1
3	Data Modeling	DBMS Research & Recommendation	
4	ERD Mapping in RDBMS		Lab 1
5	Relational Algebra & Calculus	Design Document	Discussion 2/Test 1
6	Normalization		
7	Indexing	Concept Design	Mid Term
8	Introudction yo NoSQL/Fault with RDBMS		Lab 2
9	NoSQL Formatting	Logical & Physical Design	Discussion 3
10	Data Access Control NoSQL and RDBMS		
11	Types of NoSQL—Key Value		Test 2
12	Types of NoSQL—Document Store	Laws, Ethics & Security Plan	Discussion 4
13	Types of NoSQL—Column Family		
14	Types of NoSQL—Graph Family	Peer Evaluation	
15	Project Report, Presentation & Demo		

The PBL project given allowed students to articulate and explore while developing students' expertise in DBMS as well as their HOTS skills. For this course, the project was divided into 6 milestones submitted at various points throughout the course (Table 2) to scaffold learning and ensure quality final submissions. Through project students were able to address a specific problem relying on self-guided, experiential as well as activity-based learning while experiencing team-work. The project was implemented using a general process cycle that allowed students to form an understanding, apply understanding to the problem, circle back to identify new information as needed or correct misconceptions and then alter or add to their end product design. Actions for the students in the cycle were divided into 3 main phases namely:

1) Project Assignment (weeks 2 - 4) that focuses on the selection of a project problem, team formation and brain storming;

2) Collaboration (weeks 2 - 15) that focuses on using prior knowledge as a guide for inquiries and investigations, planning, designing, development and critique of possible solution(s) through teams;

3) Product Presentation (week 15) that focuses on the project report, execution of demo and oral presentation. This set of actions addressed UDL Principle 2—Multiple Means of Action and Expression (Strategic Network) providing students with different ways of demonstrating and communicating what they have learnt.

The HPL learning environment was utilized in both years. As can be seen in Table 2 the course was delivered in a set schedule where knowledge (facts, ideas, concepts, and principles) was introduced before students needed to utilize it (knowledge-centered). In doing so receive knowledge that will help with their understanding which in turn helps to build expertise and to facilitate the transfer of knowledge to other situations. Once the knowledge is given students are assessed to provide frequent opportunities for feedback, reflection, and revision, in order to enhance the quality of learning. As such the course had formative assessments in the form of tests, discussions, labs, and project deliverable rubrics to provide continual feedback about preconceptions and performances and summative assessments in the form of final project presentation and final exam to measure the results of student learning (assessment-centered). This addressed UDL Principle 3—Multiple Means of Engagement (Affective Network). For help students learn utilizing what they already know the course incorporated use of discussions along with the PBL project to solicit their thoughts and ideas about how to solve the problem as well as to ask them to explain the reasons behind their thinking (learner-centered). All of these are done in an environment that encourages students' participation and camaraderie through discussions and team-work/collaborations (community-centered).

5.1. The Assessments Methods

The aim of the PBL project was the designing and the creation of a solution demo for a DBMS. The project was divided into 6 milestones submitted at various points throughout the course to scaffold learning and ensure quality final submissions. These milestones were assessed using measurable criteria guided by Webb's Taxonomy to have rubrics, reflections and evaluations (peer, self), that created a composite grade set that reflects the project. The rubrics utilized had four levels of student performance (Novice, Need Improvement, Proficient, Exemplary) which measured how well students acquired and integrated the desired cognitive and metacognitive strategies since their exposure to the tested concepts. Each student could refer to the given rubric at any time while completing each milestone.

Students were also assessed continuously using both formative (discussion forums, project milestones, assignments (lab & written), reflections) and summative forms (tests, midterm, final examinations, Project report & Demo) as can be seen in Table 2. This continuous evaluation accounted for 40% of the final overall grade and Exams and the Project report and demo corresponds to the remaining 60%.

5.2. Evidence of Overall Effectiveness

The research utilized a case study format which employed two groups of students (2020 & 2021) totaling 43. Data was collected from examinations/tests, project demo, rubrics, presentations, surveys, and self & peer evaluation and compared to students' performance in the 2019 cohort.

The author adopted a blended learning approach in 2019 for delivery of this course to encourage self-learning and collaboration. The same approach was adopted for the 2020 semester however half-way throughout due to the COVID-19 pandemic the delivery mode moved online and became remote learning. The 2020-2021 academic year was also affected by COVID-19, thus learning had to be fully remote.

Comparisons were made of students' overall performance against 2019 before H-CUP implementation see Figure 4. In 2019 the A/B pass rate was 44% however in 2020 and 2021 it was 78% and 68% respectively. The overall pass-rate had an

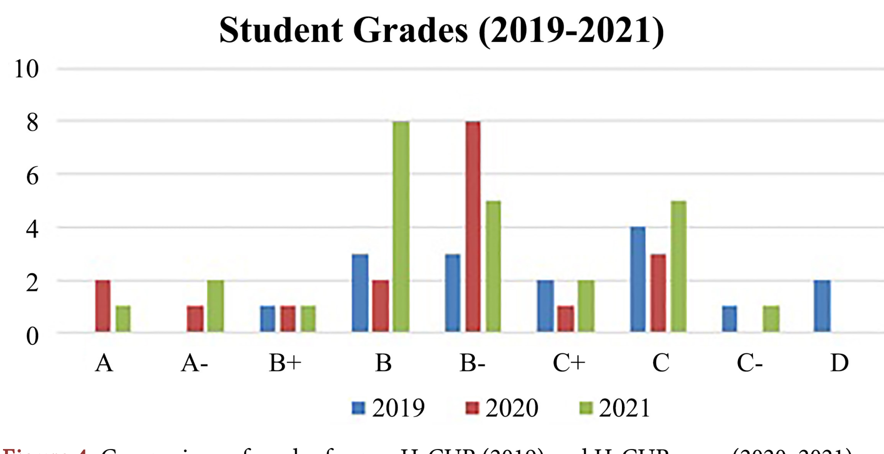

Figure 4. Comparison of grades for pre-H-CUP (2019) and H-CUP years (2020, 2021).

increase in the overall pass rate over the three years from 81% to 96% [pass rate: 81% (2019); 75% (2020); 96% (2021)] and an increase in the A/B pass rate from 81% to 83%. The drop in overall pass rate for 2020 can be related to the change from blended to remote teaching half-way in the semester due to COVID-19.

5.3. Assessment of HOTS Level

To determine the effectiveness of H-CUP in producing students with HOTS skills desired by employees this study evaluates students' performance in the four (4) main areas as named in **Figure 1**. In this study these skills were developed using mainly Examinations and the PBL project.

Critical Thinking (CTS) was promoted in the PBL project where students had to not only analyze the problem using the domain knowledge but to also evaluate, interpret and draw inference from any new knowledge obtained from reading materials, and observing or communicating with other students and faculty. They then promote their Problem-solving skills (PSS) when they took this information and discussed in their team's, possible obstacles and found different solution options for the project problem. Each then, based on the available information and evidence arrived at an appropriate alternative solution from which they designed an original and unique DBMS solution demo, promoting their creative thinking skills (CRTS). Students' metacognitive thinking skills (MTS) were also promoted during the entire PBL project as they chose appropriate strategies for the problem, monitored their own as well as team members' performance while engaging in different tasks and evaluating and reviewing the entire process. These skills were also promoted within examinations where students were again given case studies and real-world problems that received them to design solutions. Apart of these students' collaborative skills are also promoted as they work in teams of 4 on the PBL project.

5.3.1. Metacognitive Skills (MTS)

Developing metacognitive skills require students to progress through three distinct phases: 1) planning where they decide on what they need to learn and how they are going to learn that material 2) monitoring where they examine their progress and the activities they employ to achieve learning and 3) evaluation where they reflect and analyze how well they achieve learning. The students in the study Metacognitive skills levels were measured based students' performance in not only examinations but in also difference skill sets as seen below.

Collaborative Skills: At the end of the PBL project all students completed a teammate evaluation where they rated their group members' contribution to the group work and their collaborative skills. They also rated their leadership skills. The evaluation in 2020 produce an average of 28/30 points and 2021 produced 27/30 concluding that students were mostly comfortable with the teamwork and were satisfied with their teammates' performance. This was supported by the end of course survey where in both years over 86% of the students felt that their point of view was acknowledged by their peers and they were comfortable interacting with them.

Regulation & Monitoring Skills (*Reflection*): This was measured using surveys. For both 2020 and 2021 surveys were administered to students. In both years, over 90% of the students expressed that their knowledge of the course material was limited and the same number expressed that by the end of the course they had learnt a great deal. Students expressed that the real-world scenarios and hands-on experiences were extremely helpful in improving their learning and more than 80% of them stated that the learning activities helped them construct their explanations and solutions. Students (86%) also stated that there were a variety of methods used to evaluate their progress (UDP) and that the instructor encouraged student-faculty interaction outside of course time with the use of email, telephone calls, virtual meetings etc. Over 85% of the students stated that they learnt to develop solutions to course problems that can be applied in practice. Another 87% of the students felt that they were motivated to explore content related to questions given. Students (89%) also felt that they were encouraged by the instructor to explore new concepts and that they could apply the knowledge created in this course to new work or other non-class related activities.

Articulation (*Communication*) *Skills*: Researchers through the years, have stated that students who have increased their MTS levels will be much better at understanding what they read and consequently this shows in how they solve problems as well as how they articulate their responses (Guner & Erbay, 2021). The students' responses to reveal the influence of using MTS; the high the MTS levels the better the communication skills. These findings are consistent with other studies in literature (Guner & Erbay, 2021). In this study students were evaluated in all three fluencies of communication—digital, writing and speaking using oral presentations, PowerPoint and written reports. In 2019 there were 2 written reports, however, for the HCUP years, there were 6. Evaluation shows an increase in the number of A's-writing [pass rate: 25% (2019); 67% (2021)], digital [presentations (pass rate: 100% all 3 years] and oral [pass rate: 25% (2019); 33% (2020); 54% (2021)]. It can be seen that in 2020 and 2021 when HCUP was implemented, there are increases in students' communication skills when compared to the 2019 data.

5.3.2. Creative Thinking (CRTS)

Developing creative thinking in students require them to be able to look at problems or situations from a fresh perspective or angle while using the right tools to assess it and develop a plan for a new solution. The students in the study CRTS skills levels were measured based students' performance in not only examinations but in the different skills below.

Innovative Thinking: This skill set focuses on the ability to come-up with new ideas and novel approaches to solve problems. In this study this skill was developed using the PBL project where students were required to develop their own approach to solve the given problem and to design a solution. In so doing students developed their innovative skills as they completed their research on the problem with the aim of developing the necessary understanding that would lead to the development of ideas [Milestone 1 Research and Recommendation [pass rate: 100% all 3 years]]. The project also allowed students to further develop the skill set as the designed and developed a solution based on their perception and understanding. Evaluation shows an increase in the pass rate for solution designs from 2019 to 2021 [Design and Develop of Solution Milestone [pass rate: 75% (2019); 100% (2020 & 2021)].

Insight Skills (*CRTS & PSS*): This skill set is considered a wisdom that focuses in the ability to see beneath the surface of a problem and identify processes or knowledge already available that can be used in designing a solution. Evaluation through the PBL project allowed students to determine what from their collection of knowledge can be used to help design a solution and make the required recommendation. Evaluation shows an increase in the number of A's [Research and Recommendation milestone [pass rate: 100% all 3 years]].

5.3.3. Problem Solving (PSS) & Critical Thinking (CTS)

Students who are developing their problem-solving skills (PSS) should be able to understand given problems or situations and develop possible solution. They should then be developing their critical thinking skills (CRTS) when they process, interpret, rationalize and critically analyze these possible pathways while understanding the connections between them. The final result should be the recommendation and application of the best solution.

Analytical Thinking: This skill set focuses on the ability to collect, observe, research and interpret a problem in order to develop solutions. In this research this skill set was developed as students worked on the PBL project. Here students used their old and new knowledge joined with researching to brainstorm and produce possible solutions (PSS); analyze and prioritize these solutions (CTS); evaluate these solutions and select the best solution [Research and Recommendation milestone [pass rate: 100% all 3 years]]. Students also developed this skill during their lab assignments as they are required to produce an appropriate solution for the given scenarios. This reflected changes in each year in the pass rate [pass rate: 56% (2019); 83% (2020); 83% (2021)] and also in the number of A's produced [Number of A's: 28% (2019); 39% (2020); 56% (2021)].

Problem Solution Implementation: Once the appropriate solution has been selected students continue to work on improving their PSS by implementing the solution. They received this opportunity in the PBL project with the creation of Project demo [Number of A's: 25% (2019); 39% (2020); 54% (2021)], as well as in their Lab Assignments [Number of A's: 28% (2019); 39% (2020); 56% (2021)].

5.4. Assessment of Expertise Level

The aim of H-CUP is not only to increase students' competency levels in HOTS but also to increase their expertise in the course area. At the start of the course each student could be a novice, having only basic knowledge and awareness. In this research students' growth were evaluated using the PBL project and lab assignments and examinations. Since they were learning from both direct instructions and practice assessment using the PBL project, expertise level was measured based on the Dreyfus Model for Skills Acquisition using the questions in Figure 5 as the measure.

While testing students HOTS competencies in each milestone their expertise levels were also assessed. At the beginning of the semester students has little or no previous experience in the DBMS, seeing knowledge and actions in isolation thus were considered to be novices. As students received direct instructions they were able to see actions as a series of steps thus were to apply guidelines; however, they were not able to recognize the relevance of their work (Advanced Beginner). With the start of the PBL project students are able to select the relevant elements of a situation and choose a plan to achieve their objectives (Competent Level). Students were not able to be exposed to a wider variety of scenarios so they were not able to attain a vast level of experience thus they were not tested for Proficiency or mastery. Evaluation for attainment at the competency level was assessed in the Concept Design [A/B pass rate: 100% (2019); 78% (2020); 84% (2021)] as well as the Logical & Physical Design [A/B pass rate: 50% (2019); 100% (2020); 100% (2021)] milestones. How well students were able to execute this design was assessed using their Project Demo [Number of A's: 25% (2019); 39% (2020); 54% (2021)]. Figure 6 shows the students' performance in each milestone.

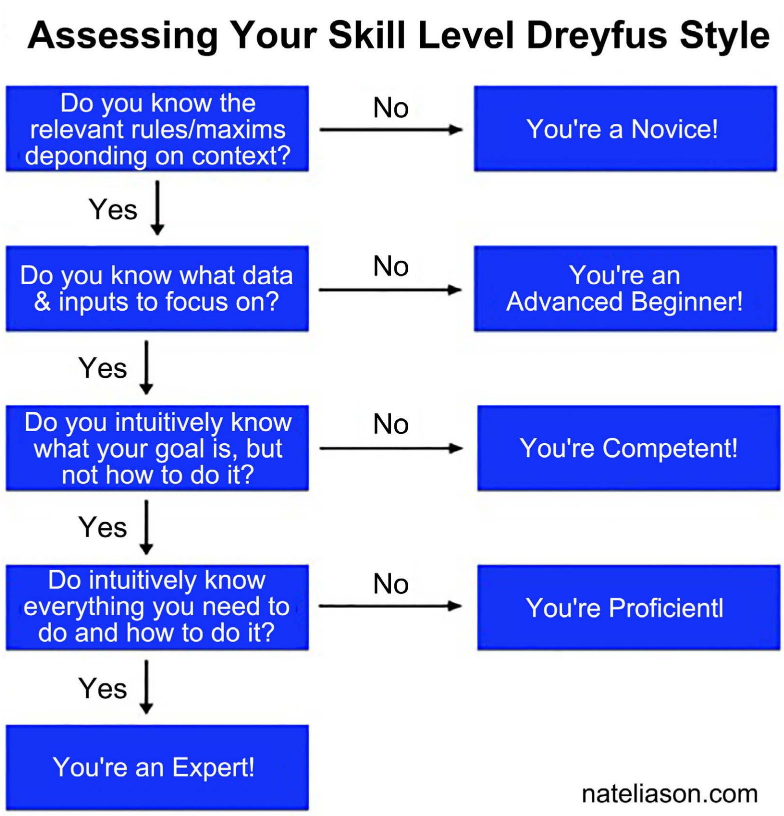

Figure 5. Dreyfus model for skills acquisition (Eliason, 2017).

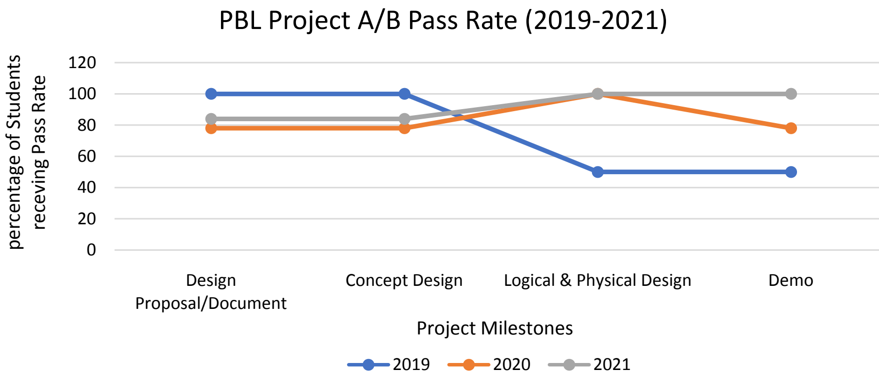

Figure 6. Students A/B pass rate for PBL project

5.5. Summary of Findings

The proposed pedagogy is designed to provide students with the necessary steps to develop their competency level in HOTS as well as increase their expertise in the taught area. To encourage them several assessments methods and rubrics were created to see their levels of development. Examination of students' performance in Section 5.3 shows an increase in the competency levels of the 4 main components of HOTS in the 2 years of H-CUP implementation. This increase occurred despite the change in delivery mode. Deliberate practice is embedded in all the milestones of the PBL project as well as the Lab Assignments. Through these exercises, students utilize required knowledge as well as internalize what they have learnt. This is reflected in **Figure 6** where it shows that students improved their grades as they moved throughout the semester from finding a solution to delivering a solution demo.

6. Discussion

HOTS is deemed as a skill that must be mastered by every student to ensure that they are ready to meet the demands of the global market. Students who have developed these skills not only know about a fact but can also understand, analyze and evaluate information to solve arising problems. This ability proofed the students' capability to connect the acquired knowledge which eventually prepares them with 21st century skills in facing real life situation. For this ability to be developed there must be a Teaching and Learning strategy that provided students with the necessary steps. This is the proposed pedagogy where it can be seen that students during the 2 years of the study have increases in their creativity, problem solving, communication, collaboration, critical thinking, analytical thinking and innovation—all the soft skills deemed to be top ones desired by employees according to WEF (WEF, 2020), LinkedIn (LinkedIn, 2019) and NACE (NACE, 2021).

The proposed framework also seeks to create a learning environment that mimics the real world taking into consideration the different learning styles of the students as well as their expertise levels. It seeks to utilize different learning methods (CA) to address the different learning types of each student (UDL) while using authentic tools and problems (PBL). It also addresses these differences in how learning is assessed as students articulate their learning in different modalities. As such, students in this framework were able to acquire and increase their domain knowledge and while solving problem acquire procedural or process knowledge when they "learnt how to do" using different methods, procedures, techniques and algorithms. Finally, students learn metacognitive/conditional knowledge which is the ability to know how to approach/solve things differently when the situation, context, or person changes inside of a problem.

H-CUP seeks to offer to students' opportunities to increase their knowledge in the desired course as well as develop their skills sets through the completion of various assignments and examinations. These same assignments foster deliberate practice which allows students to see how their domain knowledge can be used to solve problems using methods, procedures, strategies and algorithms (process knowledge) as well as develop an understanding of when and how to this knowledge. In this way students not only internalize way they learnt but also develop the mental ability to apply the said knowledge. This is the beginning of being an expert.

7. Conclusion

This paper presents a pedagogical framework designed to increase students' expertise in any knowledge area as well as their competency in HOTS skills. The framework goes beyond existing frameworks that focus primarily on the development of skills and competencies, by also focusing on students' expertise using different methodologies that cater to students' different learning styles. Comparisons of students' performance using this framework against other students' performance for the last three years have shown marked improvements regardless of the delivery mode. The research aims to carry through this research in other courses to demonstrate that the findings are not aberrant and that the proposed framework is not course specific. This implementation into other courses will help to show the flexibility of the framework and may help to carve a niche for it.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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