	Learning Technology Publication of IEEE Computer Society's Technical Committee on Learning Technology (TCLT)	

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Call for Articles

The IEEE Technical Committee on Learning Technology (TCLT) has been founded on the premise that emerging technology has the potential to dramatically improve learning. The purpose of this technical committee is to contribute to the field of Learning Technology and to serve the needs of professionals working in this field.

The Bulletin of the Technical Committee on Learning Technology aims to report (1) the up-to-date outcome of the emerging learning technologies, (2) the review of learning technology related books, instruments or reports, (3) the collaboration opportunities of work-in-progress research ideas and projects, (4) the current development status of learning technology in the developing countries, and (5) the announcements of the upcoming activities that the learning technology community may interest. It would also serve as a channel to keep everyone aware of Technical Committee's activities.

The bulletin is calling for articles in the following sections:

- **Emerging Learning Technologies:** an article with up to 8 pages the research outcome of learning technologies, including systems, tools, apps, etc., no theoretical or concept only research would be accepted.
- **Book & Report Reviews:** an article with up to 4 pages.
- **Collaboration Opportunities:** an article with up to 4 pages to talk about the research progress and stage outcome as well as the aspects and needs of looking for collaborations.
- **Report from Developing Countries:** an article with up to 6 pages to describe the current research progress/difficulties/needs/limitations of the learning technology in the developing countries.
- **Event Info & Call for Event Host:** 1 page.

The bulletin articles have to give readers clear idea and vision of the advanced learning technologies with rich and proper figures, screenshots, and diagrams.

For preparing your manuscript, please follow the IEEE guidelines and use the template at https://ieeeauthor.wpengine.com/wp-content/uploads/Transactions-brief-short-or-communications-article-template.doc. Please submit your manuscript to tclt-bulletin@ieee.org in Word format with the subject title "Bulletin Submission for [*section*]" (*section* indicates which section you would like to submit). All figures should be in high resolution and embedded in the main text.

The bulletin is included in Emerging Sources Citation Index (ESCI). The first decision for the submission is in 24 days.

Editorial

Maiga Chang, Rita Kuo, Jerry Chih-Yuan Sun, Jun Chen Hsieh,
Danial Hooshyar, Ahmed Tlili

IEEE Technical Committee on Learning Technology aims to contribute to the field of Learning Technology by serving the needs of professionals working in this field. It sponsors multiple international conferences and workshops, such as International Conference on Wireless, Mobile and Ubiquitous Technologies in Education (WMUTE) and International Conference on Technology for Education (T4E). International Conference on Advanced Learning Technology (ICALT) is one of the most important conference organized by the technical committee and the annual meeting of the committee is hosted in the conference to listen to community's words.

The Early Career Researcher Award in Learning Technologies is also announced in ICALT every year in order to encourage more young researchers contribute their works in the area of learning technology. We are honored to invite the award winner in 2020 – Dr. Ahmed Tlili – to write an article in this issue describing the path of his research career. His work focuses on collecting students' personality traits – including subjective and objective factors – to understand how students' personalities affect their learning path. He also encourages young researchers to build their research network as early as possible by contacting the researchers whose research works that they are interested in. This article can help young researchers understand how people success in their early career path.

Besides the letter from the award winner, there are two articles in Emerging Learning Technologies, one article in Report from Developing Countries, one article in Collaboration Opportunities, and one article in Book & Report Reviews section. The first article, entitled "Project OSCAR: Open-source animations repository to foster self-regulated learning," in the Emerging Learning Technologies section was written by Iyer, Sharma, Sahasrabudhe, Garg, and Lokhande. This article presents the design of an online repository of learning objects (LOs) consisting of 2D and 3D's audio-visual animations and simulations for STEM concepts; and are available in multiple Indian languages. This repository allows educators to publish and manage educational resources effectively and allows learners to access anytime online for viewing and downloading. The design of each LO with a STEM concept is based on the theory of self-regulated learning (SRL), where specific SRL strategies such as goal settings and self-assessment are integrated with the interface design. The authors evaluated the usability of the website and the effectiveness in terms of cost, time, and quality of the LOs' production time.

The second article in the Emerging Learning Technologies section is "BR∀CE: A tool for supporting the teaching and learning of database theoretical query languages through composing tiles," written by Kawash and Meston. The article presents a web-based tool called BR∀CE, where learners can construct visual and tiled-based queries of Relational Algebra (RA) and Calculus (RC). The article demonstrates the steps of using BR∀CE, which allows learners to snap the tile-based operators together, working with the relational database schema, constructing RA and RC queries, and later generating their equivalent RA/RC expression and Structured Query Language (SQL) code. Both articles provide innovative applications for learning through interactive web-based design, and the detailed illustration of design processes can be useful for relevant researchers.

The article published in Report from Developing Countries, entitled "Distance Higher Education Paradigm in Brazil", addressed distant higher education (DHE) in the Brazilian context. The analysis from a bibliographic review and official data provided by the National Institute of Educational Studies and Research Anísio Teixeira (INEP) between 2008 and 2018 revealed the substantial increase in DHE undergraduate enrollments in comparison with the little growth in face-to-face learning. The students' performance in distance education was similar to that in the face-to-face mode, suggesting its positive effects. The author, nevertheless, cautioned the need of examining the quality of distance education pedagogies before the genuine effects of distance education could be validated.

In line with the rapid adoption of the open education movement, the study in the Collaboration Opportunities section, entitled "Operationalizing the Learner-Centric MOOC model using Communities of Practice", investigates how to design efficient Massive Open Online Courses (MOOCs) that could engage students for better learning outcomes. Specifically, this study describes the MOOC design process based on the Learner-Centric MOOC (LCM) model and the theory of 'Communities of Practice' (CoPs). It then moves to talk about possible collaborations in this field, including design instructional activities based on the LCM model, as well as data analysis to evaluate 'learner-centricity' in MOOCs.

In the Book & Report Review section, Chen, Duan, and Wang in the article "Using Digital Technologies in Museum Learning Activities to Enhance Learning Experience: A Systematic Review" systematically reviewed the literature of technology-assisted museum learning. To carry out the review, PRISMA guidelines were practiced and to analyze the collected articles, the authors employed Activity Theory which helped to investigate the state of the literature through seven dimensions of subjects, instrument, object, rules, community, division of labors, and outcome.

Briefly, with regard to subjects, authors found that comprehension test can be used to make the impact of the prior knowledge clearer when analyzing the result, decreasing the impact of prior knowledge on experiments. Regarding instruments, it was found that different cognitive levels and characteristics of participants should be taken into account with the aim of providing personalized experiences according to individual's needs. Concerning object, the authors reported that creating more technology-assisted workshops that involve cooperation is one way that allows learners to learn from each other with the help of digital tools or technologies, making more positive impacts on the learning process and outcomes. With regard to rules, it was found that having more participants would help to set control groups with different conditions, removing the interferences and find more support for the results. As for community, authors recommended to keep schoolchildren's parents informed about activities and have them involved in the learning process with children with the aim of keeping a safe learning environment in museums. Regarding the division of labour, authors found that updating the role, mindset, and pedagogies of teachers, as well as their proper training could facilitate adopting new approaches to educate learners. Finally, authors found that due to contradiction in learners' experiences and the use of digital tools in museum, researchers should be aware of the tension among learners, technologies, and museum learning activities, and truly transform the way of learning as well as the mindset of learners.

The current submission statistics show that authors receive the first decision notification in average 24.15 days, and for the accepted articles the authors get the acceptance notification in average 44.29 days. The accepted articles are published online in average 90.40 days after they were submitted. Most of the editorial board members will participate in the IEEE TCLT Annual Report session, held at 1 PM in GMT on July 12, 2021, which is opened for all participants in ICALT 2021. We are looking forward to hearing your comments and suggestions to the bulletin in the meeting.

Letter from the 2020 IEEE TCLT Early Career Award Winner

Ahmed Tlili, *Member, IEEE*

In 2020, I was honored to be awarded the "Early Career Researcher Award in Learning Technologies." It is presented annually to a leading early career researcher as an acknowledgement of the impact and significance of their research work in the area of Learning Technologies. My interest in scientific research and application started in 2009 when I took an online course about human's personality and how it impacts their decisions, including the way they learn. Afterwards, I remember reading a lot of publications from famous researchers like Carl Jung to open my mind on different psychological theories and perspectives. Since then, I started being eager to know more about how to design different educational systems and approaches that could cater to the different students' individual differences for better learning experiences and outcomes.

My first research started by investigating how personality differences within students can affect computer-based learning, through a comprehensive review of the literature. We have found that personality traits affect how students prefer learning content and learning approach like collecting information, communicating with instructor and peers, study behavior, acting and performing.

After that, since most research use self-report methods like survey to identify students' differences (e.g., personality, learning style, etc.) and since these methods are subjective and participants can easily fake their answers, my research focused on designing an implicit method for modeling students' personalities. In this context, we have collected and analyzed students' interaction data in a newly designed educational role-playing game to identify their personalities. This game included different scenarios that can stimulate students to invoke their personalities. For instance, extrovert persons are more risk takers than introvert persons. Based on this, the game provided two different paths, one is written on it "danger" and the other is written on it "safe", and we let the students choose the path to take. The accuracy of our approach was compared to a reliable instrument, the Big Five Inventory, and the accuracy was high.

Since educational games yield highly interactive and massive traces of students' in-game behaviours, and since researchers have stated that educational games without analytics are like black boxes that barely offer meaningful clues to students' learning process during their play, our research further focused on incorporating Learning Analytics (LA) to provide teachers and students more insights about the learning process and achievements.

With the emerge of the "gamification" concept in education, our research then shifted to investigate how different individual differences could impact students' perception towards different game elements in a gamified course. Interestingly, it is found that educational gamification should also be personalized according to students' personalities and gender.

Combining educational psychology and technology together is a very interesting field, however we are barely scratching its surface, as there are a lot of research directions and paths that are worth being discussed. We strongly encourage researchers to put more efforts on this topic and share with us their findings.

One quick note for those young researchers out there, please take the research journey as an adventure rather than a job; be open to embrace new knowledge, meet new people and have fun! Conferences are the best place to start from. If you also find any article of other researchers online and you are interested to ask about something related to it, please do not be shy to send them an email and ask for whatever you need. Research is about discussion and exchanging thoughts and visions; *In mathematics, 1+1 = 2, but in research 1 idea+ 1 idea = thousands of ideas.*

Dr. Ahmed Tlili is the Co-Director of the OER Lab at the Smart Learning Institute of Beijing Normal University (SLIBNU), China. He has been awarded the IEEE TCLT Early Career Researcher Award in Learning Technologies for 2020. Dr. Tlili is the Editor in Chief of the Springer Series Future Education and Learning Spaces. He also serves as the Associate Editor of the IEEE Bulletin of the Technical Committee on Learning Technology, and the Journal of e-Learning and Knowledge Society. He is also an expert at the Arab League Educational, Cultural and Scientific Organization (ALECSO). Dr. Tlili is the Co-Chair of IEEE special interest group on "Artificial Intelligence and Smart Learning Environments" and APSCE's Special Interest Group on "Educational Gamification and Game-based Learning (EGG)". His research interests include open education, game-based learning, educational psychology and artificial intelligence.

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Project OSCAR: Open-Source Animations Repository to Foster Self-Regulated Learning

Meera Iyer, Roopali Sharma, Sameer Sahasrabudhe, Anchal Garg, and Ganesh Lokhande

Abstract—**Virtual laboratories provide scope for fostering self-regulated learning (SRL). Open Educational Resources promote SRL since they offer free access, reuse, and redistribution to teaching, learning, and research resources. Project OSCAR is an online repository of learning objects (LOs) consisting of audio-visual animations and simulations for STEM concepts. This repository provides anytime access to the learners and addresses the lack of laboratory infrastructure and resources in educational institutions. Project OSCAR hosts various types of LOs, 2D and 3D animations; different types of narratives, process explanation videos and interactive simulations; and even a set of free 3D models available for creating your own animations. The design of the LOs in Project OSCAR is based on widely accepted SRL strategies such as self-observation, self-judgment, self-evaluation etc. to present a new experience to the learners. This article explains the overall structure of the repository and the process of LO development. We deliberate on the examples of LOs where the specific SRL strategies are operationalized.**

***Index Terms*—Animations, Self-regulated learning (SRL), Instructional design document (IDD), Learning Objects (LOs), Open Educational Resources (OERs), Open-Source Repository (OSR), Virtual Laboratories**

I. Introduction

Laboratory experience contributes towards the students' learning. It provides a kind of experiential learning. The importance of building scientific knowledge through laboratory activities in science curricula is mentioned in the literature [1] [2]. Laboratory activities promote cognitive development, scientific inquiry, observational, manipulative, and problem-solving skills [3]. Apart from psychomotor skills, the laboratory learning process includes reflective thinking, mental rehearsal of steps involved in procedure, insight development through trial and error and social collaboration while experiencing a phenomenon [4].

In addition to the conventional laboratories, there is an increase in the use of Virtual laboratories since they offer overall reduction in cost, space, risk, and time [5]. The virtual laboratories have been tried as a supportive pedagogical approach and an affordable medium of laboratory instruction in academia [6] [7], since they promote Self-regulated learning (SRL) [8]. Virtual labs benefit in optimization of human resources by reduction of workload on laboratory staff, congestion of space and resource sharing issues commonly encountered in physical laboratories [9] [10]. Virtual laboratories consist of e-resources such as simulations and visualizations, some of which could ideally be Open Educational Resources (OERs). There are many established lab resources available. Top level academic institutions have developed virtual labs to provide easy access and educational support [11].

For developing countries like India with millions of learners in remote and rural areas, availability of basic laboratory apparatus for undergraduate programs and high schools is a challenge. The Government of India has also funded some initiatives, such as Virtual Laboratories (vlabs) portal for school education (SAKSHAT); or Project OSCAR, to create online interactive learning components [12] [13]. This article, focuses on Project OSCAR (Open Source Courseware Animation Repository) which has been conceptualized to provide audio-visual learning and teaching material, technical support and projects in STEM (Science, Technology, Engineering and Mathematics) subjects [13]. This web-based animation repository is easy to use, allows downloads and has content available in multilingual format. Mentors and developers use this platform to collaboratively create learning objects (LOs) to support in-class and online class curriculum. In addition to the animations and simulations, Project OSCAR develops academic projects, instructional design documents, research publications, and other resources. This article presents the structure and features of Project OSCAR in the light of the conceptual underpinnings of SRL by explaining the design strategies used in the development of the LOs.

The structure of the article is as follows: The description of OERs and their advantages in Self-Regulated Learning (SRL) are provided in the next section. The third section describes the evolution of Project OSCAR followed by the fourth section which explains the implementation of SRL strategies in Project OSCAR LOs. The fifth section talks about project outcomes in terms of deliverables such as LOs, research publications, projects, and research publications. In the final section, the relevance of OSCAR as a supplementary supportive resource in the post-pandemic scenario is discussed.

II. Open Educational Resources And Their Role In Self-Regulated Learning

OERs as the name suggests are teaching, learning and research resource/s (books, tutorials, lectures, reading material, research articles, courses, videos etc.) that can be freely used, retained, reused, revised, remixed, and redistributed [14]. Since inception, OERs have become prevalent and are playing an important role in bridging the learning divide and enhancing equity to quality education [15]. OERs

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and laboratory environments provide substantial scope for enhancement of SRL strategies for academic goal achievement [16]. SRL strategies include cognitive, metacognitive, motivational, and affective components of learning [17] [18].

The SRL theories of Zimmerman [17] and Pintrich [18] stem from Bandura's (1986) socio-cognitive theory of human functioning which assumes that people are proactive, self-determined and self-regulated [19]. Zimmerman suggests the following SRL sub processes:

- Self-observation of one's activities,
- Self-judgment of one's performance and
- Self-evaluation by understanding the feedback of the performance [5] [19]

While Pintrich (2004) elaborates the SRL strategies based on three categories [18]

- Cognitive: Rehearsal, Elaboration, Organization, and Critical thinking
- Metacognitive: Goal Setting, planning, self- monitoring, and self-evaluation
- Resource Management: Time and Environment planning, help seeking, collaborative learning, and regulation of effort.

The self-regulated learners are motivated individuals who plan, set and engage in strategies to pursue their goals by effective time management and seeking support when needed [18]. They are active agents in their own learning process as they use metacognition, evaluation and reflection, to monitor their growth towards goal achievement [19]. OERs offer the optimum self-paced learning environment at any time and place which is essential for self-regulated learners. A key requisite for sustained SRL is motivation [18]. It is found that despite organizations that create OERs try to motivate learners by delivering quality content, there exist some limitations. Many of the available OERs are monolithic, non-engaging [20], or may not share the source codes to be further redistributed. Project OSCAR has been planned to overcome these drawbacks and incorporate the advantages of OERs to foster SRL strategies.

III. Evolution And Structure Of Project OSCAR

Project OSCAR was conceptualized and started at IIT Bombay in 2008 and supported by the Ministry of Human Resource Development, Government of India (Fig.1). This is an Open-Source Repository that provides free access to the source code of the animations that can be easily reused and modified by the users. This online, interactive, and animated open-source repository aims to teach STEM concepts from basic to advanced level. It also has an auxiliary purpose to make the repository self-sustaining by training learners to develop these STEM based animations and simulations, collectively termed as Learning Objects (LOs), to manage the repository and also to promote educational research. A LO refers to a digital educational resource pertaining to a single STEM concept [23]. OSCAR is designed to address the paucity of effective courseware available in small units which can supplement a teacher's curriculum.

OSCAR LOs have been made using various interactive technologies such as JAVA, Flash and Blender to be incorporated in classroom and online teaching. The LOs are engaging, interactive, and are available in multiple Indian languages and are free for viewing and downloading. Large scale dissemination of OSCAR was made possible as it was released under the creative commons India 2.5 license. It currently hosts over 450 LOs contributed by OSCAR volunteers and from other sources [13]. The data reveals that these LOs have been downloaded by thousands of users.

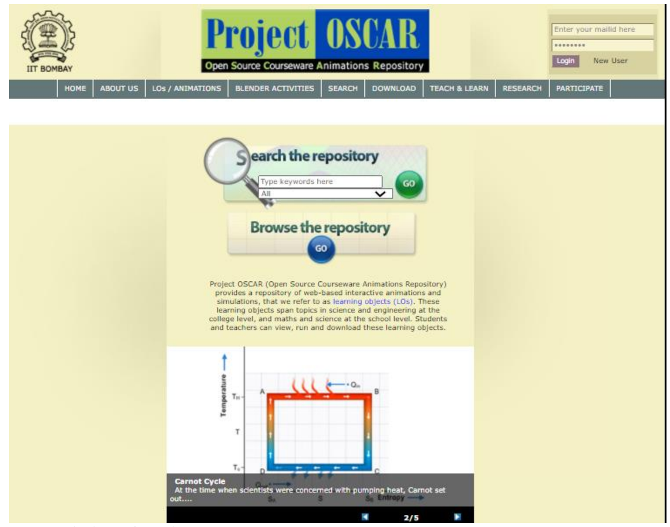


Fig. 1. Website of Project OSCAR.

A. Structure Of Learning Objects (LOs) In Project OSCAR

Each LO in Project OSCAR has six primary components (Fig. 2):

a) The learning objectives that describe what learners will be able to do after completing the LO.
b) A brief description of the concept being explained.
c) A learning activity where the user can engage by specifying and changing parameters to see the outcome.
d) Self- assessment, in the form of a quiz, where a user can self-evaluate his understanding after viewing the LO.
e) References for further reading.
f) Access to download the animation for further use.

Each LO is a stand-alone resource of two to fifteen minutes duration for the ease of cognitive assimilation. The key feature of LOs is its user-friendly intuitive interface that accommodates different learning style, preference, purpose, and pace. Also, it has a voiceover to better explain the concept [13].

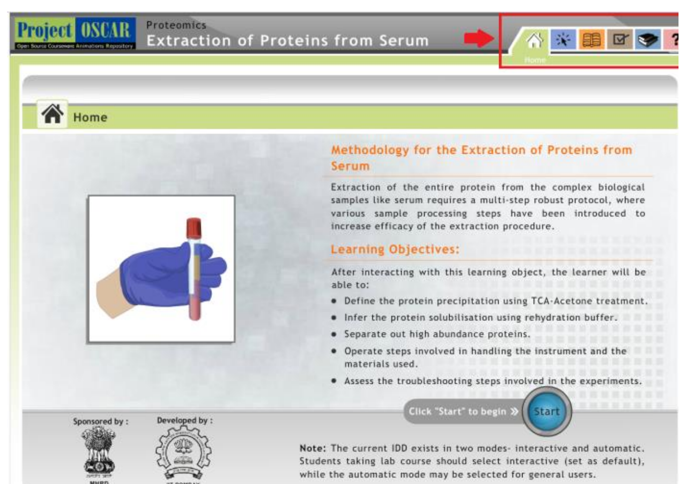
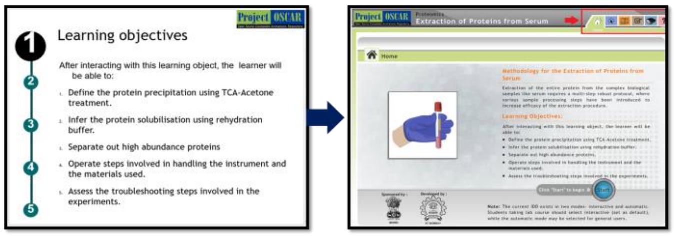


Fig. 2. Structure of a Learning Object.

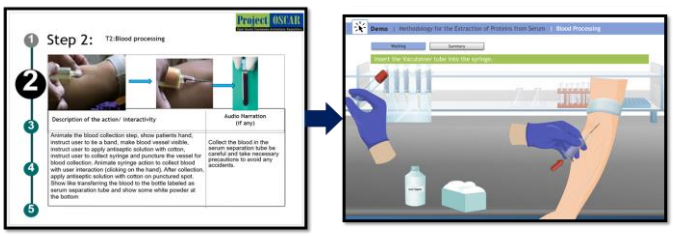
B. Process Of Creation

In Project OSCAR, a three-phase process is followed for creation of each LO.

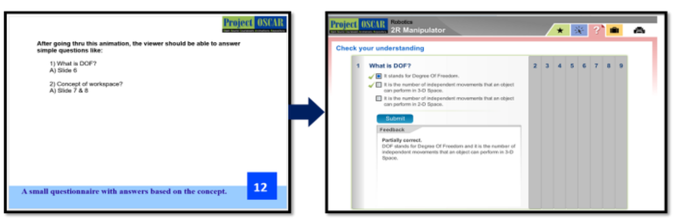
Concept Specification Phase: In this phase, selection and detailing of concepts is done by a mentor who may be a teacher, course instructor or subject matter expert (SME). The mentors interact through the portal with developers or animators. The creation of Instruction Design Document (IDD) for the concept is conducted. IDD details the description of learning objective, the sequence and detail of content, and, the details of self-assessment test with answer key. A storyboard is thus made ready for the animator based on IDD. In the first example, the IDD is shown for creating the LO ‘Extraction of Proteins from Serum’ and shows the learning objectives slide from the IDD and its corresponding final output animation (Fig 3a). In the second example, the IDD details the instructions and the script for creating the animation and its corresponding final output animation (Fig 3b). Similarly, in the third example, the IDD is shown for creating the LO ‘2R Manipulator in Robotics’ and the corresponding final output of a quiz (Fig 3c).



(a) Example of Learning Objectives in an IDD converted to LO.



(b) Example of Animation Script converted to LO.



(c) Example to Questions in IDD converted to Quiz in LO.

Fig.3. Examples of Development of IDD to LO.

LO Creation Phase: The developer uses the IDD and applet design for coding the LO. They also create animations using various tools.
Testing Phase: The animation is then tested for its accuracy in coding and for content which is then uploaded into the repository upon approval.

IV. Implementation Of SRL Strategies In Project OSCAR LOs

Project OSCAR LOs have been designed to encourage SRL. Each LO helps the learner to observe the process, interact with it and evaluate his/her learning performance based on the feedback, thus helping in the SRL process [17] [21]. Most of the SRL principles are operationalized in OSCAR LOs. In this section, we elaborate the operationalization of some SRL principles by selecting corresponding examples from project OSCAR.

A. Mental Rehearsal

The Extraction of Proteins from Serum is a complex procedure where learners need to observe all the steps carefully (Fig 4). A self-regulated learner activates his/her working memory and stores information to replicate the same, later in the actual lab settings. The LO helps in memorizing the process and it can be run, stopped, and re-winded as many times as the learner wishes. Repetition of the learning material aids in mental rehearsal [18].

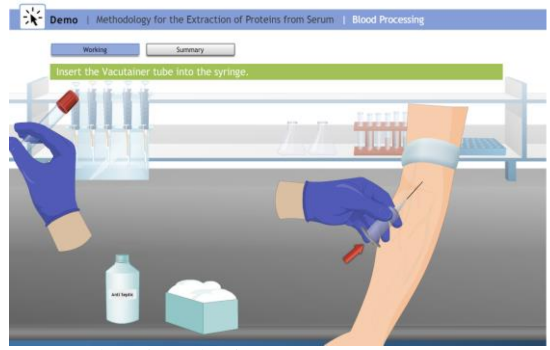


Fig.4. Extraction of Proteins from Serum.

B. Elaboration

The internal tertiary Structure of a Protein myoglobin shows the folded α-helix structure that is embedded inside the chains of the myoglobin (Fig 5). Such visualization of the protein structure is otherwise not possible with naked eye. This is another example of learning through observation. This LO aids in abstract thinking through visualization. The abstract concept is converted into visually concrete images thus promoting comprehension. As mentioned in the Elaboration principle, the learner thus can assimilate the new information with his prior knowledge by paraphrasing, summarizing, and general note taking of the same [21].

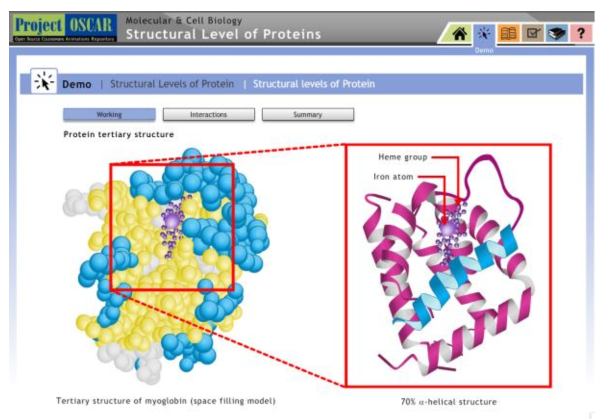


Fig.5. 2R Structural Level of Proteins.

C. Critical Thinking

The animation (Fig. 6) further aids the self-regulated learner to perform the steps and judge their understanding of the concept. It exhibits the working of a 2R manipulator from a Robotics course. One can indicate the parameters and drag the manipulator within the workspace and observe the ways in which the legs would position to satisfy the end point constraints [13]. The learner uses his critical thinking through objective analysis and manipulation of parameters [22]. Based on the results of output parameters, the learner forms a judgement regarding the appropriate input parameters to attain the desired result.

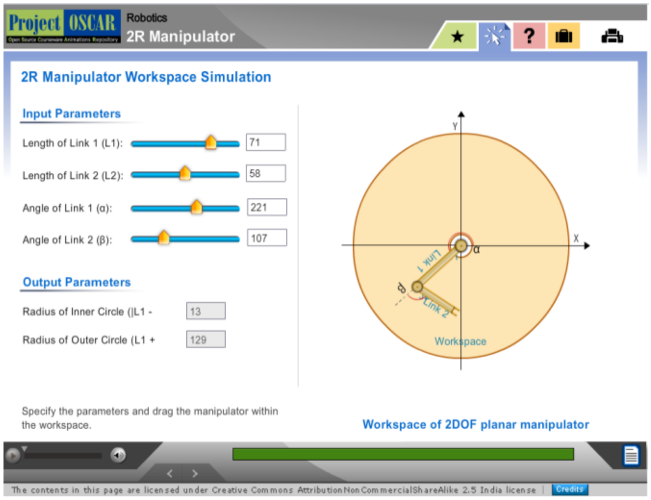


Fig.6. 2R Manipulator.

D. Organization

The LO showing working of a steam turbine-based power plant (Fig 7), demonstrates the flow of steam from the steam generator to the steam turbine that forces the high-pressure rotor to rotate and then flow into the condenser. This LO helps in organizational thinking by cognitively connecting different aspects of the content, thus developing a holistic perspective about the learnt concept [18].

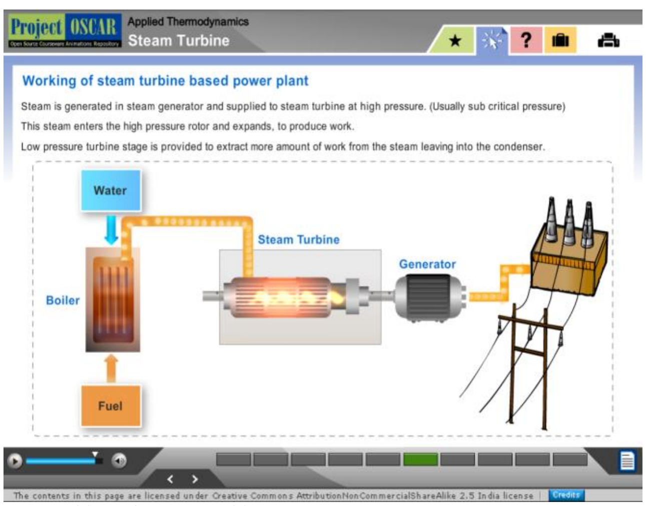


Fig. 7. Working of Steam Turbine.

E. Metacognitive Strategies: Planning, Self-Monitoring, And Evaluation.

Metacognition is awareness and control of one's cognition [23]. A learner sets a goal such as choosing a specific subject. OSCAR LOs have a quiz where the learner can evaluate his/her performance and get feedback on his/her answers (Fig. 8). Through the process of feedback from the quizzes, the self-regulated learner evaluates monitors and restructures further course of action to enhance conceptual understanding further. Thus, the Project OSCAR supports SRL through self-evaluation of one's learning[24]. Each LO in OSCAR facilitates a learner to engage in metacognitive learning strategies.

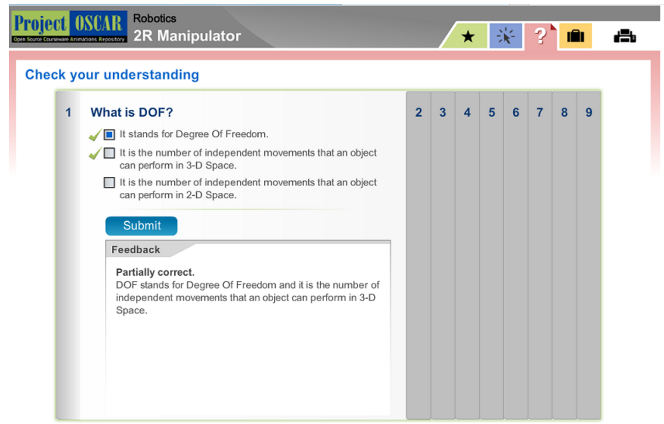


Fig. 8. Quiz supported by feedback.

F. Resource Management: Time And Effort Regulation, Collaborative Learning, And Seeking Assistance

The LOs help learners to plan and control their learning environment by providing the scope to learn at the pace, time and place, convenient to the learners. A learner can regulate his efforts based on his learning style as the LOs contain both text based as well as audio-visual based resources. Project OSCAR facilitates collaborative learning and seeking help from other learners working on the same project as well as from Mentors [18].

Apart from these LOs, the project OSCAR has produced several artifacts that are useful for both the learners and instructors. All the SRL processes are exhibited in the LOs created in Project OSCAR. There are some LOs that cover many SRL strategies simultaneously whereas there are some that may address some specific SRL strategies. In short, all the LOs of Project OSCAR are based on well - researched SRL strategies.

V. Outcomes

In addition to the LOs, initiatives undertaken during the development and implementation of the Project OSCAR have been generating several other tangible outcomes. There are 3D Models, IDDs, undergraduate and postgraduate projects as well as research publications [13]. We will elaborate each of the outcomes in this section.

1) LOs/Animations

Project OSCAR has developed a repository of 457 LOs to support teaching and learning of diverse concepts of mathematics, science, and engineering (Table I). LOs support the teachers and students at both the school level and higher education level. To support teaching learning at the undergraduate and postgraduate level, LOs have been created for diverse Engineering disciplines such as Biochemistry, Bioscience & Engineering in addition to traditional disciplines such as: Chemical Engineering, Civil Engineering, Computer Science, Mechanical Engineering, Metallurgical Engineering, etc. Likewise, LOs have also been constructed for differing areas of basic sciences such as Physics, Chemistry and Biology. The highest number of 81 animations has been created for Biochemistry.

Further, to assist school education, few LOs have been made for science and mathematics courses. High school level STEM concepts are gamified for learner engagement and motivation. In addition to this, LOs in regional languages have been designed for learning and teaching concepts of Math and Science.

TABLE I
Number Of LOs Based On Discipline

Level	Category	Number of available animations/LOs	Download Statistics
UG/PG	Engineering	150	23777

	(Chemical, Civil, Computer Science, Electrical, Electronics, Mechanical, Metallurgical)		
	Basic Sciences (Biology, Physics and Chemistry)	61	3237
	Applied Sciences (Biochemistry, Bioscience, Earth Science, Environmental Science)	109	3307
School	Science and Maths	117	15926
Total		437	46247

A sample LO representing 2D-DIGE Gel Scanning is shown in Fig 9.

Fig. 9. LO - 2D-DIGE Gel Scanning.

2) 3D Models

Free eLearning software that can create 3D animations are sparse and thus BLENDER, an open-source 3D animation suite was used to create animations and simulations. BLENDER supports modelling, rigging, compositing and motion tracking along with editing video content and 2D animations. It is easy to use and its plugins allow the projects to be rendered by any web browser [13].

The project has also been producing an open repository of three dimensional (3D) models created using Blender (Fig 10). These models are equipment from Physics and Chemistry Laboratories that can be downloaded to make animations.


Fig. 10. 3D Model of an Ammeter.

3) Instructional Design Documents (IDDs)

IDDs are documents that detail a systematic procedure of converting a standalone concept into an animation using instructional design principles. This document enables an animator to easily create animations[25]. A total of 187 IDDs have been produced as a part of project OSCAR. These IDDs act as an interface between the Instructional Designer and the Animator and thus aids in creation of LOs. The details on the process to be followed for generating IDD is very well documented and published [26].

4) UG/PG Projects Based On BLENDER

Project OSCAR also includes projects made by UG and PG students based on Blender. These projects are created by students from Engineering domain, who wish to use 3D animation to explain concepts. Some of the student projects include a 3D Ammonia Fountain laboratory experiment for better understanding of the experiment, a 3D interactive content creator for dissemination of educational content, a 3D interactive interface for creating eLearning animations, an interactive learning environment using gesture recognition, interactive circuits using augmented reality, an eLearning application called 3D Netra for enabling school students to learn the concepts of human eye, etc. [13]

5) Research Publications

Research papers are published based on the experience during the Project OSCAR [13]. These research papers provide a roadmap to other researchers interested in implementing similar proposals.

There are several other outcomes of the Project OSCAR such as the trained teachers and students and communities of practice. Also, more artefacts (LOs, 3D models, IDDs etc.) are regularly being developed and added to the OSCAR repository.

The effectiveness of the OSCAR LOs in enhancing self-regulation among the users will be addressed in the upcoming research. As the collected data is insufficient to conduct quantitative data analysis and draw any conclusive inferences, it is considered inappropriate to mention it in this paper.

Researchers who have worked on the OSCAR project have demonstrated its usability and published widely about it. We list some of these papers to highlight the various facets described in these publications.

(i) Usability and effectiveness [25, 27]: Iyer et al. have shown the usability and effectiveness of OSCAR LOs through statistical data about the downloads recorded on the repository. The economic, user friendly and wide accessibility features of Blender for creation of eLearning 3D animations were demonstrated through a case study in the domain of Chemical Engineering.

(ii) Developmental methodology for 3D model creation [28]: The developmental methodology for creating 3D simulations for lab experiments lists the three stages, namely, Modeling, Animation and Adding Interactivity. The paper also provides a path for others to create their own model repository by describing the process of creating 3D models using Open-Source software, BLENDER.

(iii) Cost and time effective LO production through DOM [29]: The domain owner model (DOM) for rapid and large-scale development of LOs, is compared with other asynchronous models, namely, online distributed model, individual faculty model and fully outsourced model. LOs created through this model proved most effective in terms of cost, time, and quality with a mean production time for each LO of 0.375 months.

(iv) ELAM (E-Learning Acceptance Model) [30]: A conceptual framework, ELAM identifies the factors required for acceptance of e-learning by students and teachers. This was done by observing the behavioral intention and actual use of the e-learning technology.

VI. Future Implications Of Project OSCAR

Recently, Flash has been retracted by Adobe, efforts are being made to build animations HTML 5 compliant.

During the pandemic, classes in both schools and colleges are being conducted online in most part of the world. The teachers and course instructors are relying largely on available online material that is free of cost and of good quality to supplement their classes. The instructors can bank on the advantages that OSCAR offers, especially in the post pandemic situation, where various efforts are being made to strengthen teaching-learning processes. Animations and simulations have become the need of the hour to explain complex concepts to learners as practical and demonstrations in laboratories and in-class teaching remain suspended. Many audit and credit courses are being floated by universities such as MIT, Harvard etc. [31] which are freely available or charge minimal for certificates. However, there remains a deficit of free open courseware that have concepts in a stand-alone manner and which can be used in both online live classes as well as in classroom teaching. Project OSCAR is a promising handy pedagogical web based OER that can easily work on mobile devices, laptops and other devices and can be integrated with existing teaching resources for an enriched learning experience.

The National Education Policy (NEP 2020) released by the Government of India focuses on a student-centric interdisciplinary education. The learner will now be able to take up subjects of his own will in multiple streams, and not restricted to a particular discipline. The LOs of Project OSCAR can prove useful in such a scenario. This policy has furthered the need for self-regulated learning and self-motivation to develop competence and skill in subjects of interest. For example, a student choosing a social science subject and a STEM subject like Physics to pursue in high school will require developing projects that address both domains simultaneously. Project OSCAR holds a futuristic scope of providing a platform to design such projects in the form of LOs.

Further, the implementation of NEP will be challenging to schools and colleges as catering to individualized education programs would require more resources, infrastructure, and teachers. Here again, Project OSCAR can aid in catering to the deficit by helping the learner to access knowledge to gain conceptual understanding in small units. A proposal to make OSCAR a part of NEP and Atal tinkering Labs by assigning singular projects to developers and students to create LOs and 3D models will aid in enriching the existing repository. The educational institutions may collaborate to create LOs and 3D models in different Indian languages. Thus, the focus would be on knowledge acquisition instead of language comprehension to understand STEM concepts.

OSCAR is a supportive and integrative pedagogical tool. The promotion and integration of Project OSCAR in existing MOOCs will be an added advantage as it will make the courseware more engaging and motivating to learners. The development of LOs and 3D models in foreign languages will be helpful to international students. Course instructors and teachers can enrich their lectures and online classes by embedding small LOs from OSCAR. Promoting the LOs in remote areas with lack of adequate infrastructures to support can prove useful to many students. If promoted well, it has the potential to be a supportive mechanism to cultivate self-regulated learning among learners and instructors.

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BR∀CE: A Tool for Supporting the Teaching and Learning of Database Theoretical Query Languages through Composing Tiles

Jalal Kawash and Levi Meston

Abstract— **Learning theoretical query languages, namely rela-tional algebra and calculus, is beneficial to students. However, it is often challenging for both students and educators since textbook coverage of the area is purely theoretical with "pencil--and-paper" exercises. Hence, there is no mechanism to validate student queries using a database management system or by automatic translation of these theoretical expressions to an actual database query language like SQL. To answer these limitations, we developed a Web-based tool called BR∀CE that allows users to visually formulate relational algebra and calculus queries in a Scratch-like, tile-based manner. BR∀CE translates the visual query to the equivalent theoretical expression and it also generates an equivalent SQL expression. To use the tool, a user simply needs a browser. BR∀CE also allows the user to work with any database schema. These factors coupled with our plan to make it freely available online make it an important resource for students and educators alike. This paper walks readers through BR∀CE to formulate relational algebra and relational calculus queries.**

***Index Terms*— Database Education; Queries; Relational Alge-bra; Relational Calculus; SQL**

I. Introduction

Computer Science, Software Engineering, Information Systems, and similar programs include database systems as a core topic that students need to master before they are ready for their future jobs. The Structured Query Language (SQL) constitutes a substantial part of any course on database systems. It is by far the most commonly used query language in Relational Database Management System (RDMS) implementations. Oracle, MySQL, SQL Server, and Microsoft Access are just a few examples of RDBMS implementations that utilize SQL. Hence, it is not a surprise that database textbooks allocate a substantial space for the topic. In addition to SQL, many textbooks also dedicate space for theoretical query languages (such as [3], [8], [17]). There are two such languages: Relational Algebra (RA) and Relational Calculus (RC) [2]. SQL was intended to be an implementation of RC [2]; however, the language ended up being a hybrid implementation of both the RC and RA.

RA is a procedural language, where the way the query statement is defined dictates how the query is executed. Most RA operations were implemented into SQL. These include selection, projection, joins, set operations, and aggregate func-tions. RA also includes a division operation, which was never implemented in SQL. RC, on the other hand, is non-procedural or declarative, where a query statement describes the result set of the query. Hence, the query statement does not dictate how the query is executed. RC has two types: The Tuple-RC and the Domain-RC. Both types of RC are similar, and they use predicate logic to define the result set of the query statement.

Therefore, they both use quantifiers: existential ($\exists$) and universal ($\forall$). The only difference between these two relational calculi is the range of the predicate variables, which range over tuples in the former and domains in the latter. RC queries in BR∀CE are restricted to Tuple-RC since it is the more popular calculus.

SQL has direct support for the existential quantifier ($\exists$) through its EXISTS function. However, universal quantifiers ($\forall$) are not directly supported and must be also expressed in terms of EXISTS, exploiting the fact that the proposition $\forall x P(x)$ is equivalent to $\neg\exists x \neg P(x)$. This is normally a source for confusion and struggle for students [11].

Teaching and learning these theoretical query languages has many benefits to students [14]. We list three major and obvious benefits. First, they provide a theoretical platform for students to develop and sharpen their problem-solving skills, especially in the query formulation domain. These skills are necessary regardless of the language employed. Second, they provide a theoretical vehicle for learning SQL. SQL combines design elements from both RC and RA. Finally, they provide an opportunity to contrast procedural, as it is the case with RA, versus non-procedural query language design, such as in RC, allowing for important refection on language design philosophies as well as query processing.

The coverage of RA and RC in textbooks is purely mathematical and the provided problems are "pencil-and-paper" exercises, as noted by McMaster et al. [14], rather than being of the programming nature. This adds an extra layer of com-plexity to an already complex and unpopular subject among students. Our experience is consistent with others [12]–[14] and shows that students struggle with these languages in part due to the lack of computer tools that can support them with their learning. In SQL, the students can test and validate their SQL code using a database management system, and therefore, verify the correctness of their code. However, this feature is not easily available with RC or RA. This impacts how and if this subject is taught at all. Instructors can easily shy away from it unless they can provide appropriate support for students to check and validate their on-paper answers. Another challenge that faces students is that it is often cumbersome to relate RA or RC queries with SQL [12], especially for involved and complex queries.

To answer these limitations, we developed a Web-based tool called BR∀CE (short for Blockly Relational Algebra and Calculus Environment) that allows students to construct visual, tile-based queries in both RA and RC (See Figure 1). That is, the queries are written in a Scratch-like fashion. The tool generates the equivalent RA or RC expression to the visual query and translates the RA or RC expression to SQL as well. This provides the opportunity for students to validate their queries, through validating the SQL statement as well as the opportunity to better relate these theoretical languages with SQL. BR∀CE is available along with the support resources at the URL https://www.cpsc.ucalgary.ca/~jkawash/brace.html.

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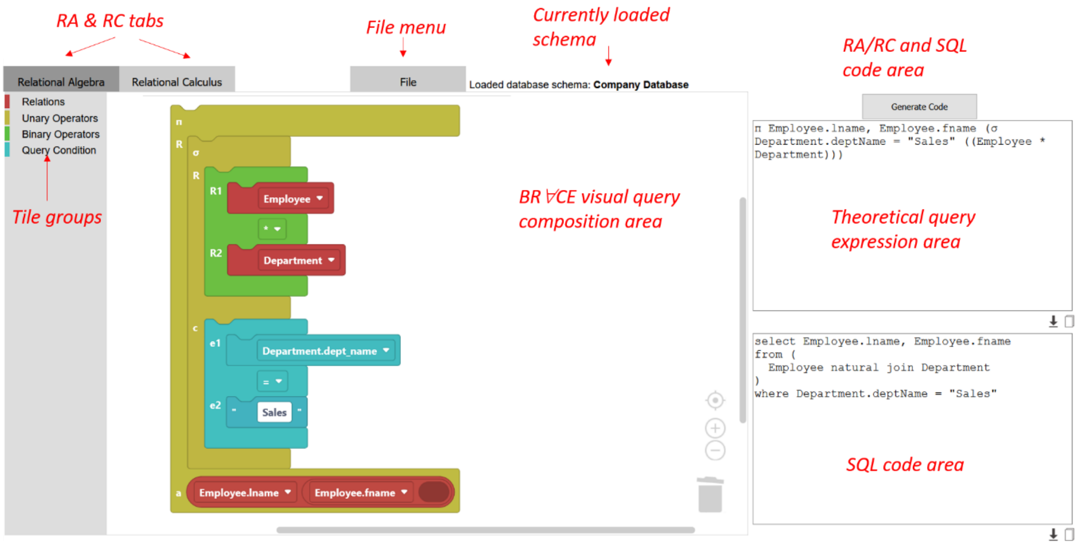


Fig. 1. The BR∀CE interface

In this paper, we present the BR∀CE interface and utilize it to formulate example RA and RC queries. The internal workings of the tool, including the developed compilers, are a subject of another publication.

The intention of this paper is to take educators through the steps of using BR∀CE for formulating RA and RC queries. That is, our objective is to provide this primer to those educators who would incorporate BR∀CE in their courses and encourage their students to utilize it. This will also provide opportunities for evaluating the tools and assess how it is helping in the teaching and learning processes.

The remainder of the paper is organized as follows. Section II discusses related work. Section III walks through the steps of using BR∀CE to formulate RA and RC queries. Section IV concludes the paper and discusses possible future research projects.

II. Related Work

Other tools that target the teaching and learning of RA and RC exist. These are listed in Table I. The table also compares these tools against each other and against BR∀CE. The comparison criteria used is whether the tool:

1) supports RA,
2) supports RC,
3) generates SQL code,
4) works with any database schema,
5) is independent (it does not require additional libraries, extra installation elements, or any other additional steps to be used),
6) is Web-based,
7) utilizes tile-based programming,
8) generates query result (directly validates the query against a specific data set, providing the data that con-stitutes the result for the query).

Supporting both RA and RC in the same tool is important since these topics are taught together in the same course. The generation of SQL code is also essential since RA and RC are simply theoretical foundations for SQL and database applications are built using SQL as a central component. The ability to work with any database schema allow the students to work with any example databases given in their courses and textbooks. Independence and Web-based access makes a tool easily available for its users. A visual, tile-based interface makes the formulation of queries easier and less prone to syntactic errors.

Finally, the ability to see the query result allows the students to verify the correctness of their query. While some tools, such as ours, do not generate an immediate query results, they do, however, generate the SQL code which can be easily run against actual database implementations. That is, query verification is still possible in these tools, but requires an extra step.

DBsnap [18] allows the user to build visual queries using a tree structure. It only supports RA but does not include the division operator. It generates the RA expression, but unlike BR∀CE, it does not generate equivalent SQL to the RA. Unlike BR∀CE, it shows the user query results and intermediate results as well.

TABLE I
Tools for Teaching RA and RC

Tool/Approach	Supports RA	Supports RC	SQL Code	Any Schema	Independent	Web-Based	Tile-Based	Query Result
DBsnap [18]	✓			✓	✓		✓	✓
WinRDBI [6]	✓	✓		✓	✓			✓
iDFQL [1]	✓			✓			✓	✓
Relational [19]	✓			✓	✓			✓
RALT [15]	✓			✓			✓	✓
QVis [4]	✓			✓	✓			✓
Bags [9]	✓			✓	✓	✓	✓	
FP&P [14]	✓	✓		✓				✓
IRA [16]	✓		✓		✓			
YRA [20]	✓		✓		✓			
Relax [13]	✓			✓	✓	✓		
CalEm [7]		✓	✓		✓			
QuantX [11]		✓		✓	✓			
BR∀CE	✓	✓	✓	✓	✓	✓	✓	

WinRDBI [6] is a Windows implementation of RDBI [5]. It is a stand-alone application implemented in Prolog. The database and its schema are loaded to the tool as Prolog facts. The query is executed using the loaded database. No translation to SQL is provided and it is not clear if all the RA operations are supported.

iDFQL [1] is limited to RA. It is not maintained and is not available for testing. The tool is visual, but it does not show the RA expression. Is not independent, requiring a connection to a RDBMS to validate queries.

Relational [19] is also limited to RA. It does not generate equivalent SQL code to the RA query expression. The tool allows the user to create their own data set and schema and shows the query result.

RALT [15] requires a connection to an external Database, and it does not show the RA expression nor SQL code. The tool is not available for testing.

Query Visualiser (QVis) [4] is also limited to RA but does not support division. It executes a query and shows the results rather than generating equivalent SQL code. This tool is not available for testing either.

Bags [9] only supports RA as well. It is based on Snap [10], hence, it is Scratch-like similar to BR∀CE, but does not generate the RA expression or the equivalent SQL code.

McMaster et al. [14] describe two programming approaches. For RA, they present a function library using Visual FoxPro, and for RC, they provide a Prolog library. This is not an independent tool; instead, it is two add-ons to FoxPro and Prolog. In Table I, we call this approach FP&P. Obviously, some knowledge in FoxPro and Prolog would be required from students to use these libraries. In addition, defining the predicates that represent a database schema in Prolog adds an extra layer of overhead for students. The RA and RC queries are executed against a database without the intermediate step of generating the equivalent SQL code.

IRA [16], RA [20] (we will call it YRA using the authors initial to avoid confusion with our RA acronym), and Relax [13] are all limited to RA. RelaX and IRA provide the result of the constructed RA query. However, neither provide the user with the equivalent SQL. IRA is limited to a fixed database schema, where RelaX allows users to create their own. Both are limited by not providing support for all RA operations, namely aggregation. YRA is an RA interpreter that translates given RA queries into SQL that is then executed. YRA can provide the user with the generated SQL query, however, these are only provided through additional debugging information rather than by default for the user's benefit. YRA also must be installed directly onto the user's system rather than being an online tool, making it slightly more cumbersome to use. None of these tools provide a block-based environment to construct RA queries in.

Tools that deal with RC only also exist. We are only aware of two such tools: Calculus Emulator [7] (we used CalEm to refer to it in Table I) and QuantX [11]. CalEm is a stand-alone application that generates the equivalent SQL code. QuantX [11] is also a stand-alone application, but it simply teaches the users how to translate a complex RC query to SQL, but it does not provide any validation for the RC query.

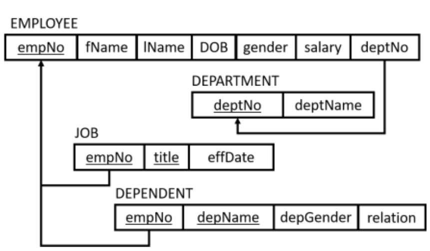


Fig. 2. A simple company database schema.

III. Composing Queries

A. Running Example

In this paper, we will use the database schema depicted in Figure 2. This database keeps information about employees, who are described by their numbers, names (first and last), date of birth (DOB), gender (we assume the gender values are M for male, F for female, X for LGPTQ, and O for other), salary, and the department (number) they work for. A department is described by its number and name. Employees may have dependents, who are described by their name, gender, and relation to the employee. The job title of an employee is also recorded with its effective start date (effDate).

B. BR∀CE Interface

The BR∀CE interface is shown in Figure 1. In BR∀CE, the schema is loaded to the tool as an XML file, which follows a very simple Document Type Definition (DTD) that lists the relations and their attribute names. To use your own schema, code in XML and load it to BR∀CE through the **File** menu choosing the *Load Database Schema* option.

Next, click the **Relational Algebra** or the **Relational Calculus** tab to start composing your RA or RC query, respectively. A query can be composed by selecting a *Tile Group* and then dragging and dropping the required tile to the *query composition area*. Some tiles require a relation or an attribute name. BR∀CE populates the field that require relation or attribute names in these tiles with drop-down lists. You can scroll down these lists and select the required relations or attributes for your query. Some tiles require a constant value or a quantifier variable name (only in RC). For these tiles, use the keyboard to enter the required value into the appropriate tile.

Once your visual query is composed and is complete, click the Generate Code button. The equivalent theoretical expression to your visual query and the equivalent SQL code will be shown in their respective areas. You can copy each of these expressions to the clipboard, using or download them as a file, using . You can save your query from the File menu. BR∀CE queries are saved with the extensions *raq* and *rcq* for RA and RC respectively. Note that the schema representation is piggybacked to the query since queries are schema specific. When you load a query from a file, the database schema is also loaded to BR∀CE.

C. Relational Algebra Examples

We will present queries of increasing complexity, formulate these in BR∀CE, and generate the equivalent RA and SQL expressions. The operands in the RA tiles are labeled as follows:

1) R, R1, are R2 are relation operands
2) a is an attribute name list operand
3) c, c1, and c2 are logical conditions
4) e1 and e2 are expressions which can be an attribute name or a constant value entered by the user.

An operand can be left blank if the label is enclosed in square brackets, such as [a]. We do not intend, nor we have space to cover every possible RA operation supported by BR∀CE. However, we will demonstrate at least one RA operation from each tile group.

The RA tile groups are:

1) The Relations group contains the *relation* and *attribute* tiles to be used in the next two groups.

2) The Unary Operators group contains the tiles for the RA unary operators (they have one relation operand): *select*, *project*, *aggregate functions*, and *aggregate functions with grouping*.

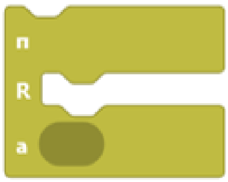
3) The Binary Operators group contains the tiles for the RA binary operators (they require two relation operands). Many of these operators share the same tile. The required operator is chosen from a drop-down list in the tile. There are four tiles in this group: (i) joins that do not require conditions (namely, *natural join* and *cross join*), (ii) joins that require conditions (all forms of *theta joins* and *outer joins*), (iii) set operations (*intersection*, *union*, and *difference*, and (iv) *division*.

4) The Query Condition group contains the tiles for formulat-ing logic conditions. There are six tiles in this group: (i) the logical *and* or *or* tile, (ii) the logical *negation* tile, (iii) the comparison operators tile (=, ≠, <, >, ≤, and ≥), (iv) the *attribute* tile needed for attribute names in conditions, (v) the *number literal* tile, and (vi) the *string literal* tile.

Any of the tiles in the unary and Binary Operators group can serve as a container for the RA query.

1) Projection and selection: The project unary operator, denoted by the Greek symbol π, filters a relation vertically. That is, it can eliminate some of its columns. We start by formulating a projection query. Because this is our first RA query, we will go through its construction step by step in Figure 3. The query *retrieves the first name and last names of employees.*

1. Drag the *project* (π) tile from the Unary Operators group and drop it in the query composition area:



2. The *project* tile requires a relation (*R*) operand. From the Relations group, drag the *relation* tile and snap it into the *project* tile. Then, choose from the drop-down list the required relation:

3. The *project* tile also requires an attribute list operand(*a*). From the Relations group, drag the *attribute* tile and snap into the *project* tile. Then choose from the drop-down list the required attribute:

4. More attributes can be added to the attribute list by snapping more attribute tiles onto the last added *attribute* tile:

Fig. 3. Steps for creating an RA query in BR∀CE.

Once the visual query is complete, click the **Generate Code** button to generate the RA and SQL expressions that are equivalent to the BR∀CE query. The equivalent RA expression generated by BR∀CE is:

```
π Employee.fName, Employee.lName (Employee).
```

The equivalent SQL expression generated by BR∀CE is:

```
select Employee.fName, Employee.lName
from Employee.
```

The *select* operation, denoted by the Greek symbol σ, filters a relation horizontally. That is, it can eliminate some of the rows. The following is a selection query that *retrieves the employees who were born before 1970-1-1* is shown in Figure 4.

The equivalent RA expression generated by BR∀CE is:

```
σ Employee.DOB < "1970-1-1" (Employee).
```

The equivalent SQL expression generated by BR∀CE is:

```
select *
from Employee
where Employee.DOB < "1970-1-1".
```

The query in Figure 5 combines both projection and selection. It retrieves the first and last names of employees who neither identify as males nor females. The equivalent RA expression generated by BR∀CE is:

```
π Employee.fName, Employee.lName (σ
(Employee.gender ≠ "M" ∧ Employee.gender ≠ "F")
(Employee)).
```

The equivalent SQL expression generated by BR∀CE is:

```
select Employee.fName, Employee.lName
from Employee
where Employee.gender != "M"
and Employee.gender != "F".
```

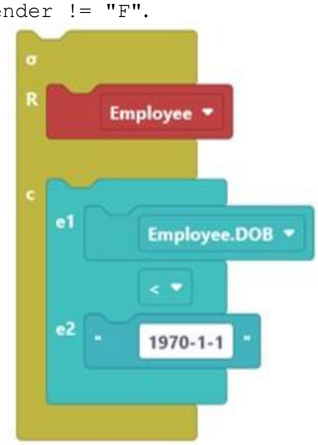


Fig. 4. A selection query in BR∀CE.

2) Aggregate functions: The aggregate functions in RA are *min*, *max*, *sum*, *count*, and *average*. Calculations can be performed to compute a single value, such as the average salary in the company, or to compute a single value for a group of rows, such as the average value per gender. The query in Figure 6 *retrieves the average salary*.

The equivalent RA expression generated by BR∀CE is:

```
AVG (Employee.salary) (Employee).
```

The equivalent SQL expression that BR∀CE generated is:

```
select AVG (Employee.salary)
from Employee.
```

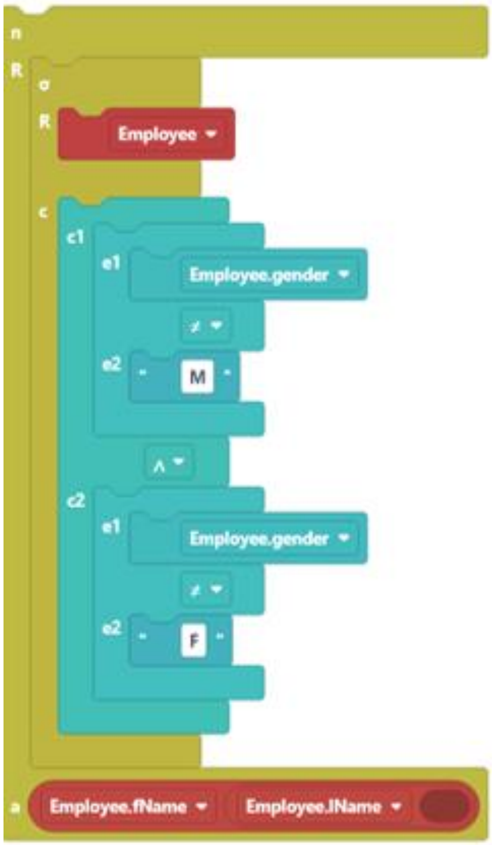


Fig. 5. A query that combines selection and projection in BR∀CE.

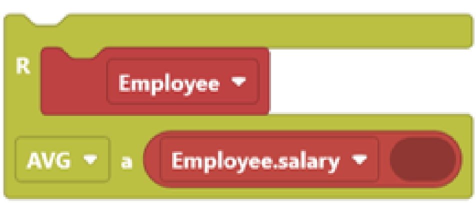


Fig. 6. An aggregate function query in BR∀CE.

To calculate any other function, such as the *min*, *max*, or *sum*, it is only necessary to choose that function from the drop-down list in the aggregate function tile. To retrieve the maximum salary for each gender group, the query is written as is shown in Figure 7.

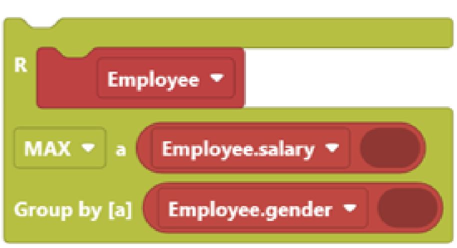


Fig. 7. An aggregate function query with grouping in BR∀CE.

The equivalent RA expression generated by BR∀CE is:

```
MAX (Employee.salary) (Employee) (Employee.gender).
```

The equivalent SQL expression generated by BR∀CE is:

```
select Employee.gender, MAX (Employee.salary)
from Employee
group by Employee.gender.
```

3) Set operations: There are three set operations in RA: *union*, denoted by ∪, *intersection*, denoted by ∩, and *minus*, denoted by –. These are binary RA operators requiring two relations as operands. To *retrieve the depNos for departments that have male employees but do not have female employees*, we formulate the minus query in Figure 8. The first set (R1) contains departments that have male employees, and the second set (R2) contains departments that have female employees. The result is the first set minus the second set.

The equivalent RA expression generated by BR∀CE is:

```
(π Employee.deptNo (σ Employee.gender = "M" (Employee)) - π Employee.deptNo (σ Employee.gender = "F" (Employee))).
```

The equivalent SQL expression generated by BR∀CE is:

```
select Employee.deptNo
from Employee
where Employee.gender = "M"
except
select Employee.deptNo
from Employee
where Employee.gender = "F".
```

Note that the query that *retrieves the depNos for departments that have both male employees and female employees* would only require changing the "–" to "∩" in the above query. The query that *retrieves the depNos for departments that have male employees or female employees* require using "∪" instead of the "–".

4) Joins: Join queries cross reference two relations against each other by pairing each row in the first relation with each row in the second relation. For all the joins, except for the *cross join* (denoted by ×) and the *natural join* (denoted by *), a selection condition is applied to eliminate some of the irrelevant rows. The *natural join*, say of Employee and Dependent, eliminates the rows where empNo from Employee is not equal to empNo from Dependent. The * must be chosen from the drop-down list in the tile and the equivalent RA expression is: `(Employee * Dependent)`. The equivalent SQL expression generated by BR∀CE is:

```
select *
from Employee natural join Dependent.
```

This can also be expressed as an inner-join query as is shown in Figure 9. Note that the natural and inner joins eliminate the employees who do not have any dependents. To include such employees in the result with the dependent information left blank when it is not applicable (for employees who have no dependents), an *outer join* is needed. In the above query, it is sufficient to replace ⋈ by ⋉ in the tile's drop-down list to create a right (Employee) outer join. The equivalent RA expression generated by BR∀CE is:

```
(Employee ⋉ Employee.empNo = Dependent.empNo Dependent).
```

The equivalent SQL expression generated by BR∀CE is:

```
select *
from Employee right outer join Dependent on
Employee.empNo = Dependent.empNo.
```

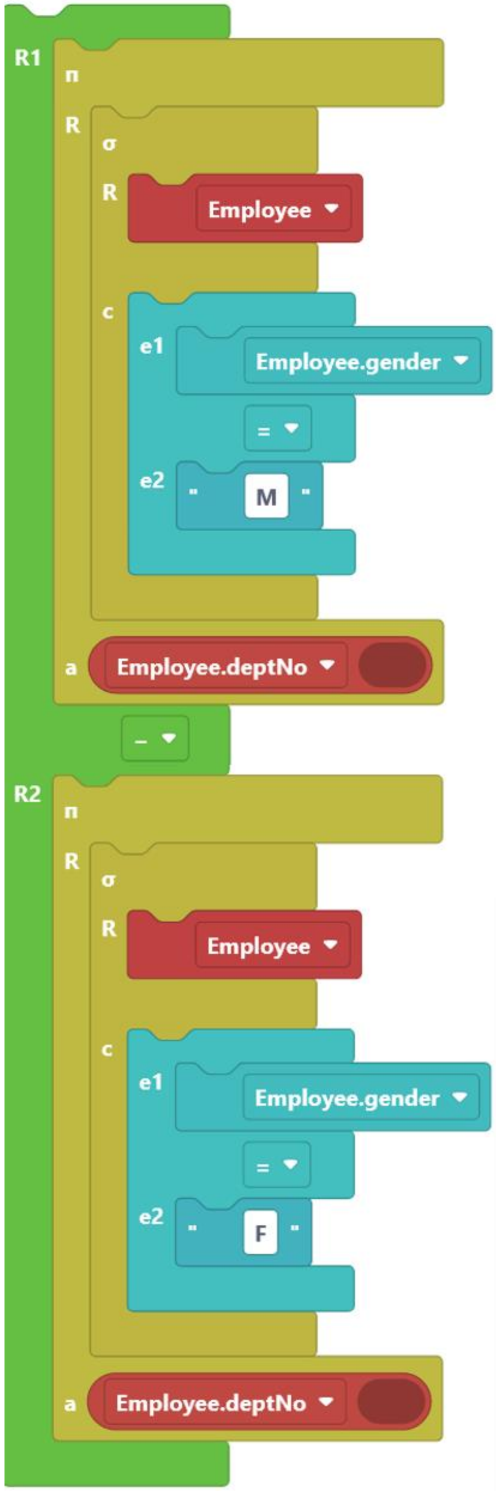


Fig. 8. A minus query BR∀CE.

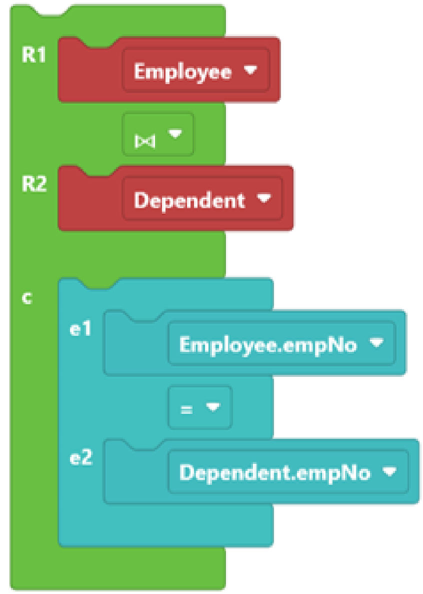


Fig. 9. A natural join query in BR∀CE.

D. Relational Calculus Examples

There are four groups of tiles for RC in BR∀CE:
1) The Main group contains two tiles. The *main* tile is a container for all RC queries. The *attribute* tile is used to specify attribute names in RC queries. Similarly, to RA tiles, optional operands are enclosed in square brackets.
2) The Predicates group contains two *predicate* tiles. The first tile represents the predicate *P(x)* and the second represents $P(x) \wedge c$, where *c* is a logical condition.
3) The Quantifiers group has two tiles. The *exists* tile corresponds to the predicate $\exists x(P(x) \wedge c)$ and the *forall* tile corresponds to the predicate $\forall x(P(x) \rightarrow c)$, where *c* is a condition.
4) The Query Condition group has the same tiles as the same group in the RA tab.

1) Simple query: We start with one query that does not require the use of quantifiers. The query in Figure 10 shows the steps to formulate a query that *retrieves the employee names (first and last) who do not identify as male or female*.

The equivalent RC expression generated by BR∀CE is:
$\{e.fName, e.lName \mid Employee(e) \wedge ((e.gender \neq \text{“M”}) \wedge (e.gender \neq \text{“F”}))\}$.
The equivalent SQL expression generated by BR∀CE is:

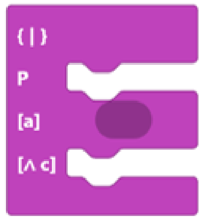
```
select e.lName, e.fName
from Employee as e
where ( e.gender != "M" and e.gender != "F" ).
```

2) Existential quantifiers: Joins in RC require the use of the existential quantifier. The query in Figure 11 *lists employee names who work for the Human Resources department.*

The equivalent RC expression generated by BR∀CE is:

$\{e.fName, e.lName \mid Employee(e) \wedge \exists d(Department(d) \wedge (d.deptName = \text{“HumanResources”}) \wedge (d.deptNo = e.deptNo)))\}$.

1. the *main* tile is required as a container:



2. This tile requires a predicate (*P*). From the Predicates group, drag and snap the simple predicate tile. Then change *Var* to *e* and choose Employee from the drop-down list:

3. Drag and snap two attribute tiles and select *fname* and *lname* from the drop-down lists:

4. Formulate the condition ($e.gender \neq$"M")$\wedge$($e.gender \neq$"F"):

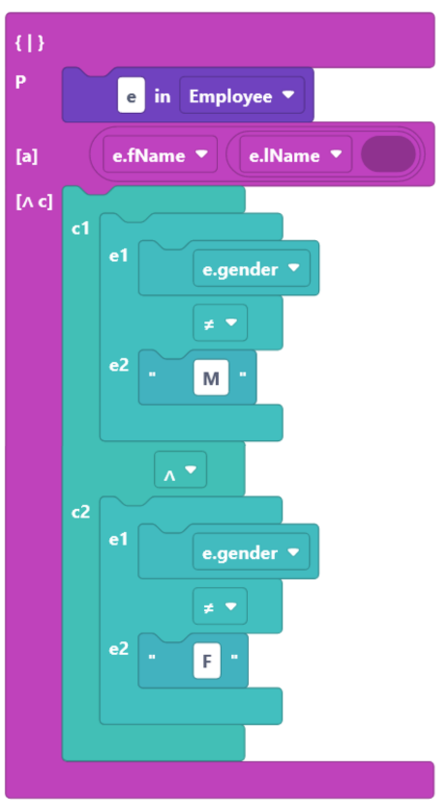


Fig. 10. Steps for creating an RC query in BR∀CE.

The equivalent SQL expression generated by BR∀CE is:

```
select e.fName, e.lName from Employee as e
where exists (
  select *
  from Department as d
  where (
          d.deptName = "Human Resources"
          and d.deptNo = e.deptNo )
).
```

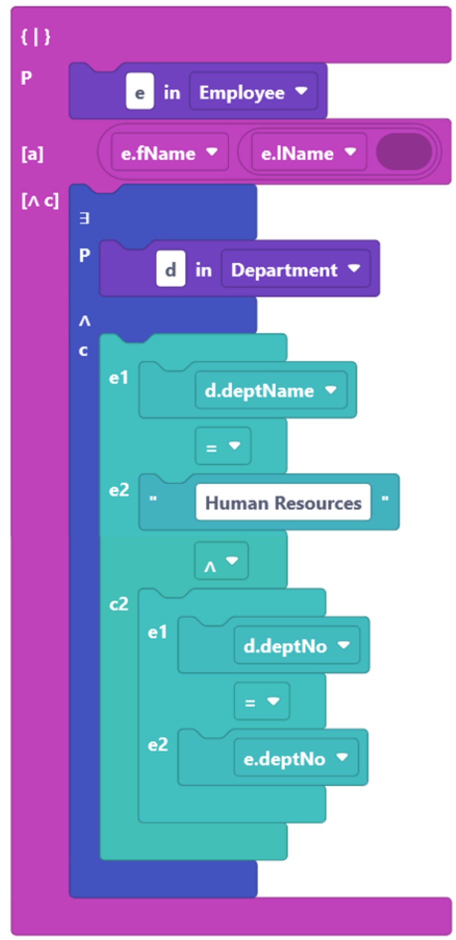


Fig. 11. An existential quantifier RC query in BR∀CE.

3) Universal quantifiers: The query in Figure 12 illustrates the use of the universal quantifier and it *retrieves the departments that have every employee earning at least 45000*. The equivalent RC expression generated by BR∀CE is:

$\{d|Department(d) \wedge \forall e((Employee(e) \wedge (e.deptNo = d.deptNo)) \rightarrow (e.salary\ \delta\ 45000))\}$.

The equivalent SQL expression generated by BR∀CE is:

```
select * from Department as d
where not (exists (
                    select *
                    from Employee as e
                    where (
                          e.deptNo = d.deptNo
                          and e.salary < 45000 )
)).
```

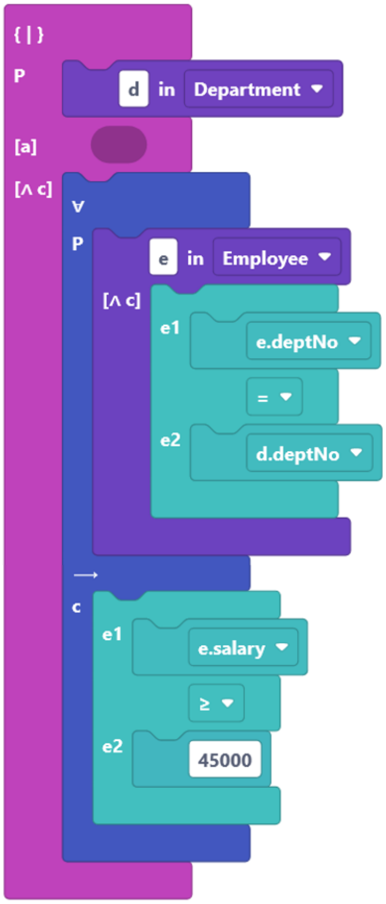


Fig. 12. A universal quantifier RC query in BR∀CE.

IV. Summary And Future Research

Using BR∀CE, RA and RC queries can be formulated by snapping tiles together. The tool allows the user to work with any relational database schema. It generates the RA or RC expression as well as equivalent SQL code. In this paper, we showed detailed examples of formulating queries that use most of the essential tiles. Previous research showed that students (and some educators) find the subject of theoretical query languages to be challenging. Given that there are many benefits for learning these languages, our freely available Web-based BR∀CE will help alleviate some of the challenges.

Several questions remain to be answered: Is there a notable effect of using BR∀CE on students learning, grades, and retention? In what ways is this tool better helping students learn the subject of theoretical query languages? How is it alleviating some of the inherent difficulties in these languages? What are the tool's limitations and how can it be improved?

The authors will be designing experiments and surveys to answer some or all these questions. The experiments will compare the performance of groups students with and without exposure to the tool. It will assess their grades in various course components that relate to query formulation. Our thesis is that the group with exposure to the tool will outperform the other group. The student surveys will aim at a minimum assessing the engagement of students with subject (will the tool improve engagement), their perception of learning (do they think the tool improved their learning.), and what improvements to BR∀CE will be needed from a functionality and usability perspectives. Now that the tool is available to the public, we also invite educators and education researchers to report on their experiences with the tool.

The introduction of tile-based programming made the subject of programming more accessible to middle-level K-12 students. We conjecture that BR∀CE will also make the subject of relational modeling and queries accessible to segments of K-12 students, specifically, junior high school students. This needs to be verified and it is our intention to do so in future research.

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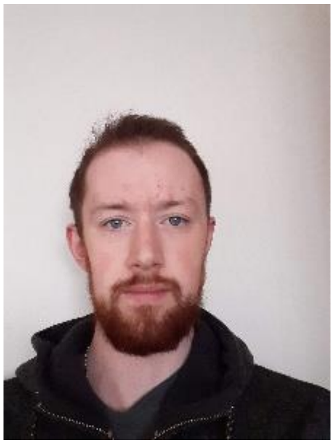

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Distance Higher Education Paradigm in Brazil

Dario da Silva Monte Nero

Abstract — **The technological advance has favored the increase in the number of distance education - DE courses throughout Brazil, facilitating access to higher education in an increasingly computerized and diversified way. The objective of this study is to contextualize how Distance Higher Education- DHE in Brazil has been produced. This is a critical essay based on a bibliographic review and official data provided by the National Institute of Educational Studies and Research Anísio Teixeira - INEP. In the period between 2008 and 2018 the number of DHE undergraduate enrollments increased 196%, while in the face-to-face mode the growth was only 10%, in 2018 when the number of graduates of DHE undergraduate courses was analyzed, even with 40% of the total courses registered, it was observed that only 21.7% were among the graduates, while in the face-to-face system it was 78.3%. In the National Student Performance Exam, in the same year the DHE courses had a balanced performance in relation to the in-person courses, being that 6% of the courses had the maximum score in the exam, while the in-person courses were 5.8% and when analyzed the worst results the average of the DHE courses was 3.7%, while the in-person courses had 3.6%. Nevertheless, DHE has been increasing its collaboration in the expansion of the democratization of education and in the conquest of the most diverse academic contents, however, it is necessary to have a careful analysis about the quality of this teaching method.**

Keywords: Education, Distance Education, Higher Education, Graduation, Technology

I. Introduction

Education in Brazil is going through a period of great transformations because the advance of digital information processing is favoring the growth of the quantity of online courses, which goes from recycling courses to postgraduate courses throughout the country. Thus, due to this rapid and significant increase in computerization and use of digital resources in the educational field, teaching has been shaped to DHE standards, which can provide an alternative for social inclusion, despite doubts about its effectiveness in quality, even being supported by the law and inspected by competent agencies [10].

The Law of Guidelines and Bases of Education-LDB of 1996, shows the difference between the principles of DE, in which it favors the offer of courses in many categories and at various levels [5]. Until then, the courses were held infrequently and applied more in their supplementary character as TV or telecourse courses and only the University of Brasilia had been offering some courses in both extension and correspondence specialization [20].

As a result, DHE has been consolidated since 2000 with the Open University of Brazil - OUB, an entity that favored the dissemination of DHE and consequently expanded the number of undergraduate courses throughout the country, providing access to students due to important characteristics such as: low cost, geographical positioning, and time flexibility for working students [6].

Although the DE modality has such a capacity to mold itself to the market system, based on the necessity of the mode of production that society is inserted in. [30], it should not be perceived as a substitute for face-to-face education, but as a way of conducting the same education process in a way that enhances academic skills.

Since of this, while technology brings possibilities of information mediation, it also adds complexity to the process, in that there are difficulties to be overcome for an optimal use of the media in the process of knowledge construction, because the characteristics of technology require methodological concepts, linked to educational policies, computerization and different traditional concepts [28].

However, various resources can be adopted to promote interactions, providing exchanges between individuals, as well as the formation of collaborative groups, where participants can express thoughts, dialogue, exchange information and experiences, through the Virtual Learning Environment - VLE, making it an instrument that allows socio-cognitive exchanges between teachers and students, providing interaction tools [33].

According to [16] Distance Education – DE seems to be translated into a breaking down of the barriers of space and time, allowing people to access this mode of teaching, where information and education technology is one of the main mediators of teaching learning.

In the last decades DHE has shown a very expressive numerical evolution in the number of undergraduate enrollments [14]. However, it is important to analyze whether this growth has provided a good level of quality in education and whether the expansion of digital education was enough to break down barriers that were already encountered in face-to-face education.

Thus, this work aims to conduct a study on how DHE in Brazil is being produced and what are the barriers faced in this new technological context.

Thus, discussing the advances and challenges of this educational system can bring us a critical understanding of DHE in Brazil and its possible gaps, deepening the understanding of this teaching structure.

This is, therefore, a bibliographic review, with analysis of official data provided by the Anísio Teixeira National Institute for Educational Studies and Research - INEP, a federal agency linked to the Ministry of Education - MEC, which involves the generation of information that subsidizes the formulation, monitoring, and evaluation of public policies focused on education, making it an important element in the development of studies and research on the educational sector.

II. Brief History of Distance Education in Brazil

The development of DE in Brazil began in the 20th century, more precisely in 1904, when an advertisement was found in the Journal do Brazil, on the classifieds part, offering a correspondence typing course [19]. From then on, DE appears as an alternative for the process of

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training workers, through radio equipment, especially those who were unable to attend courses in person due to an irreconcilable location.

In this way, the context of DE in Brazil demonstrates that it has always had a connection with professional training, enabling the "workforce" to undertake certain activities or to master certain skills, motivated by issues inherent to the market system. Public policies aimed at education began to visualize from 1930 onwards the potential that DE had to reach people from various social classes, especially the less favored, without allowing for great reflections on egalitarian issues [9, 10].

With the establishment of the *Estado Novo* in 1937, the intention was to train workers so that they could serve a slice of the market that needed administrative modernization, so following this idea of training, the Technical Radio Institute was created in 1939 and three years later, the Brazilian Universal Institute [12].

In the following decades, modernization was achieved through the television system, replacing the radio experiences in 1950, allowing for "television education" as early as 1960, which in the following years favored the training of teachers by the Brazilian Association of Television-ABT and MEC through seminars [41].

Despite the creation of the Law of Directives and Bases-LDB in 1961, endowed with several characteristics in favor of education, it was only in 1971, through the approval of a new version of the law, that DE was inserted, through art.25, which authorized technology as a possible educational tool [16].

This inclusion was directly related to the arrival of technological resources of information, more precisely in 1970, where such advances allowed a greater interaction between teacher and student, giving more agility to the process [39].

However, the affirmation of DE in Brazil occurred in 1996, through its regulation, after the creation of the Secretariat of Distance Education-SEED in 1995, this entity was linked to the MEC and articulated with LDB, so this process favored the implementation of several courses at various levels of education through (Law 9,394, 1996), this made DE be a teaching modality as any other, becoming included in public educational policies [19].

During this same period, the National Center for Distance Education was created, where it was formulated by the Department of Education, in which its guidelines remain up to the present day, always involving the strengthening of DE through better infrastructure and regulation [19].

Thus, the idea of the education system was to encourage the expansion of the DE for DHE, through the public power and this was also given by the regulation of art. 80 through Decree No. 2. 494, of February 10, 1998, this law according to [10] brought a confusion in the way in which DHE was being linked, in which it claimed a concept that DE was the solution to educational problems present in society.

Because the way in which DHE was being treated would favor an offer of numerous undergraduate courses and low costs, since it would not need a large staff of teachers and large physical structures, where the virtual rooms would embrace a much larger number of students.

In 2005 the decree of N° 5622, [13] was published in the official gazette. According to [33] it sought to constitute a quality education through DHE based on the registration of teaching, supervision, monitoring and evaluation institutions, harmonized with quality standards enunciated by the Ministry of Education - MEC. In this context, [16] affirm that the DHE demonstrates that it would be in a process of overcoming the difficulties encountered in educational policy, in which it would facilitate the access of students to this modality of education.

Thus, in the process of building and strengthening the DHE, the government instituted in 2006, by Decree 5,800, the UAB system, an organ that was created in 2005 with the objective of expanding digital higher education in the country and with the intention of disseminating the offer of courses and programs of higher education throughout the national territory [3,5].

In addition to promoting the implementation of DHE in public institutions, the OUB supports research into innovative teaching methodologies supported by Information and Communication Technologies-TIC [19], operating through the support of Polos de Apoio Presencial-PAPs, which are distributed in municipalities and micro-regions without undergraduate courses [3].

III. Advancement of Distance Education in Brazil

However, this expansion of digital education for [10], emerges as an alternative public policy, aiming to promote an accelerated increase in the number of students enrolled in higher education, because physical and structural barriers would be minimized in the face of this innovation and politically this would be an important point, which would use DHE as a democratic alternative for educational inclusion, through technology.

Since this type of teaching exposes advantages in its application, both for its low cost and for its great possibility of expanding territorially, besides favoring to the student the possibility of aggregating other activities associated to social necessity such as work and home administration.

In the last ten years, between 2008 and 2018, DHE showed a very expressive numerical evolution in the number of undergraduate enrollments, with an approximate increase of 196%, going from 463,093 and reaching a total of 1,373,321 enrollments, while in the same period, in the face-to-face mode there was an approximate increase of 10%, representing 1,873,806 and reaching the mark of 2,072,614 [14].

These data reinforce the idea of the exponential explosion of digital education and perhaps the scrapping or lack of incentive of public education policies with the traditional graduation itself, since according to data from [14], between the years 2017 and 2018 we had inverse advances between these modalities of education, where the DHE came out of 1. 756,982 reaching a total of 2,056,511 registrations, with an increase of approximately 17%, while in face-to-face education we had a drop of -2% from 6,529,681 to 6,394,244.

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Based on these data it can be affirmed that this century is being marked by the new communication and information technologies that are reconfiguring our societies under the most different aspects: economic, social, political, and cultural.

Thus, a relevant cause to be studied among these aspects is related to the character of change in this new era, it would be in the question of identity, in the process of change known as "globalization" and its impact on the formation of the subject and education [2].

For [17], technological systems are as producers of new languages, new information and new concepts, presenting to the post-modern society a man-machine relationship. This is a situation that is displayed by the technological system of communication, unlike the other machines that are at the service of man, they are more than performing tasks, they are transformers of opinion and transmit values of formation and ideology. Forming institutions that participate and interfere in the dynamics of human relations.

Thus, the DE is seen as a great opportunity for the expansion of the DHE, because the viability of the degree courses serves to show their increasing supply in a surprising way [23].

Due to the circumstances of the DHE implementation, it is possible to have in a short period a record number of openings in the national scene. It can also be embraced by a large part of the population, especially by those who live in regions farther away from large urban centers and have difficulty in reconciling study and work [27, 23].

However, this type of education is still seen by many students as an accelerated and easy way to obtain a higher education diploma, in which they will be able to "calmly" acquire such certification and present themselves to the market, even if without having placed confidence and greater efforts to acquire new knowledge and a critical view of the world, from the information provided in the course [25].

IV. Quality of Education

The meaning of educational quality is contained in the extension of many factors, ranging from the accumulation of knowledge throughout history to economic and especially social aspects. According to [24], educational quality is associated with the link, demands and actions of society of a given historical process and that in order to achieve excellence in education one must build actions aimed at overcoming the socioeconomic and cultural disparity present in the regions.

Therefore, the use of the word quality in education is still a challenge since it involves a multiplicity of factors and can be understood in different ways. Thus, defining or evaluating the quality of an institution's teaching is something complex that involves a delicate interpretation since, according to [39], quality can be associated with the possibility of mastering content, technical capacity, critical spirit, or even the efficiency, effectiveness, effectiveness, and relevance of the educational sector.

In this sense, the process of defining or evaluating the quality of an educational institution must be participative and involve the whole community, for [36] who determines the quality of education in the country is the MEC; which regulates, guides, and legislates about its application.

Consequently, this body published in August 2017, with the objective of establishing quality indicators for the DHE, the points that determine the category in DHE, based on principles, criteria and guidelines, which are: To guide students, teachers, technicians and managers of higher education institutions, this to evaluate existing courses or even the opening of new DHE degrees in Brazil [21].

Although these quality indicators are references, for the agencies to direct legal actions to the specific processes of evaluation, regulation, and supervision of the DHE, they do not have the force of law. Thus, the quality of a distance learning and postgraduate program is generally evaluated by the structure of the institution, by the students, by the degree of teacher training, by the didactic material, by the technological structure, by the support services [6].

Within this context, the National Commission for Higher Education Evaluation-CONAES coordinates the evaluation system and the National Institute for Educational Studies and Research Anísio Teixeira - INEP operates the process, through the National System for Higher Education Evaluation-SINAES, which aims to verify the quality of scholars as to the contribution of undergraduate education [4].

Therefore, the evaluation of the quality of higher education is made up of three indicators: National Student Performance Exam (ENADE), the Preliminary Course Concept (CPC) and the Course Concept (CC), these procedures seek to identify what the level of quality of education is through the evaluation of student performance, training of teaching staff, pedagogical project, and infrastructure [28].

Within the instruments, ENADE is the most important indicator, because in addition to gauging skills focused on the mastery of academic information, it informs the quality of the student to the market [9]. So far, the only artifice capable of identifying the level of training of undergraduate students.

However, the result of this process depends on the sovereignty of the commitment of all students involved and this weakens the exam; while some students receive incentives to take it, others due to some dissatisfaction promote the boycott, if absent or even delivering the test blank [42].

In addition to the suspected fraud situations [37], where colleges are accused of accelerating the graduation of students considered less qualified and anticipate those who have a better performance, to have good grades and consequently a supremacy in the educational market.

In this way, all the governmental effort to try to quickly increase the number of access to DHE, through the debureaucratization of the Institutes of Higher Education-IES, may bring some failures in the qualification and/or student learning, even considering positive numbers from ENADE, which may not be a consistent parameter with the academic reality.

Despite this, the system still relies on numbers to perform analysis and demonstrate questionable results.

Thus, in 2018 the INEP published ENADE results showing that the in-person courses had an average of 6% of the courses with the maximum grade, and the attendance courses reached an average of 5.8%, showing an evolution in relation to the same exam taken in 2017, in which the DHE graduations obtained an average of 2.4% of their courses with the maximum grade, while the in-person courses reached 6.1% [14, 15].

It is worth noting that the areas evaluated were different for both years; 2017 were evaluated 34 courses including undergraduate degrees such as: pedagogy, history, geography lyrics and music, bachelors in the areas of Environmental Engineering; Civil Engineering; Food Engineering and Computer Engineering and Technologists in the areas of System Analysis and Development; Industrial Production Management; Computer Networks; Information Technology Management [14].

While 28 areas were evaluated in 2018, among them are the bachelor's degrees in Psychology, Journalism, Administration, Law and International Relations, in addition to the courses that confer a technologist's degree in the areas of Technology in Marketing, Technology in Interior Design, Technology in Graphic Design, Technology in Gastronomy and Technology in Commercial Management [15].

Another interesting data is about the worst grades, where the average of the DHE courses stood out over the face-to-face courses, reaching 6.3% in the year 2017 while the face-to-face colleges reached the mark of 4.9% and in 2018 the DHE courses within the worst grades had 3.7% of the courses while the face-to-face courses had 3.6%

[14,15]. Such data can be challenged due to the disproportionality of the institutions evaluated, as these figures refer to the average of the grades of the chosen courses and there is a difference in the number of colleges, in which the in-person institutions had a greater predominance in the act of evaluation, as well as there is a public and private administrative discrepancy over DE.

This statement is even more striking when the [14], discloses the great difference over the administrative category, public and private within DE, because the absolute dominance of private institutions is notorious in the period of 2017 adding 90.6% of students enrolled, leaving 9.4% of public DHE teaching in charge, affirming the market sovereignty over the expansion of education. With this, the needs of the market system to have a skilled labor force with a level of training, favors the dissemination of DHE and facilitates its acceptance, since future graduates will not suffer prejudice due to the lack of a diploma and will thus meet society's demand for continuing education [34].

The computerized system is becoming more and more present in the contemporary world and this can have a significant influence on people's lives, since these technologies broaden the world view, transform communications, and change behaviors bringing new ethical standards, new conceptions of reality, in which it puts the higher education system in a condition to review its role in the processes of subject formation [17].

The conception of a quality education has been embraced in different organizations, with the sense of incorporating in people and in the social organization itself a posture of continuous improvement. Based on this concept, it is necessary to reflect on DE, since there is still not enough scientific data to prove its quality in relation to face-to-face education. Since DHE has its deficiencies and still needs elements that can control, measure, and evaluate indicators related to the quality of courses and knowledge acquired by undergraduate students [38].

For [20] the learning and development of students are goals that diverge between distance and in-person courses. Perhaps didactic changes are needed in the constitution of DHE teaching, through technology and organizational factors of learning, for a potential development of student exercise.

There is a tendency for communication, through the digital process, to provide changes in the teaching system by changing the traditional classroom teaching, not to mention its rapid implementation process [21].

Emphasizes the need for student participation in learning gain, where any information to be passed on to the student will be a stimulus, highlighting the importance of rapid feedback to students, a key aspect in the teaching communication process in DE courses, as well as the relevance of teaching materials and their applicability, and a two-way communication with the student, for the success of DHE [21].

But if there is no adequate guidance on the quality and recognition of the institutions that provide virtual education, it will have difficulties to be characterized as a democratic mode of learning, even taking into account the whole process that involves it due to its possibilities of breaking physical barriers and its easy access to population [10].

And a more critical analysis of the evaluation process, so that it becomes more than a universal and procedural requirement, so that in fact there is more profound data on the educational progress of these students, breaking with this prejudice about the digital teaching method.

V. Democratization of Higher Education

University life is a process of complexity that is still out of the reach of many students, as such a journey requires adaptations that range from displacement to a readjustment of the organization of time to deal with the new activities of academic life, so these adaptations go through a multifaceted process that establishes to the student the obligation of change. Therefore, the lack of options can become a major obstacle to student progress, which makes the phenomenon of evasion a very worrying issue for educational public policies [35].

Thus, one of the ways to promote the democratization of higher education is to encourage the expansion of DHE; it allows students to maintain themselves at a lower cost and also with less availability of time, since the use of technology allows those students who live in more distant places to overcome such geographical position [1]. This approach of the student, with the studies, through computerization, may in the future make the evasion rate decrease considerably, but it is necessary to pay attention to other variables that may make the maintenance of the student in the institutions unfeasible.

Despite the great representativeness of DHE courses in Brazil, which was 40% of the total number of courses registered in 2018, when compared with the number of graduates in the same period, there is a gap; only 21.7% of the students enrolled in DHE education were able to complete [15].

And in face-to-face education there was a much greater amount than 78.3%, this data leads to doubts about the barriers that technology can provide for the student and that other variables must still be considered for the maintenance of students in college until their completion [15].

Based on this, some studies show that there are variables that contribute to the occurrence of this dropout in higher education such as: age, gender, failure, debt, readjustment of the value of the school semester. And what institutions can intervene in these aspects stimulating the students' academic lifetime, with the exception of age and sex, because the other factors can suffer direct interventions, whether pedagogical or financial, thus providing a service to the students in order to solve their difficulties in following the course, which culminates in failing, or even in relation to the payment of the course fees [11].

Point out that among the main situations that encourage students to drop out are the conciliation between study and work, readjustment to the new teaching method, understanding more complex information, basic knowledge of students from underprivileged classes, as well as situations that involve the need for financial investment such as the purchase of teaching materials and registration for academic events. And that for such situations to be overcome, it is necessary to have a good institutional support through a qualified team and with a methodology favorable to the student, thus meeting the different profiles [29].

Consequently, educational institutions need to be more prepared to take responsibility for factors that affect student evasion, providing a universe of flexibility so that academic adaptation becomes more simplified, minimizing the impacts caused by social distance [35]. Making the digital world a quality support for the increase of learning and allowing the democratization of education.

VI. Challenges of Distance Education in Brazil

Some social investigations within the learning environment study and analyze more efficient ways of improving learning, including for those students who have a certain difficulty in assimilating the content passed by the teachers [32].

Although all knowledge is changeable and enriching, the new technologies provoke a certain resistance among teachers, thus there is a certain opposition to the use and appropriation of educational technologies, hindering the emergence of new forms of language, new ways of exposing and explaining reality. Thus, with the arrival of computerized systems, innovative situations of knowledge transmission and production of a thinking and qualified society emerge [1].

For these methods broaden the world view, transform communications and change behaviors bringing new ethical standards, new conceptions of reality, in which it puts the higher education system in a condition to review its role in the formation processes of the subject [17]. But it should not be understood as a substitute for face-to-face education, but as a way of adding the same education process according to [7].

Therefore, one of the expectations for the coming years is to expand educational centers, increasing the possibilities of learning, through technological alternatives, within an increasingly computerized and diversified social conjuncture [10] .

Thus, this computerized "revolution" will bring more learning possibilities, integrating the traditional environment with technology, developing digital learning environments for human formation [2].

Presents in his study a need for a new context of graduations; the conflict between traditional and digital institutions can bring difficulties in teaching, in which it demands readjustments to the new demands of society, through wide receptivity to changes and the search for new teaching models, from the redirection of its mission. Thus, the computerization of education can favor such adaptation for the growth and or improvement of institutional teaching, but it must be done in a harmonious and complementary way to improve the learning system [31].

To change the higher education system, the Brazilian government, through an implementation of public policy focused on diversity and the specificities of society, sought to expand the number of vacancies in DHE [18]. However, the acceleration of this growth through immediacy becomes a factor that influences the fragility of higher education, corrupting the system and stimulating a false sense of qualitative learning [8].

In the Brazilian education scenario, despite the advance in the number of vacancies in higher education [15], we can observe an approach of many DHE colleges with a context similar to face-to-face education, including systems of verification of student learning through traditional assessments.

Though, it must be taken into consideration that education is a procedure inherent to man with a high degree of complexity, where cultural, economic, social, political, and religious aspects are involved, thus becoming an indispensable practice for the growth of a just society, with critical ideas and understandings.

In this way, ICT becomes an indispensable instrument in the generation of new knowledge, as well as in the exercise of power and the creation of cultural codes, while generating wealth for society/community.

However, for these technologies to produce wealth it is necessary to have a mediator, someone capable of having all the information processed and reverted into knowledge and opportunities, through the teacher who will favor the communication between the student and the technology [17].

Still, the faculty at a distance has a low-quality image, the teachers and tutors have little or no experience for DHE training, the institutions have limitations of infrastructure and technological resources, precarious performance of the teacher/tutor, precarious pedagogical support and high number of students per teacher/tutor [28].

And that if the idea is to "revolutionize" by promoting access to education through computerization, it is necessary for educational centers to look for complementary alternatives such as "hybrid" teaching, by joining classroom methods and technological learning innovations, provide more possibilities for knowledge and not use DHE as a substitute for traditional teaching.

VII. Conclusion

The DHE has expanded its collaboration in increasing the number of vacancies in Brazilian higher education and in the conquest of the most diverse academic content, especially because it is a teaching method that involves digital environments and can break the barriers found in traditional education. Because of this, it is believed that inclusion in undergraduate education will be even greater when there is a large-scale digital reach, in which it will stimulate the most diverse academic skills, through this innovative method, which has great territorial reach.

Yet, if there is no stricter control over the institutions and more standardized teaching criteria, DHE will have difficulties in being characterized as a qualified learning modality, even considering all the process that involves it, which are its possibilities of breaking down physical barriers, its easy access to the population, and the debureaucratization of the institutions for implementing this education.

In this way the educational public policies should work in order to favor the student community through the adequacy and interaction of the use of technologies, so that through a set of elements the access to learning quality is allowed, as well as the maintenance of the students in the graduations. The data show that in 2008 only 21.7% of the students enrolled in DHE education were able to complete it and in face-to-face education a much higher amount was verified, which was 78.3%.

However, it is necessary that new studies be conducted on the subject, bringing new scientific approaches to DHE, as well as points not covered in this article. Treating, this type of teaching as an additional element in human formation, by means of adequate didactics, well-defined and collective pedagogical projects in their phases and methods, allowing the evaluation of the progress of more effective teaching.

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Operationalizing the Learner-Centric MOOC model using Communities of Practice

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***Abstract*—Massive Open Online Courses (MOOCs) have been around for quite some time and have revolutionized the field of education. They have gained popularity and have grown exponentially during the COVID-19 pandemic. The challenge is to design and develop a MOOC which can engage the learners. In order to achieve this, the two important requirements are a robust MOOC creation model, and a collaborative team to orchestrate the design elements of the MOOC in an effective manner. In this research, we have selected the Learner-Centric MOOC (LCM) model and used the theory of 'Communities of Practice' (CoPs) to facilitate and implement the LCM model. We found that the collaboration focused around the LCM model has helped the model evolve in various dimensions. There is a modular adoption of the model in face-to-face, blended, and online learning sessions. The CoPs also resulted in capacity building, collaboration, and adaptation of the LCM principles to different teaching-learning environments. This mode of operationalizing the LCM model paves way for a larger, but organic reach out, systematic upgradation of its tenets, and evaluation of the model across domains.**

***Index Terms*—Collaboration, Communities of Practice, Discussion Forum, Learner-Centric MOOC Model, Learner Engagement, MOOC Design, Teaching-Learning**

I. Introduction

For almost a decade, Massive Open Online Courses (MOOCs) have transformed education by their ease of access, flexibility, and diversity. MOOCs have also been changing education dynamics and student learning [1]. With the COVID-19 pandemic and more learners resorting to online education, MOOCs seem to have consolidated their position. This growth is similar to that of the Year of MOOC in 2012 [2]. The characteristics of MOOCs such as flexibility, autonomy, remote and anytime access confer benefits of MOOCs [3]. These advantages also give rise to a unique set of challenges. MOOCs are reported to have lesser engagement and reduced peer learning [4]. MOOCs report a high drop-out rate with an average completion rate of 10-12% [5]. The other charges that MOOCs face are ill-established teacher-learner relationships, a sense of isolation, and disconnect which is said to adversely affect the learning outcomes and course completion rates.

Multiple pedagogical designs have been used to offer MOOCs. These are not uniform across courses and each of the design features have strengths and weaknesses [6]. Models have been proposed to design MOOCs based on connectivist, intrinsic motivational, and social constructivist theories and enhance the content quality [3], [7]. To promote engagement and to improve MOOCs, strategies such as active learning, interaction of student and faculty, student interaction, immediate feedback, scoping for diversity, communication of time commitments and expectations, deep learning possibilities have been listed from successful MOOCs [6], [8]. However, universal acceptance and widespread adoption of such designs are limited.

The LCM model was developed as a prescriptive model that would guide planning, implementation, and design of MOOCs [4]. There has been active academic dissemination of the model which has led to a number of courses and online instructional initiatives that are based on the model. A wider reach of the learner-centric strategies of the LCM model were facilitated by establishing CoPs among interested members of the teaching profession. This was achieved by systematic collaborative opportunities and capacity building exercises. The structure of the LCM model and the operationalization of the model through establishment of CoPs forms the ensuing narrative.

A. *The LCM Model*

The LCM model consists of Learning Dialogue (LeD), Learning by Doing (LbD), Learning Extension Trajectories (LxT), and Learner Experience Interactions (LxI), along with the dynamics of Orchestration [4]. Figure 1 shows the overview of the LCM model.

1) *Learning Dialogue (LeD)*

A LeD is a short video which has a strategic pause point where a question is asked to the learner. This requires the learner to recollect, apply or evaluate the content and frame an appropriate answer. The instructor anticipates learner responses and summarizes answers in the subsequent part of the video. This pause point is called a Reflection Spot (RS), which prevents passive watching of the video.

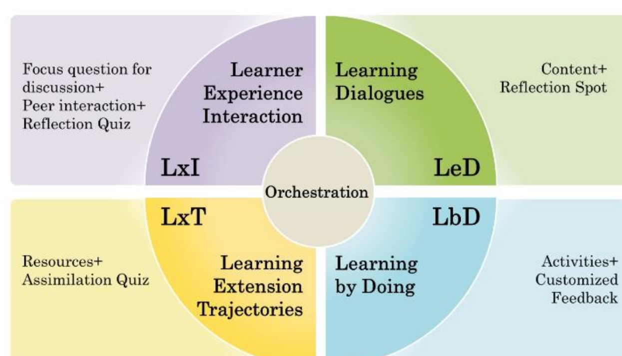

Fig. 1. LCM model overview.

2) *Learning by Doing (LbD)*

The LbDs are activities that would normally constitute the 'homework assignments and practice activities'. LbDs follow every

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LeD and are made up of practice questions that are ungraded. They provide an opportunity for immediate consolidation of content explained in the LeD. Constructive feedback is provided to the learners to enhance their learning. Feedback mentions where and why the learners went wrong and how they should progress ahead. Such feedback and individualized attention that is possible in an in-class session is facilitated through the LbDs that point the learner towards achieving learning goals.

3) Learning Extension Trajectories (LxT)

The LxTs correspond to extra learning materials in a normal classroom. Learners are provided with a wide variety of learning resources related to the course content such as videos, links to various web pages or even research papers. These selected resources are categorized into two or more trajectories, which learners can access based upon their interests. To assimilate concepts in the trajectories, learners attempt an Assimilation Quiz based on the chosen trajectory.

4) Learning Experience Interactions (LxI)

Discussion Forums (DFs) in MOOCs face problems such as conversation scatter [9], lack of meaningful participation and productive interaction [10]. The LxI, is designed to address this challenge. LxIs helps in bringing in the learners into the DF with the help of Focus Questions (FQs) that prevent scatter and anchor discussions around a topic. FQs then drive the discussions by requiring the participants to share their perspectives and experiences and interact with other learners on the forum. Graded Reflection Quizzes (RQs) are based on the interactions on the DF, thus incentivising participation and perusal of the posts of fellow learners. LxI fosters collaborative learning and creates an added learning resource pool within the course that is monitored and moderated by the instructor, Teaching Associates (TAs), and Discussion Forum Moderators (DFMs) [11].

5) Orchestration

The orchestration of the MOOCs created using the LCM principles involves constant monitoring of learning trends using learner performances and reports. This allows periodical cognizance of challenges encountered by participants. Appropriate measures are instituted to address these challenges, such as extension of deadlines, flexible hours of live interaction when necessary, and personalized reminder emails and text messages that encourage more participation and also serve to overcome the transactional distance encountered in online learning courses.

The orchestration and implementation of the LCM model requires dedicated personnel and time commitments. This can be made possible by the collective efforts of a larger course team, comprising multiple focussed groups or communities.

B. Communities of Practice

Communities of practice are defined as "groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis" [12]. Members of this community spend time together, share information, insight, and advice. They ponder over common issues, help each other to solve problems, explore ideas, accumulate knowledge and become informally bound by the value that they find in learning together. They also develop personal relationships and established ways of interacting [12]. A Community of practice is evolved around three characteristics: Domain, Community, and Practice [13]. These are described as below:

Domain: The members have a shared area of interest and on common grounds, they inspire more members to participate, guide them and operationalize the activities.

Community: Based upon this interest, a strong community that continues these activities through shared and collective discussions is built. The focus is to establish a working relationship that fosters interactions and shared learning.

Practice: Community members are actual practitioners in the domain of interest. They practice with a specific focus around which the community develops, shares and maintains the process of learning.

In the field of education, there already exist domain-specific networks of faculty members at departments and universities, ICT specialists, MOOC creators, instructional designers, moderators, demonstrators and so on, who facilitate the teaching-learning process. These networks have been leveraged upon to constitute CoPs, who are thereby involved in working with the LCM model. These CoPs work collaboratively to implement the LCM model at various levels, to achieve intended outcomes.

II. Outcomes of Operationalization

Unlike many other MOOC models developed, the LCM model has been evolving. One of the reasons for this perpetual evolution is its structure. LCM model doesn't restrict the entry point. It has a 'Low floor' for anyone to implement the model. Secondly, the model allows partial operationalization, where practitioners can implement any number of elements, without being constrained to implement ALL. This provides the 'high ceiling'. Finally, the model is generalizable across domains, which is because of its 'wide walls'.

We present some examples, where the application of the LCM model has been possible using 'low floor, high ceiling, and wide walls' feature.

A. Application of LCM Model

The LCM model was developed by a team of researchers from a single institution, yet in a short time span, it has been internalized and implemented across multiple institutions and by multiple instructors in varied ways. This was achieved by the inherent nature of the model and the CoPs that ensured that the components of the model were applicable as a whole or module wise. They are practicable in school, college, faculty development courses, and in face-to-face, online and blended environments. The model is dynamic and open to interpretation by course creators looking to enhance learning outcomes and hence there is a scope for improving the model and evolution of the elements. The model lends itself to customization across multiple domains and diverse learners and has opened up research avenues. Listed below are some of the interesting applications of the model which are evident as the outcomes and artefacts of implementation.

1) Development of MOOCs

Initially, courses and Faculty Development Programs (FDPs) from IITB were designed based on the LCM model. It was seen that outcomes such as course completion rates and learner reported engagement with the course were higher than that compared with traditional courses and FDPs [5].

A total of 15 MOOCs based on the LCM model have been offered on platforms like Swayam (National MOOC platform of India), IITBx (Online platform developed by IIT Bombay) and edX. MOOCs based on the LCM model have been created and offered in the diverse domains of education, chemistry, computer teacher training and skill based courses such as animation. Basic 3D Animation using Blender, Designing Learner Centric MOOCs, Demystifying Networking, Open Educational Resources are a few examples. The feedback and performance analytics of these courses are encouraging and show higher completion rates and learner engagement and interaction.

The LCM model was also used to deliver faculty development courses. For instance, the Education Technology Department, IIT

Bombay collaborated with TAs from various institutions to design and conduct a MOOC based on the LCM Model that was offered to faculty of engineering colleges nationwide. The MOOC was titled 'Digital transformation in the Teaching-Learning process' (DTITLP) and focussed on pedagogical and technical use of smart boards to deliver learner-centric instruction. A total of 5954 participants across 184 institutions participated, spread over four offerings of the course, with completion rates ranging from 59-85%.

2) Research Ideation and Innovation

The LCM practitioners in different domains have contributed to the research on application of LCM model. The role of the LxI was studied through participation in DFs. Positive results were reported and a majority of surveyed participants acknowledged the positive impact of the DF in the course on their learning [14]. Different modes of participation that progressed beyond superficial posts were described in a LxI [11]. Application of the LCM model principles in augmentation of OERs enhanced interactivity and engagement [15]. The collaborators also used their experience in creating learner-centric content in offering faculty development programs and short-term training to faculty members [16]. These were delivered with the intention of increasing the use of learner-centric video dialogues, LbD activities, LxT resources, and enriched LxIs among teachers using the online and blended modes of instruction.

3) Modular Adoption in LIVE Sessions

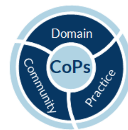
Online and blended LIVE teaching were conducted by modular adoption of the LCM model. LIVE sessions have their own unique challenges. In order to meet them, RS of the LeD component was introduced in live sessions with the prime aim to gauge the understanding of the audience or to seek their opinions. RSs were included at strategic spots in the session where instructors anticipated less engagement. RSs were implemented in real-time by conducting polls, quizzes with the help of various technology tools. This gained the attention of participants during the conduct of the sessions, allowed active learning and micropractice. This was well-received as seen from participants' feedback who indicated that the sessions were very interactive and engaging. More than 40 such sessions were held to carry the message to ten thousand faculty from varied domains.

The far reach of the model to multiple institutions, individual faculty members and beneficiaries of learner-centric MOOC pedagogy, is attributed to the specialized hubs of practice, that were the CoPs, whose domains, practices and community were tailored for the LCM model.

B. CoPs: Establishment and Best Practices

Course designers created specific CoPs to implement the LCM model. They included participants and proponents of the LCM model. Figure 2 shows how the LCM based CoPs were developed and progressed. All members were stakeholders in optimizing the use of Information and Communication Technology (ICT) enabled teaching using learner-centric methods, and also had interests in associated research. The members were involved in team based activities related to operationalizing the LCM model, such as developing LeDs, preparing LxTs, monitoring DFs, etc.

Participation in the Community of Practice (CoP) led to an inherent learning experience for self-improvement. The collaboration allowed for further capacity building, and co-creation of other MOOCs and online learning modules that followed the LCM model. The model was taken up by faculty in association with the creators of the LCM model, leading to value addition and proportionate increase in adoption of the model. This contributed to the constant evolution and improvement of the model.



Domain	Practice	Community
Effective integration of ICT	Designing ICT based curricular material	Course designers
Research based teaching strategies	Sharing of contextualised best practices	Teaching Associates
Learner-centric approach	Facilitating peer interaction and peer learning	Mentors
		Local facilitators
		Discussion forum moderators

Fig. 2. Framework of LCM based CoPs.

Multiple CoPs operated with specific task specializations. CoPs such as those of course designers, TAs, local facilitators, and DFMs were functional. This enabled effective deployment of skill sets to meet the varied task requirements that are part of MOOCs. However, these roles were not rigid and allowed for members to work on their interests and strengths and move to a CoP where their talents found a niche. While overall orchestration of the MOOCs were overseen and mentored by the CoPs of the course creators, the moderator and facilitator CoPs were instrumental in the micromanagement of the LCM model components of courses and sessions.

1) Course Creator CoPs

The creators of the LCM model envisioned that MOOCs would be co-created by a team of instructors. Accordingly, the team comprised members who were subject matter experts, content developers and designers. Roles and responsibilities were assigned to members who worked on formulating the content of the course which included the LeDs, LbDs, LxTs, and LxIs. They were reviewed by fellow members of the CoP. This ensured quality of content which is a pivotal factor in the success of a MOOC. The CoP was instrumental in establishing a safe environment for ideation, contribution, discussion and materialisation. Individual strengths of CoP members in the use of LCM components were fostered. However, role reversal within the team was implemented following a period of observation and guided work. This allowed the members of the CoP to gain experience in all aspects of MOOC creation. Liaison tasks such as working with the technical support team and the administration were also part of the responsibilities shared by CoP members. Real-time orchestration of the MOOC was made possible by this CoP. Course progression was monitored and appropriate timely corrective measures were instituted through personalised reminders, extension of deadlines for quiz submissions and so on.

2) Moderator and Facilitator CoPs

Interested and meritorious participants from the previous run of LCM course were invited to contribute as DFM and Facilitators. Their participation was voluntary and tasks were based on teamwork and interaction with other members, guided by course designers and mentors. Scaffolding was used for capacity building that ensured greater autonomy with practice. Online communities were formed which allowed brainstorming and rapid problem solving. This also led to peer learning among members. Different levels of participation of the members were accepted, in order to balance time constraints. The diversity of members ensured a wider range of shared expertise which helped in building the learning environment of the DF.

3) Integrated Role of CoPs in Operationalizing the LCM Model

The various CoPs worked together to achieve a single goal, which is operationalizing the LCM model. The following is an example that describes how this was accomplished and specific teaching-learning outcomes were achieved.

The course creator CoPs designed the DTITLP course on the usage of smart boards, based on the LCM model. The members collaborated to integrate multiple components of the LCM model in the course. When the course was offered, the CoPs of course instructors and TAs appreciated good responses and constructive feedback given by the learners on the DF. In addition, the instructors also introduced a strategy where the 'best post of the week' was highlighted on the forum. This encouraged more participation in the forum. Participants created innovative content such as demonstration videos and FAQ repositories. These were uploaded on the course platform and video aggregator sites such as YouTube. Such participants formed part of the newer CoP of DFMs who worked to involve and encourage learners from subsequent offerings of the course. They ensured further spread of this model among their institutions and domains. The members helped to localize the content of MOOCs by translating content and providing institution-wise learner support by forming communities of local facilitators. This CoP of moderators and facilitators trained further DFMs and facilitators. Based on their interests, they also formed part of Instructor and TA CoPs, creating their own LCM based courses.

This is an exemplar of learner engagement and achievement of higher order learning outcomes, such as synthesis, that was made possible through the LCM model facilitated through CoPs. In order to scale up, and expand the scope of the model and its mode of community supported implementation, there is a need for multiple collaborators who can contribute, by bringing in their own range of expertise and perspectives.

III. Collaboration Possibilities

The LCM model lends itself to customization and multiple interpretations by users to suit various platforms. These LCM-based projects are validated by several research communities who have reiterated the robustness of the model. The involvement of collaborators who are willing to proactively participate in relevant teaching and research activities will further enrich the model. So we are looking for collaborators to:

- Implement each element of the model in diverse learning environments, thereby devise methods for easier and user-friendly adoption.
- Use ICT tools in developing templates for adoption of LCM elements. This can include development of self-assessment rubrics which help in scaffolding the transition to learner-centric methods.
- Identify data parameters to evaluate 'learner-centricity' in MOOCs and publish the research findings of the studies.
- Design instructional activities based on LCM model to enable learners to attain the course outcomes.
- Document and publish experiences of collaboration regarding the challenges faced and best practices implemented during the creation of courses.

The findings of the collaborators would help us to gain valuable insights and contribute in making the LCM model more robust and universally applicable.

IV. Discussion

CoPs established a strong collaborative support network that facilitated efficient workflow and a constructive review process. The collaboration resulted in the usage of various ICT tools (Online platforms such as Moodle, Mentimeter, Padlet, Google drive) and creation of various online communities (using WhatsApp, Slack, Facebook) exclusively for building the community. Various ICT based curricular materials were also designed by CoPs.

The manner in which the LCM model was implemented through CoPs has resulted in amplification of the intended outcomes. This is evident in the examples shared in the article. This has led to organic growth and sustainable practices that has led to evolution of the model. Each CoP has contributed towards honing the methodology of practice of each element and the model as a whole inclusive of the orchestration dynamics. Further validation and evolution of the model requires additional research in order to universalize the adoption of LCM principles.

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Using Digital Technologies in Museum Learning Activities to Enhance Learning Experience: A Systematic Review

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***Abstract*—Technologies are used to boost learning experience in museums, and experts from various fields have joined in and collaborated to make contributions. However, the roles of stakeholders and the selection of digital tools, learning objects, and outcomes are underrepresented. To cover this gap, a systematic review using Activity Theory was conducted, where 32 studies in technology-assisted museum learning were examined. Seven dimensions including — (a) subjects (learners from different groups), (b) instrument (educational technologies and digital tools), (c) object (academic or behavior goals), (d) rules (design, implementation procedures, and performance measures), (e) community (stakeholders of museum learning activities), (f) division of labors (relevant works distributed to different roles in community during the whole process), (g) outcome (academic performance or learning behaviors) were analyzed. Furthermore, existing gaps were examined within the studies (e.g., lack of collaboration from different stakeholders), challenges (e.g., limited number of participants and faculty), and recommendations were identified and provided under each content analysis section.**

***Index Terms*—Technologies, Learning activities, Museum education, Activity Theory**

I. Introduction

The educational function of museums has been prompted by the wave of equal opportunities of learning since the 18th century and has been universally recognized after the benchmark documents published by AAM [1] and UNESCO [2], which clarified its role and public responsibilities on education. The International Council of Museums (ICOM) has also highlighted museums' "purposes of education" in its latest definition of museums [3]. Learning activities in museums are designed as structured, supportive, and student-centered non-formal learning experiences, with interdisciplinary contents based on objects in the exhibitions [4]. This has provided multiple educational opportunities and entry points to satisfy multiple instructional needs of learners, and usually foster high-level skills for the 21st century, such as critical thinking [5]. Inextricably interweaving, those elements allow the learning activities in museums to be more contextualized and authentic.

With the aim of transforming learning experiences in museum education activities, diverse digital technologies have been applied, such as Virtual Reality (VR), to increase learners' engagement and interactions with learning objects and contents, or to facilitate collaborative learning among students [6-8].

Despite that many ongoing practices and research have been conducted about using technologies for museum education, no systematic review, to the best of our knowledge, was conducted on what and how technologies have been integrated into those learning experiences. Consequently, limited information is found related to this field, as well as the associated challenges.

To close this gap, this study provides a systematic review of the use of digital technologies in museum learning activities. The purpose of this study is to provide an overview of the current research field, suggest the type of digital tools and instructional methods to use in museum education, and highlight future research directions.

The research questions of this study are as follows:

RQ1: What relevant features concerning the design, implementation, and outcome of museum learning activities using technologies can be identified through the lens of Activity Theory?

RQ2: What recommendations can be made to improve research about integrating technologies into museum learning activities?

II. Method

A. Search Strategy Process

Using PRISMA guideline [9], the systematic search focused mainly on journal papers within the Web of Science database. First, all the three researchers conducted title and abstract screening with keywords including "museum", "education", "technology", "digital tools" and so on. Studies (based on the title, abstract and full text) were excluded because: the study (a) is not an empirical study, (b) does not aim at offline museum education within physical museums, (c) does not involve human participants, and (d) does not have sufficient description of research design. Researchers first screened independently, and then the result of each screening will be checked by a different researcher; also, all divergences were discussed until the agreement is reached: the agreement ratio was around 90% first and reached 100% after discussions. Finally, a total of thirty-two studies were included. Fig. 1 presents the selection process.

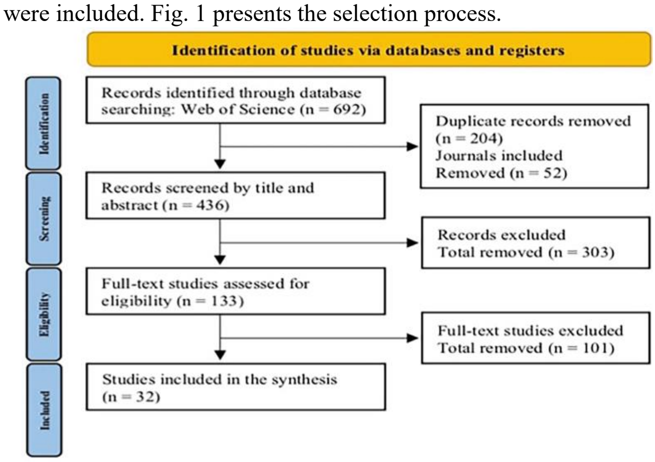

Fig. 1. Flow chart for the study search and selection process.

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B. Data Extraction according to the Activity Theory

In this study, the Activity Theory was adopted to analyze the learning where multiple technologies have been used inside the museums in each study. Particularly, the learning in museums is defined as learning activities, for the learning happens in the form of operations and actions embedded in activities [10], including all kinds of learning activities happen in the museums, such as visiting, workshops, family tours, and curriculum [11]. The Activity Theory can be used as a philosophical and cross-disciplinary framework to understand human practices [10]. Thus, different components in learning activities (e.g., learners, learning tools, learning goals and achievements, etc.) and their relationships can be studied under this framework. In this way, the result of this review will be according to the seven dimensions in the Activity Theory (see Fig. 2). The data was extracted through the identification of seven dimensions of the learning activities each study carried out. The model shows the seven dimensions below, namely subject, instrument, object, rules, community, division of labor, and outcome.

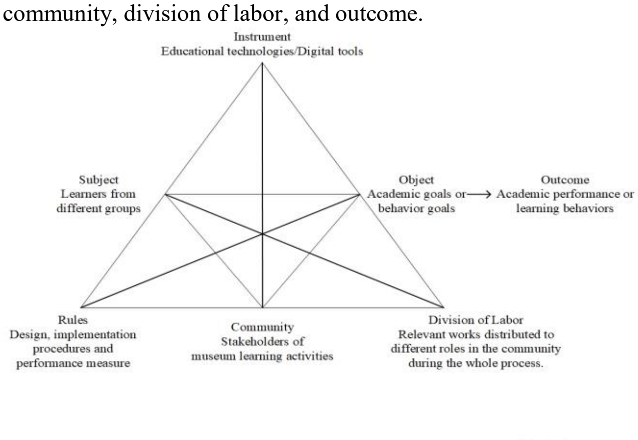

Fig. 2. Using Activity Theory to analyze technology-assisted museum learning activity studies.

III. Results And Discussion

A. Subjects

The sample size within most studies (n=22) ranged from 20 to 100. However, two of the studies only have subjects less than 20 [12-13], which may not provide enough data for solid results [14].

Considering the selection of the participants, the age range of the subject chosen by the studies was from 7 to 79 years old. Particularly, most of the subjects are from primary schools and universities.

Moreover, to instruct learning activities or eliminate effects of disturbance, the prior knowledge of participants was measured by pre-tests or investigation of learners' background in ten studies, concerning the target learning content in museums [15], the information of museums or exhibitions, or the technology or devices that would be used inside museums [14].

Recommendation:

To increase the sample size, future researchers can collaborate with several schools [16] or repeat the same experiment several times with different participants [17]. Also, to decrease the impact of prior knowledge on the experiment, the comprehension test can be used, and the impact of the prior knowledge can be clearer when analyzing the result.

B. Technology

The technology component involved various kinds of educational tools used in museums. Table 1 shows how each kind of technology was used in museum learning. Different devices assisted the usage of technology in museums; twenty-five studies adopted mobile-assisted devices, such as mobiles, iPods, tablets, or other types of interactive display screens, and three studies used computers or laptops to run the software.

TABLE I
Learning Objects and Scenarios Supported by Different Technology in Museums

Technology	Purpose	Scenario
AR/VR (n=9)	To enhance the interaction and engagement with real-world objects	Participants immersed in and interacted with the real and virtual environment to form a better understanding of the learning objects.
RFID (Radio frequency identification) technology (n=4)	To improve interactivity and participants' learning motivation and efficiency	Students used RFID readers and RFID tags to sense the objects in museums to get related information and simulate real-life scenarios; the RFID technology also helps teachers to monitor students' real-time learning progress in museums through RFID [18].
Digital database/ resources (n=13)	To increase participants' knowledge	Participants have easy access to retrieve digital information of the museum.
Robots (n=2)	To increase collaboration and interaction and participants' motivation	Participants worked in pairs and to solve challenges when building robotic models [19], or participants could interact with the robotic rover to get oriented and virtual information of objects in museums [20].
QR code (n=3)	To display comprehensive information of specimens in museums	Participants were able to get the main information and virtual images of the real-life specimens in museums through scanning QR codes [21].
Location detects (GPS) (n=2)	To enhance participants' engagement in learning tasks	Students' locations in museums are detected so that teachers can send related materials or tasks to students based on their locations [22].
Animation and games (n=6)	To provide a greater sense of interactivity and authenticity to the learners	Participants explored learning concepts by interacting with virtual models of museums' objects; they also could finish learning tasks through the designed games [16][23-24].
3D printing (n=1)	To facilitate participatory learning and enhance understanding	Children and their parents could play with different 3D printed models of the artifacts [25].

Recommendations:

Since several challenges related to educational technology in museums have been identified, some recommendations were proposed. First, different cognitive levels and characteristics of participants should be identified in advance so that the technology used can be personalized to meet various preferences or needs. Second, the training of using the target technologies before learning activities is helpful, allowing participants to be familiar with the technologies, and the usability issues should also be investigated first and to assess its impact on the experiment [26].

C. Object

The objectives of the reviewed studies were to improve learners' (a) learning outcomes, including academic skills in STEM, subjects such as climatology [27] and medicine [28], (b) social and interactive skills, and (c) interest, motivation, and attitudes. Even though a large number of studies focused on improving academic learning outcomes as well as learners' motivation or interest, few studies were dedicated to investigating learners' interactivity or social interaction (n=2).

Recommendations:

The focus should be shifted from only promoting academic skills and learning outcomes to also promote collaborative learning that focused on increasing interactions between learners. Creating more technology-assisted workshops that involve cooperation is one way that allows learners to learn from each other with the help of digital tools or technologies, making more positive impacts on the learning process and outcomes.

D. Rules

In this part, the experiment procedure and performance measures are examined.

For the experiment procedure, all the studies chosen followed clear implementation procedures [29], including (1) recruiting the participants (target learners) based on the selection criteria; (2) introducing the procedure of learning activities to participants (target learners and/or teachers); (3) designing the learning activity for the experiment; (4) implementing the learning activity with participants and (5) evaluating the learning outcome of participants based on the elaborated performance measures. Four out of thirty-two studies did not instruct participants to learn and practice the target technology formally [17][21][30-31]. Moreover, eleven studies did not involve control groups.

Seventeen out of thirty-two reviewed experiments adopted pre-assessment, and all of the experiments include post-tests. Nineteen studies used interviews and observations to do a summative assessment. Some of the studies (n=4) consider the long-term effect on the subjects' learning achievement by the second time post-test.

For the performance measures, the academic achievement was the most measured one (n=22) in the post-test, and the second was the usability and usage of the target technology (e.g., [16][21]). Some studies also focused on the learners' experience inside the museums to identify the way to enhance learning, including the motivation (e.g., [18][24]), the engagement (e.g., [13][23]), interactions (e.g., [17]), and the learning styles of participants (e.g., [18][26]).

Recommendations:

Researchers could recruit more participants to set control groups with different conditions, remove the interferences, and find more support for the results. Then, researchers should design the post-test that assesses the retention of learning outcomes, and the test result can be collected online.

E. Community

The community component includes learners, teachers/instructors, parents, museum staff, subject matter experts, and research and design professionals. Most of the reviewed studies involved students as participants (n=25), and only six studies had other people as participants, such as randomly chosen visitors, local aboriginal elders, outside collaborators, and teachers or experts [23]. There were twenty-two reviewed studies involving research and design professionals, namely researchers, research associates, designers, technicians, and project managers. Twenty studies included teachers or class tutors for participants in the learning environments. One-third of the studies (n=11) involved museum staff, and three studies invited subject matter experts in the learning activities in museums. Only one reviewed study had parents involved, and one study had interpreters joined to communicate with various participants with different language backgrounds.

Recommendations:

To achieve pedagogical transformation through the integration of technologies, it is necessary to involve more subject matter experts and museum educators in the design of innovative learning activities for better learning outcomes. Second, to keep a safe learning environment in museums, schoolchildren's parents should know what would happen in activities, and it is better to have them involved in the learning process with children.

F. Division of Labor

The Division of Labor was among (a) learners, (b) staffs and partners at museums, such as museum docents, photographers, and artists, designers, and craftsmen, and (c) teachers, field experts, and educational professionals. Their roles played in the examined studies are elaborated as follows. Learners participated in (a) taking assessments that tested their prior knowledge, (b) learning fundamental knowledge, (c) participating in experiments, and (d) providing feedbacks through tests or interviews. Staffs and partners at museums (a) collaborated to design the learning activities, (b) guided or instruct students during the visit and workshop, and (c) coordinated a suitable date and time of the experiment with the school and researchers. Teachers, field experts, and educational professionals (a) selected learning target and designed learning activities, (b) designed assessments to evaluate the learning effectiveness, (c) provided fundamental knowledge teaching, (d) monitored students' progress and gave counseling, (e) facilitated in-class experience and (f) conducted the assessment of the experiment.

Recommendation:

As technology has become an indispensable part of education in museums, the role, mindset, and pedagogies of teachers should be updated, and proper training should be provided meanwhile so that new approaches to educate learners can be adopted. Concerning the activity design, teachers' recommendations should be taken into consideration to realize a comprehensive museum learning program.

G. Outcome

Three main clusters of the outcome were identified from the reviewed studies, the promoted academic performance or learning effectiveness (n=22), increased engagement, motivation, or interactions (n=20), and the positive experience using technologies (n=12). The outcome shows that the learners' acquisition of knowledge and skills are improved. Also, one-third of those studies showed the technologies indeed can enhance learning effectiveness.

Second, for studies that focused on the attitude of using technologies (n=13) and user experiences [32], most gained positive results. Furthermore, in more than half of the studies (n=20), the level of motivation or engagement is enhanced by the target technologies, and it is also concluded that technologies can provide learners better methods to learn (n=2).

Recommendation:

Despite the positive outcome above, questions are remained regarding whether museum education should generalize the use of technologies. For some learners, the experiences in museums contradict the use of digital tools [17]. To erase the resistance of the learners and fully embrace the potential to enhance learning experiences, researchers should be aware of the tension among learners, technologies, and museum learning activities, and truly transform the way of learning as well as the mindset of learners.

IV. Conclusion

To understand how technology is used in museum education, this systematic review explored the many empirical research implemented in museums through the perspective of Activity Theory. Seven major components of learning activities with technology in museums were analyzed, and results showed that the museum educators should integrate technologies for thorough pedagogical transformation for learners with diverse backgrounds to obtain different learning content in multiple ways.

Several limitations of this systematic review should be acknowledged. First, the review consists of a small number of studies within only one database. However, the findings provide directions for research design and implementation of technology-assisted learning in museum education, especially in ways to maximize the potential of enhancing learning using technologies. Future research may focus on making the design of learning activities in museums more align with the learning process of participants, as well as designing enough portable technologies to benefit a broader scope of subjects.

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