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

Volume 20 Issue 2 ISSN 1438-0625 December 2020

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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 28 days.
Editorial

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

Junior researchers in learning technology usually meet different difficulties when they are establishing their career path. For example, they would like to know what are the up-to-date techniques in solving a learning/teaching issue, what research methods are appropriate for specific research issues, how to find the cooperation opportunities in the research domain, and what communities they can join to establish their research network.

Bulletin of Technical Committee on Learning Technology aims to deliver that information to junior researchers and encourage senior researchers to share their works and experiences on this platform. After reviewed by associate editors and executive reviewers, seven articles were selected to publish in this issue, including four articles in Emerging Learning Technologies section, one article in Book & Reviews section, one article in Collaboration Opportunities section, and one article in Event Info & Call for Event Host section.

The articles in Emerging Learning Technologies section aims to provide a platform where researchers can share their research outcome offering insights into learning technologies, including systems, tools, apps, etc. The first paper, entitled “A performance-based assessment platform for developing computational thinking concepts and practices: EasyCode,” was written by Kong and Liu. This work presents the design and implementation of EasyCode, an innovative performance-based assessment platform, for students developing their computational thinking skills. Students can not only get timely feedback to understand the correctness of their codes but also get the evaluation results for their computational thinking skills. In addition, EasyCode can also decompose the complex tasks to subtasks that follow the key steps in the algorithm. These mechanisms can help students build computational thinking skills easier with navigation and feedbacks.

The second article documents how Takemata, Nunotani, Maekawa, and Minamida developed the game that can be used in color vision detection for elementary school students and their guardians. The game is a 2D action game with guides navigating players proceed from one to the next stage. The guides are difficult to be recognized by people who have poor or deficient color vision, so players who repeating taking more time to reach the goal can be considered color blindness. The game can help students and their guardians to screen their color blindness and promote understanding of color blindness.

In the third article, Srivastava, Jaiswal, Lamba, and Prabhakar introduce how they developed a desktop application entitled “Hindi-CNLM-Coder,” helping naive/beginner non-English learners (NEL) or English as second language (ESL) programmers to learn to code using their native Hindi-language. Hindi-CNLM-Coder designs several programming concept-based coding templates that are analogous to the equivalent concepts in standard programming languages. Based on the learning by imitation theory, NEL and ESL learners can migrate the coding experience from Hindi-CNLM based codes to the standard coding languages smoothly.

The fourth article, entitled “The Go-Lab ecosystem: A practical solution for school teachers to create, organize and share digital lessons,” was written by Siiman, Rannastu-Avalos, Mäeots, and Pedaste. The authors present the Go-Lab ecosystem, a cohesive set of digital tools and services aimed at increasing the meaningful use of technology in teaching and learning. Teachers can not only organize the content for inquiry learning but also use the asymmetric simulations to develop students’ collaboration skills. All of the four articles provide important development processes and applications for the learners, which are useful for the relevant researchers.

In Book & Reviews section, Shi reviewed “Handbook on Facilitating Flexible Learning During Educational Disruption: The Chinese Experience in Maintaining Undisrupted Learning in COVID-19 Outbreak.” In brief, the hand book provides comprehensive knowledge and practical strategies, including criteria to select the most appropriate resources and tools, for educators and parents to facilitate implementation of flexible learning beyond the restrictions of space and time. Given that the global COVID-19 pandemic has accelerated the use of technology-enhanced learning in an unprecedented way, the handbook could provide researchers, teachers, students, instructional designers, and policy makers with rich opportunities to improve teaching and learning. In addition to a concise summary of the book chapters, together with strengths and potential issues, the handbook provides a set of comprehensive suggestions that consider flexible learning from six aspects: infrastructure, learning tools, learning resources, teaching and learning methods, services for teachers and students, and cooperation between schools, governments, and enterprises. Finally, according to the review’s findings, the handbook calls for further strengthening the adaptability of flexible learning in different contexts.

In Collaboration Opportunities section, Srivastava, Verma and Prabhakar (2020) presented a framework that can help educators design courses for Visually Impaired Learners (VIL) based on both learning by imitation and learning by doing. The authors further highlight several challenges that VIL are facing, and present some solutions that the authors are currently working on. Finally, the authors are calling for collaborations on this topic to fulfill the goal of inclusive education.

Event Info & Call for Event Host section brings out an event relevant to language learning. Aiming at promoting the collaboration between researchers in the fields of Technology-Enhanced Language Learning (TELL) and Computer-Assisted Language Learning (CALL), the 4th Pedagogical and Practice in Technology Enhanced Language Learning (PPTELL 2021) will be held in a hybrid mode on 28-30 June, 2021. With the theme “Contextualized multimodal language learning”, PPTELL 2021 welcomes abstract submission for oral presentation, poster presentation, and technology showcase. PPTELL 2021 provides a channel through which researchers and educational practitioners could be inspired for theory-based technological integration in the 21st century.

The current submission statistics in 2020 show that authors get the first decision notification in average 28.02 days and get the acceptance
notification in 48.61 days. To make the articles are published as quickly as possible, the Early Access (https://tc.computer.org/tclt/early-access/) page is added on the TCLT bulletin website. As long as the articles that are reviewed and accepted they will be published on the Early Access before assigned to an issue of a volume in order to deliver the most up-to-date information to the Learning Technology community.

Siu Cheung KONG and Bowen LIU

Abstract—Computational Thinking (CT) concepts and practices involve higher-order cognitive skills. Higher-order cognitive skills can be assessed using a performance-based assessment of programming processes. This study presents EasyCode, a performance-based assessment platform for developing CT in students. Distinct from existing methods that rely on the static code analysis of students’ artifacts, EasyCode conducts a dynamic code analysis, enabling the assessment of CT practices throughout the programming process. EasyCode aids student learning by setting performance tasks and providing an online judgment service, which tests the functionality of students’ submitted code and provides immediate feedback. For students with needs, EasyCode provides a support mode with tailor-made toolboxes and decomposed subtasks to help them develop CT concepts and practices. The performance tasks on EasyCode are categorized into three difficulty levels to provide a progressing ladder for students. A sample CT performance task is provided to illustrate how EasyCode facilitates students’ learning of CT concepts and practices.

Index Terms—Computational Concepts, Computational Practices, Computational Thinking, Performance-Based Assessment, Platform

I. INTRODUCTION

Computational Thinking (CT) is a type of analytical thinking that uses fundamental computing concepts and practices to solve problems, design systems and understand human behavior [1]. It is recognized as a skill that can benefit everyone in all walks of life. Researchers and educators agree that kindergarten to grade twelve (K-12) learners should learn CT [2]. Much effort has been devoted to incorporating CT courses into K-12 education curricula. Fueled by the availability of visual programming environments, CT courses are designed in the content of programming activities that expose students to different dimensions of CT, such as computational concepts (e.g., loops and conditionals) and computational practices (e.g., testing and debugging). Although teaching CT in the context of programming is advantageous because programming is closely related to computation, assessing the learning of CT in programming environments is still a challenge. Reliable and effective assessment is necessary for widely incorporating CT courses into K-12 school education at scale. CT assessment plays an important role in K-12 CT education. It provides students with feedback throughout the learning process, and, if effective, informs students how well they understood a concept and mastered a skill. It also provides teachers with information on the extent to which learning goals are being achieved.

Nevertheless, CT assessment is challenging. CT not only involves concepts of computer programming, but also higher-order cognitive skills such as testing and debugging, being incremental and iterative, and reusing and remixing [3]. Thus, a single assessment method may not be sufficient to achieve a comprehensive understanding of students’ CT development. Although much effort has been devoted to developing tools and methods for accessing CT, researchers have yet to reach a consensus on a standard assessment [4]. Previous research on the assessment of CT concepts and practices can be grouped into two types: (1) traditional assessment using standardized paper and pencil tests with task-based and multiple choice questions and (2) performance assessment based on static code analysis [5] that relies on assessing learning outcomes by programming artifacts. Some studies [6–8] use both methods to capture a holistic view of students’ understanding of CT. The traditional assessment is designed to test students’ CT concepts, whereas the performance-based assessment is used to evaluate students’ programming artifacts.

Performance assessment based on static code analysis is widely used in CT assessment because of the convenience of collecting students’ artifacts at scale, the accessibility of static analysis, and the availability of automatic assessing tools. However, static code analysis on students’ artifacts cannot maximize the capacity of performance assessment in evaluating the higher-order cognitive skills of CT. Static analysis does not examine the functionality of the codes. Therefore, it does not accurately show whether students constructed CT concepts in their codes. Some CT practices, such as being incremental and iterative, are only observable in the programming process. A static analysis of the final programming products does not show whether students experienced the CT practices. In addition, although existing automatic assessing tools can efficiently conduct static analysis in a very short time, they only provide feedbacks after students finish their coding. They cannot provide support during the programming process.

To address the existing inadequacies of the static analyses of learners’ programming artifacts, this study designs and creates a performance assessment platform that can dynamically assess students’ programming code and provide them with timely feedback throughout their programming process. This platform can help students develop CT concepts and practices and can allow researchers and teachers to design and administer performance tasks according to their own curriculum. It also provides them with a feasible and convenient way to observe students’ problem-solving process in programming activities.

This paper is organized as follows: First, the authors review the current research on CT assessment. It also examines how performance-based assessment can be used to support students’ CT development through the learning process. Second, the authors present a design of the EasyCode platform, describing its system architecture, main features, and the function of each component. Third, the authors focus on how to design a performance task that can facilitate students...
in the programming process and help them develop their CT concepts and practices. An example of a CT performance task is provided to illustrate how the platform facilitates the learning of CT concepts and practices. Fourth, the authors summarize the paper and provide recommendations for further work and improvements to the platform.

II. RELATED WORK

A. Assessment of Computational Thinking

Since Jeannette Wing’s seminal work on CT in 2006 [1], research on K-12 CT education has grown. An important task in K-12 CT education is to assess students’ CT development. Brennan and Resnick [3] proposed a theoretical framework for assessing CT in three dimensions: CT concepts, CT practices, and CT perspectives. In this study, we focus on finding an effective and efficient tool for assessing CT concepts and CT practices. Traditional multiple choice open-ended essay tests are often used to assess CT concepts and practices. For example, Meerbaum-Salant et al. [9] developed an instrument to measure students’ understanding of programming concepts in Scratch throughout the intervention. Grover et al. [10] developed a paper-and-pencil instrument to assess students’ understanding of specific computing concepts and CT skills such as debugging. Jenson and Droumeva [11] designed a test to evaluate students’ CT concepts by assessing their knowledge of computer science concepts. Román-González et al. [12] developed a CT test composed of 10 items that evaluate four computational concepts, and they verified that CT is correlated with reasoning and problem-solving abilities. Portfolio assessment, which analyzes students’ learning outputs, has also been widely adopted for assessing CT [13–15]. Many CT learning activities have been designed for a programming context. The artifacts produced by students in the learning process are systematically collected and graded according to scoring rubrics [16]. For example, Dr Scratch [5] is a Web-based automatic analysis tool for Scratch programming projects. Code Master [17] is a Web application that provides grading and assessing services for App Inventor [18] and Snap! [19] programming artifacts. These automatic assessment tools relieve teachers from the labor-intensive assessment of students’ artifacts and thus improve efficiency. However, they may not accurately reflect students’ achievements in CT learning, because they perform static code analysis on programming project outcomes and evaluate CT concepts based on the frequency of the programming blocks that students used in the learning environment. They do not examine the functionality of the artifact and cannot identify whether the corresponding CT concepts were properly used in the programming tasks. In addition, CT is essentially a higher-order cognitive activity, and CT practices can only be observed in the programming process, not in the final programming artifact. For example, CT practices such as incremental and iterative progress can only be evaluated by investigating the series of programming tasks that students perform during a programming activity.

B. Performance-based Assessment to Support CT Development

Many CT learning activities take the form of problem-based and project-based tasks, wherein students develop CT skills while finding solutions to well-defined problem spaces. In the learning process, the learning status of students varies because of differences in their prior knowledge, learning pace, and learning abilities. Some students may need help in the learning process, whereas others may be able to move on without support. Providing formative feedback to students during the learning process helps to address this learner diversity. It encourages students to reflect on their learning progression and provides opportunities for them to make progress. A performance-based assessment platform is a useful tool for providing formative feedback. Koh et al. [20] designed a real-time CT assessment tool that provides teachers with information to make effective instructional decisions. The assessment system is embedded in the Scalable Game Design Arcade and offers real-time CT pattern analysis outputs on programming projects. The analysis results are made into visuals that give teachers a high-level sense of the progression both entire class and individual student. With this system, teachers can provide timely support to students in need. Choi et al. [21] designed a puzzle-based program for algorithm learning and found that it was effective in improving students’ CT competency. The designed puzzles enabled students to apply algorithm design skills to solve tailored-made real-world problems. Students were required to explain their algorithms. The algorithms were then verified and evaluated by teachers during the learning process. Fronza et al. [22] used agile software engineering methods to teach CT and designed CT learning activities that followed the general procedure of software development. They used programming project analyses and artifact-based interviews to assess students’ performance at multiple points across the learning process. The planned assessment was augmented by unplanned assessment based on the students’ progress to provide the necessary support. Teachers regularly interviewed students about their learning and guided them through their understanding of CT concepts. Vallance and Towndrow [23] used a transforming pedagogy for CT. They pointed out that the concept of feedback is missing from Brennan and Resnick’s assessment framework and that it is an essential characteristic for CT learning. In their study, teachers utilized the Welsh Baccalaureate Essential Skills assessment to provide formative feedback and help students reflect on their learning experience after each task.

To sum up the key points of the research studies on CT development, providing formative feedback at the right time during the learning process is important and, in general real-time feedback is preferred. However, all previous learning studies, teachers have provided most of the formative feedback, but in practice limited time and resources means that teachers are not able to care for the learning needs of all students. Without the support of automatic tools, it is difficult to implement a large-scale performance-based assessment of CT learning. In addition, well-defined tasks are needed to help students develop CT concepts and practices in the problem-solving process. Therefore, in this study, we designed a performance-based assessment platform to provide real-time feedback to students as they solve well-defined programming tasks. One of the aims of building this platform is not to compete with existing block-based programming environments, but to provide a complementary platform that focuses on fundamental CT concepts and practices across platforms to aid in the assessment and development of CT concepts and practices among students inexperienced in CT.

III. DESIGN OF THE PERFORMANCE-BASED ASSESSMENT PLATFORM EASYCODE

Performance-based CT assessment requires a performance assessment platform that provides well-defined CT tasks, real-time feedback, and practical ways for researchers and practitioners to observe students’ performance. Although numerous block-based programming environments are available for K-12 students, no platform allows researchers and practitioners to design and administer programming tasks for assessment or provides automatic judgment of those tasks. Therefore, we developed the block-based EasyCode platform. It provides tasks and judgment services online, to help develop students’ CT concepts and practices. The EasyCode platform contains a Learning Analytics Agent that captures the programming process and stores programming artifacts throughout the task. The
EasyCode platform supports students’ CT development by setting performance tasks and a series of progressive subtasks.

A. System Architecture of the EasyCode Platform

The system architecture of the EasyCode platform is shown in Fig. 1. The platform contains four components: Interface Agent, Judgment Agent, Learning Analytics Agent, and CT Performance Task Database.

The Interface Agent controls user interaction through a block-based visual programming environment with a code submission entry. It is the front end of the platform. Fig. 2 shows a screen capture of the interface. Users submit their solutions to the server. The submitted solution is then executed by the Judgment Agent and tested on predefined test cases in the system. Cases that fail the test are presented along with the output generated by the users’ programming code. Users are allowed to test their solutions on custom test cases.

The Judgment Agent provides the online judgment service. It executes the submitted code for the predefined test cases in each task. The submitted code is first converted into a textual programming language such as JavaScript or Python before execution. To prevent malicious code entry, the conversion is conducted on the server side rather than the client side. The submitted code is executed in a Docker container for security and for preventing accidental crashes caused by programming errors. The executed result is then compared with the expected output and feedback is generated for the user.

The Learning Analytics Agent records user operations in the programming environment and stores both intermediate and final programming artifacts. The Learning Analytics Agent backs up every user submission to the Judgment Agent. When users test or debug their code using the self-defined test cases, the Learning Analytics Agent records both the code and the test cases. In addition, user operations during the programming process (such as drag, add/delete, connect/disconnect blocks) are all captured in the user logs stored by the Agent.

The CT Performance Task Database stores open-ended programming tasks, solutions, and related test cases. The database is designed to store all of the feasible answers to programming tasks to enable the automatic assessment of student submissions. Researchers and practitioners can design their own programming tasks according to their CT curriculum and provide test cases for those tasks. An example of a CT performance task is given in this study. The EasyCode platform also provides labels for task designers to mark their tasks to indicate the CT concepts and practices that are needed to complete the task.

The workflow of the platform is presented in Fig. 3. The Interface Agent fetches tasks from the CT Performance Task Database and display them to the students. Students can write codes in the programming environment provided in the Interface Agent and submit their codes to the Judgment Agent. The Judgment Agent executes the submitted codes and returns the execution result to the Interface Agent. The Interface Agent will display the result to students so that they can revise their code accordingly. In the students’ programming process, the Learning Analytics Agent will record student’s operations in the programming environment, self-defined test cases and intermediate coding products.

B. Key Features of the EasyCode Platform

EasyCode has two distinctive features that the existing online block-based programming environment and assessment tools do not have: a support mode and dynamic code analysis.

1) Support Mode

Some students may find it difficult to determine which blocks should be used to design a feasible solution to a problem, or they may encounter difficulties picking up useful blocks from the programming environment to solve the problem. EasyCode provides students with a support mode for each CT performance task. As shown in Fig. 2 and Fig. 4, the user can switch between “normal mode” and “support mode” by clicking a button on the interface. In the normal mode, a standard toolbox with all usable blocks is provided. In the support mode, a tailor-made toolbox is provided that contains only the blocks required for a feasible solution, thus providing hints to students by eliminating unnecessary blocks and helping them focus on the algorithm design. The support mode also provides a progressive ladder to help students develop CT, whereby a challenging task is decomposed into a series of subtasks to guide students through the solution process. Students progress by accomplishing the subtasks one by one.

2) Dynamic Code Analysis:

Existing automatic assessment tools mainly conduct a static code analysis of students’ final programming outcomes. By measuring the block codes’ frequency, the tools make inferences about whether students have achieved a suitable understanding of certain CT
concepts. Although frequency information can assess some attributes of students’ understanding of CT concepts, static code analysis cannot determine whether the blocks that have been used were properly applied to formulate the solution. For example, using a “while-do” block does not necessarily mean that a student has mastered the “loop” concept if the block has been applied incorrectly in an endless loop. Static code analysis is also easily misled by codes that contain a lot of unrelated blocks that do not function properly. The EasyCode platform conducts dynamic code analysis in which the submitted code is executed on the server to test its functionality. The output generated by the submitted code is compared with the pre-defined expected output of the task to judge the correctness of the coding. This online judgment service provides clear goals for students in testing and debugging their codes.

Fig. 4. User interface of EasyCode’s support mode and tailor-made toolbox.

C. Design of CT Performance Tasks

A successful performance-based assessment requires well-designed performance tasks. A well-designed performance task usually has three criteria: real-world context, sufficient complexity, and clear performance criteria. A well-designed performance task should be like or similar to a real-world task and should require similar cognitive skills. The task should be complex enough to require effort from students. The performance criteria should be clear so that students can set goals for problem-solving. Careful task design is needed to fulfill these criteria. Task designers need to formulate the tasks in a concrete context that is familiar to students. The task description should be precise and concise so that students can set clear goals for the programming tasks. Task designers can manage task complexity on the EasyCode platform by designing appropriate subtasks and toolboxes for the support mode. In terms of performance criteria, students’ main objective is to work out a feasible solution and submit it to the EasyCode platform for online judgment. The online judgment service can provide timely feedback, but it can only determine the correctness of the coding. That alone is not sufficient, as CT involves more than correct coding. The platform is designed to provide performance-based assessment of both CT concepts and CT practices. CT concepts can be assessed by observing whether students properly applied the correct programming blocks and functions in solving the programming tasks. Such assessments can be made in a single task. However, assessing CT practices requires the continuous evaluation of a series of tasks. The EasyCode platform achieves this by studying the solving process of a series of subtasks.

Task difficulty management is important for performance assessment because task difficulty is closely related to students’ performance. Previous research suggests that the relationship between task difficulty and performance is an inverted-U, which means that students’ performance first increases then decreases as students experience increased difficulty [27,28]. The increase in task difficulty at the beginning can cause a corresponding increase in performance [29]. However, when the task difficulty reaches a certain level, it begins to impair students’ performance [30]. To ensure that each student is challenged but capable of progressing, we categorized the performance tasks into three levels of difficulty. They are defined according to the CT concepts required for the tasks. Level 1 tasks are the least difficult. They can be solved using one CT concept. They assess fundamental CT concepts. For example, the Level 1 task “Sum of Two Numbers” requires students to write a program that can add two numbers. Students should have the knowledge of mathematic operators such as addition, subtraction, division, and multiplication. They accomplish the task using an “add” block. Level 1 tasks also assess students’ testing and debugging skills with the help of the online judgment service. Students receive error messages from the Judgment Agent if their programs do not work. They will need to modify their codes accordingly. When students submit appropriate test cases, they will be informed that their programs work and are fully tested and debugged. In this case, students will have a record of successful practices of testing and debugging at Level 1. Another goal of the Level 1 tasks is to familiarize students with the programming environment and functions on the EasyCode platform. Students who are beginners in programming learn about fundamental CT concepts by working on Level 1 tasks. Students who are users of other block-based programming environments such as Scratch and App Inventor can easily transfer their programming knowledge and quickly familiarize themselves with EasyCode toolboxes and functions by accomplishing Level 1 tasks. For example, the Level 1 task “Calculating the remainder” teaches students how to use the modulo operation. The modulo operation is provided via a “the remainder of” block on the EasyCode platform. Users familiar with blocks for the modulo operation from other programming environments can easily transfer their knowledge to EasyCode by working on this task.

Level 2 tasks require users to apply two CT concepts to produce a solution for a programming task. For example, the task “Swap” requires users to exchange the value of two variables. Students need the CT concepts of variable and assignment, which entail resetting the value stored in one variable to another variable. The related CT practices required in this task include designing a simple algorithm of swap as well as testing and debugging the program with a test case showing the result of swap. A level 2 task can also be grounded in an operation on data structure. Students must know data structures, such as list, which is a collection of items, and how to operate on them. The Level 2 task “Print a non-empty list of numbers” assesses students’ CT concepts of a list that holds items with index and their use of a loop to traverse the list using its index to print all the numbers in the list. Students need to understand that a list is a sequential data container and that items in the list can be retrieved with index. Students need to demonstrate the CT practices in the task, such as designing an algorithm for performing the task and testing and debugging the program to complete the task. The list in this task is constrained to be non-empty. Without this constraint, the difficulty of the task would be too high for a Level 2 task because students would need an extra CT concept, the conditionals, to solve it. Students need to employ a conditional statement to determine whether the list is empty and display an empty list notice if the list does not contain an item.

Level 3 tasks require users to apply more than two CT concepts to solve a programming task. Level 3 tasks are relatively complex and require the use of multiple CT concepts. Students need to understand the programming task and devise a plan to solve the problem. For example, the Level 3 task “Prime number or composite number” asks
students to develop an algorithm to determine whether a given positive integer is a prime number or a composite number. Prime numbers have two factors while composite numbers have more than two factors [24]. Students need to find the factors of the given positive integer, store the factors in a list, and make decisions based on the length of the list. This level 3 task is a difficult task because it contains multiple computational subtasks with each subtask involving several CT concepts. This platform provides support mode for difficult tasks to support learner diversity. In the support mode, the platform provides a suggested plan. It decomposes the task into subtasks to help the user through the programming task. For example, the Level 3 task “Prime number or composite number” in the support mode advises the students to divide the task into three subtasks. The programming codes in subtask can be reused to construct the solution for the next subtask. In the next section, we will discuss this Level 3 task in detail and illustrate how students can develop CT concepts and practices using the support mode.

IV. EXAMPLE CT PERFORMANCE TASK: PRIME NUMBER OR COMPOSITE NUMBER

Many curriculum and assessment tools have been developed for K-12 CT education [4], [10], [25]. In this section, we present an example of a CT performance task that develops CT as students learn a primary mathematics topic. This section builds on the work of Kong [26]. In this learning task, students are asked to develop an algorithm to determine whether a given positive integer is a prime number or a composite number. The EasyCode platform is well suited for this kind of task for three reasons. First, the learning task is situated in a solid computing context that primary school students are familiar with through their mathematics learning. Second, deciding whether a number is prime or not requires several computational subtasks, suggesting that the task has sufficient complexity. Finally, the task has a clear and programmable goal that enables us to develop corresponding performance subtasks for the support mode.

This task is formulated in the EasyCode platform for presentation to students. It is a complex task for students. The EasyCode platform sets up a progressive ladder to help students tackle the task in the support mode. In the support mode, the original task is decomposed into three subtasks. The task description and the required CT concepts and practices are listed in Table I. The decomposition follows the key steps in the algorithm for deciding whether a given positive integer is a prime number or a composite number. The design of the subtasks reduces the complexity of the original task and provides a clear road map for students to solve the problem.

In the first subtask “Is it a factor?”, students need to demonstrate knowledge of CT concepts such as conditionals, modulo operator and comparison operator, which are needed to determine whether a number is the factor of another number. The modulo operator is needed to build a block to calculate the remainder in the division. If students know the corresponding concepts in the mathematics curriculum, they can use the modulo operator to solve the subtask.

The concept of comparison is needed to compare whether the calculated remainder is zero. The concept of conditionals is required to generate the output text based on the comparison result. Students also need to demonstrate the practice of testing and debugging using the online judgment service on the EasyCode platform. After constructing the code, students test their programs then submit the solution to the platform. The program should function properly under two situations: (1) A is a factor of B and (2) A is not a factor of B. Students need to design test cases, which are recorded in the Learning Analytics Agent of the EasyCode platform. Researchers and practitioners can then examine whether students considered all situations by examining the submitted test cases. After students submit their codes to the server, the Judgment Agent informs the students whether their code correctly determines whether A is a factor of B. If the submitted code fails the pre-defined test case on the platform, the failed case, the expected output, and the user’s output are fed back on the interface. Students can then debug their code accordingly.

The second subtask “Find all factors of a positive integer” is a subsequent task that requires students to find all of the factors of a given positive number. In this task, students need to demonstrate the concept of loops using a “for” block to enumerate all numbers that are less than or equal to the given number A. Students will need to know the concept of lists because the task requires storing factors in a list. The second subtask is closely related to the first task because deciding whether a number is a factor of another number is also a core part. The solution to the second subtask can be achieved by adding loops and list operations based on the solution to the first subtask. Students therefore experience incremental and iterative programming as well as reusing and remixing.

The final subtask “Prime/composite?” is the undecomposed original task from the normal mode. In this task, students need to write a complete program to decide whether a number is prime or composite. This task may be challenging if students do not have the results from the previous two subtasks to solve it directly. Students need to know the concept of factors and how to calculate a number’s factors before deciding whether the number is prime. However, if students have solved the two previous subtasks, they may have an easier time with the final subtask. The final subtask allows students to demonstrate certain CT practices, such as being incremental and iterative and reusing and remixing. As shown in Fig. 5, they can also build their solution by reusing part of the code they generated to calculate the factor list in the second subtask. Students can then use a conditional block to judge the length of the factor list and determine whether the given number is a prime number or a composite number.

V. SUMMARY AND FUTURE WORK

In this study, we present a performance-based assessment platform called EasyCode for developing CT concepts and CT practices. The EasyCode platform is equipped with a block-based visual programming environment and a Learning Analytics Agent that captures students’ programming processes. The EasyCode platform also provides an online judgment service that gives students timely feedback on their performance in solving tasks or subtasks of a given programming activity. With EasyCode, researchers and practitioners can design and administer tasks according to their curriculum. An example on how to develop a CT performance task based on a mathematics curriculum is provided. It shows how CT performance tasks can be based on a context familiar to students. In the future, we will expand the CT performance task database. The platform presented in this study is still a prototype. Students’ experiences on our platform remain unknown. A user study will be conducted to address this limitation. We will improve the user experience of the platform accordingly.

CT practices are an important aspect of the assessment of CT development. CT practices are best evaluated through high-level programming skills such as testing and debugging, being incremental and iterative and remixing and reusing. Therefore, to assess CT practices, we need to study students’ programming processes. The EasyCode platform keeps a log of user operations in the programming environment with the Learning Analytics Agent and uses them as a basis for assessing CT practices and higher-order cognitive skills. Future work will involve the development of further analysis tools for extracting learning features from the user logs in the Learning
Analytics Agent. Visualization of the learning trajectory of students using EasyCode will also be explored in future research.

REFERENCES

Fig. 1. System architecture of the EasyCode platform

<table>
<thead>
<tr>
<th>Task Order</th>
<th>Subtask Name</th>
<th>Brief Description of the Task</th>
<th>Required CT concepts</th>
<th>Required CT practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Is it a factor?</td>
<td>Given a positive integer A and a positive integer B, design a program to determine whether A is a factor of B.</td>
<td>Conditionals, operators (modulo, comparison)</td>
<td>Testing and debugging</td>
</tr>
<tr>
<td>2</td>
<td>Find all factors of a given positive integer</td>
<td>Given a positive integer A, design a program to calculate a list that stores all of the factors of A</td>
<td>Conditionals, operators (modulo, comparison), loops, data (list)</td>
<td>Testing and debugging, being incremental and iterative, reusing and remixing</td>
</tr>
<tr>
<td>3</td>
<td>Prime / composite?</td>
<td>Given a positive integer A, design a program to determine whether A is a prime number or a composite number according to its number of factors.</td>
<td>Conditionals, operators (modulo, comparison), loops, data (list)</td>
<td>Testing and debugging, being incremental and iterative, reusing and remixing</td>
</tr>
</tbody>
</table>

Fig. 5. Example of an alpha-test user’s submitted solutions and their reuse of codes.
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Development of a Digital Learning Game with Preliminary Screening for Congenital Color Vision Deficiency

K. Takemata, Member, IEEE, K. Nunotani, M. Maekawa, and A. Minamide, Member, IEEE

Abstract— It is advisable to perform color vision screening tests in Japanese schools during the lower grades of elementary school and the first and second years of junior high school. This would allow schools to appropriately meet the needs from elementary school pupils in lower grades and junior high school students to avoid troubles when advancing to higher education or finding a job. However, guardians or parents’ understanding of color vision screening tests is crucial since the screening tests in schools are conducted only upon their “requests.” The “color vision education leaflets” issued by the Japan Society of School Health and the Japan Ophthalmologists Association are aimed at promoting the understanding of the screening tests. This research develops a digital learning game that can be used in color vision education for elementary school students and their guardians and also has the feature of color vision screening. This paper focuses on the “difficulty in identifying certain color combinations instantaneously,” which afflicts people with color weakness. This was incorporated in the digital learning game as the feature for the screening test. Furthermore, it was confirmed through experiment verification that the feature is effective as a preliminary screening test.

Index Terms—color vision, color blandness, color universal design

I. INTRODUCTION

In the human body, there are three cones with different spectral characteristics. These cones have visual cells that perceive the red, green and blue colors, respectively. People with these three types of visual cells are called people with normal color vision. As for people with one of the three types of visual cells missing, they are called people with dichromatic color vision (or color blindness). As for the case where the three types of visual cells are present, but one of them has reduced functionality, it is called anomalous trichromic vision (or color weakness). If the visual cells that perceive the red color have a low degree of perception, it is called type 1 trichromacy. If the visual cells that perceive the green color have a low degree of perception, it is called type 2 trichromacy. If the visual cells that perceive the blue color have a low degree of perception, it is called type 3 trichromacy.

Most people with congenital color weakness have type 1 or type 2 trichromacy, while type 3 trichromacy is rare. As for the percentage of people with color weakness, 5% of all Japanese males and 0.2% of Japanese females have color weakness. In the USA, 8% to 10% of males have it, while in Africa, 2% to 4% of males have it. The subjects of this research are people with anomalous trichromacy.

In accordance with the School Health and Safety Act (the School Health Act was renamed the School Health and Safety Act on April 1, 2009), the educational institutions in Japan conduct medical checkups for students annually. Until 2002, color vision tests were included in the mandatory items in medical examinations and were conducted annually for the children who reached the fourth grade of elementary school. However, in 2003, color vision tests were removed from the mandatory items in medical examinations by what was called the School Health Act amendment at the time. The color vision tests were conducted as exceptional procedures for those who desired it. However, at that point in time, color vision tests for young students were eliminated in effect. Underlying were social problems such as young students with congenital color vision anomalies facing discrimination due to problems related to color vision or suffering from disadvantages. As a result, around 2010, there emerged problems such as a problem in which middle or high school students do not know that they have a color vision anomaly until they start pursuing higher education or finding a job and have to change their life paths. This coincided with the timing of the students of the first generation after the elimination of color vision tests becoming high school students. Therefore, the society started questioning whether they should conduct color vision tests again. In response to that situation, the School Health and Safety Act was amended in 2014 and the matter of handling color vision tests was to be reviewed. Since 2016, the decision to conduct color vision tests has been up to each local government and each school and color vision tests were revived in effect in Japan. The schools that implement the tests conduct a thorough “questionnaire for color vision tests for young students” targeted at guardians while adequately protecting the privacy of the people undergoing these tests [1-5].

The color vision test in Japanese schools is a mere screening, and the actual test is left to medical institutions. Guardians’ understanding and teaching staff’s proper handling of children and parents are crucial in conducting the screening tests at schools. Therefore, the Japan Society of School Health and the Japan Ophthalmologists Association issued “color vision education leaflets.” In Japan, there are educational activities for disseminating the characteristics of color vision deficiency and what kind of care is required for color-blind people in school and at home, in order to promote color vision screening. In this study, we have developed a digital learning game aimed at contributing to such educational activities. We have developed a digital learning game with preliminary screening for color vision deficiency, taking into account the situation of Japanese color vision problems. In this paper, we focused on the fact that people with imperfect color vision “have difficulty in swiftly identifying specific color combinations,” and utilized this characteristic in events in that game, so that people with imperfect color vision would play the game...
for a longer period of time than normal people. This serves as the screening function. This paper mentions a verification experiment carried out for the purpose of checking whether the developed digital learning game is effective for preliminary color vision screening.

II. CURRENT SITUATION OF COLOR VISION SCREENING IN JAPAN

In Japan, color vision screening was discontinued in 2003 and resumed in 2016, as mentioned in the previous section. Figure 1 shows the procedure for color vision screening in school after the resumption. After the resumption, a survey for checking whether guardians demand color vision screening was started. The procedure based on the guidelines by Japan Ophthalmologists Association is as follows [6].

- Step 1: To survey the demand from guardians of target students, such as second graders, first-year junior high school students, and first-year high school students. To distribute survey sheets to guardians of students for explaining color vision screening and asking whether they want the students to undergo the screening.

- Step 2: To conduct the screening targeting the students who demanded color vision screening in school. It is recommended to use “14 tables of the concise version of Ishihara Color Vision Testing Table II” during the screening. It is globally common to use Ishihara Color Vision Testing Table for color vision screening [7].

- Step 3: To encourage students who are suspected of having color vision deficiency to go to an ophthalmic hospital for a detailed examination [8, 9].

- Step 4: If a student is diagnosed as having color vision deficiency at an ophthalmic hospital, the student and his/her guardian will receive guidance about what they should care in school, etc. Then, the guardian will submit the results of diagnosis at the hospital and the report including what they should care in school to the student’s school.

- Step 5: With reference to the submitted documents, the school gives appropriate instructions and necessary support to the student.

At Step 1, it is necessary to pay attention to students who did not demand color vision screening. There is a case in which such students advance from elementary school to middle/high school without noticing his/her congenital color vision deficiency and face a difficulty due to his/her color vision deficiency when finding a job or going on to college. School education is supposed to avoid such a case and provide students with sufficient time to think over their career paths. To do so, the color vision screening at Step 1 is important, and it is important to provide guardians with information about color blindness in society as Step 0. This study is an activity between Step 0 and Step 1.

Nakada et al. reported on the current situation of the number of students demanding color vision screening in Japan [10]. That surveyed and researched the current situation of color vision screening and effects of measures in schools in Sapporo City, Hokkaido. According to that report, the number of guardians of second graders demanding color vision screening was surveyed in Sapporo City in 2016, and it was found that 1,274 (52.3%) out of 2,438 respondents were demanding color vision screening. Around half of them demanded color vision screening, but the number is not so large. This result indicates that it is essential to promote educational activities regarding color vision screening.

It is necessary to not only make color vision screening known by more people, but also establish a diverse society tolerant of color vision deficiency. Having a color vision anomaly only means that a person has a color vision that causes him/her to have difficulty distinguishing some colors. Moreover, the misperception of a color varies among color-blind people, hence the problem cannot be solved just by substituting a specific color with another. Color Vision Barrier-Free Design (hereinafter referred to as “Color Universal Design”) is the design of products that takes into consideration the color vision diversity to prevent people with color weakness from misperceiving colors and make sure that the information is conveyed accurately to everyone. Moreover, a lot of efforts related to color vision diversity were made by Kei Ito (currently a professor at the University of Tokyo) and Masataka Okabe (currently a professor at the Jikei University School of Medicine). In 2004, they established an NPO called Color Universal Design Organization that continues to disseminate information on how to create a society that takes into consideration color vision diversity. Also, companies, administrations and associations joined Color Universal Design Organization, and the committee for producing a set of color combinations recommended by Color Universal Design was established in 2007. This committee facilitates the research, development and dissemination of the printed, painted and display screen versions of “Set of Color Combinations Recommended by Color Universal Design” [11,12]. In Japan, information is transmitted in public places in an improved way so that there is no substantial gap in information received no matter whether the person is in a color vision majority or minority. When creating products and services, special designs suited for people with color weakness are not prioritized, but they use colors in a manner that takes into consideration the various types of color vision among users. Thus, the approach of creating products and services that pursue a color arrangement considering the diversity in color vision among users can also be regarded as one of the trends of design thinking.

![Fig. 1. Care for students with color blindness in Japan. Here, the procedure made with reference to the recommendations of the Japan Ophthalmologists Association is introduced.](image-url)
III. Experiments Investigating the Effects of Game Design Factors

A. Research into the Inconvenience for Color-Blind People and their Worries in their Daily Lives

Through the distribution of PCs, opportunities to judge “information according to color differences” increased rapidly. Therefore, it became necessary to consider the visibility of color blindness in the manufacturing field, and a check tool for understanding how color-blind people sense colors (or face difficulty in distinguishing colors) has been put into practice. The check tool developed by Maekawa, et al. was adopted for the displays of EIZO Corporation and the software of Adobe Systems Inc. (Adobe Photoshop and Adobe Illustrator). By using them, normal people can virtually experience “what kinds of colorations are difficult to distinguish for color-blind people” [13]. In addition, web browsers, such as Google Chrome, are equipped with a color weakness simulator as an extended function, and this is an effective check tool for website design. Furthermore, portable check tools include the smartphone app “Color Simulator” developed by Asada [14] and the eyeglasses for virtually experiencing color weakness “Variantor” of Itoh Optical Industrial Co., Ltd. [15].

In this study, how color-blind people perceive colors in their daily lives were studied, in order to design software for detecting color weakness. Since the research was conducted while walking, the eyeglasses for virtually experiencing color weakness were used considering safety. After obtaining permission from the staff of a shopping mall in the vicinity of the university, we walked while wearing the eyeglasses inside the shopping mall (Fig. 2). For example, it was found that the location of a fire extinguisher shown in an emergency escape map is difficult to see.

From this on-site research, we confirmed the necessity to support the visibility of color-blind people by utilizing not only colors, but also symbols and indices, for information to distinguish. However, it was also found that they cannot distinguish colors based on indices and symbols in a blink, and that it is difficult to convey information with them. We considered that it is possible to realize the detection function by adding a program for assisting color-blind people in distinguishing colors in a blink, when designing color vision screening software. Since color vision screening is targeted at children in the lower grades of elementary school, we decided to utilize a digital game for testing color vision while giving the pupils enjoyment.

B. Prototype of a Digital Learning Game with a Color Vision Screening Function

In this study, we develop a digital learning game while expecting that it will motivate game players to undergo the screening test for color blindness, if they are not aware of color weakness [16,17]. The game will have the following features.

- The game can be enjoyed by anyone, including normal color vision people and color-blind ones.
- Target players are kindergarteners and children in the lower grades of elementary school.
- The game can be played with various devices, including tablet terminals and desktop PCs.

1) Shooting game development

This is a conventional 2-dimensional shooting game. One can move in all directions and shoot by operating the system. We prepared two types of ammunition for enemy attacks. One type of ammunition is red (RGB color code: 255.0.0), and the other is yellow (RGB color code: 255.255.0). The background color is set to be brown (RGB color code: 93.85.36). Due to this, people with color vision deficiency will have a hard time discriminating the red ammunition because it will blend into the background.
hard time discriminating the red ammunition because it will blend into the background. The attacks from the enemy are set so that both red and yellow ammunition will be shot simultaneously. A person with color vision deficiency will tend to deal with only the yellow ammunition during play, and this action by the game player will indicate the possibility of the player having color vision deficiency. Fig. 3 is a screenshot of the shooting game. The red ammunition is pointed by the arrow in the figure.

We submitted the prototype shooting game to the festival of a junior high school in Kanazawa city in Nov. 2014. The aim was to find out if the digital learning game can be enjoyed by a junior high schooler, whether they have color vision deficiency or not. In other words, we confirmed its entertainment characteristics. Therefore, we did not give instructions about color vision to the game players. We considered that by letting them know, they may not enjoy the game as much. Therefore, junior high schoolers who simply wanted to enjoy games participated. The game received high marks from junior high schoolers, and many played the game multiple times. Most of them gave positive opinions, such as the opinion that they "enjoyed" the game. Also, the degree of difficulty was evaluated as "just right," and so we concluded that it is appropriate.

The game was played by mainly male students, and there was a possibility that 5% had color vision deficiency. However, we did not find anyone who had discomfort about discriminating the two colors. We observed them when they played games, and we feel that it would be difficult to find players with color vision deficiency during game play. The reason for this is that compared to other types of games, shooting game players operate their system according to split-second decisions in the game field. Therefore, it would be difficult to discriminate between "simple operation errors" and "delays caused by color vision."

2) Mazing game development

The player's ball is located in the center and two colored balls (red and blue), which will serve as a guide through the maze, are located at the start point (Fig. 4). The player selects one of the balls to use it as a guide, and follows the ball until they reach the goal. When a red or blue ball is on a gray background, people with normal color vision will notice the red ball first. On the other hand, people with color vision deficiency will have a hard time visually recognizing the red ball, and will select the blue ball. We will detect the possibility of a game player having color vision deficiency by using this mechanism. Since this is a maze game with guides, a wide target age range can be assumed.

Fig. 4. A conventional two-dimensional maze game. The player's ball is located in the center and two colored balls (red and blue), which will serve as a guide through the maze, are located at the start point. The player selects one of the balls to use it as a guide.

We exhibited the maze game at a "civil science awareness event" sponsored by the local government in Dec. 2014. All who experienced the maze game judged that the game is enjoyable. The pre-schoolers and grade schoolers said that they "enjoyed following the ball." However, the pre-schoolers not only played the game once, but wanted to play it the second time. They tended to select a different color ball from the one they selected first. The maze game will be improved and configured to have multiple screens, and players will be able to enjoy the game by selecting a ball for each of the screen. We feel that we may be able to find people suspected of having color anomaly by recording the guide balls they selected during the game. It has been found to be effective to incorporate a mechanism related to color screening as a "guide" for advancing in a game.

IV. DEVELOPMENT OF DIGITAL LEARNING GAME FOR SCREENING COLOR BLINDNESS

From the surveys and trial experiments in the previous section, the following conditions are crucial factors in the proposed game in order to detect color blindness.

- As a student plays the game, there are components embedded to detect color blindness.
- The game will not be over by the player's inadvertent wrong operation or mistake.

The proposed action game incorporates the two conditions stated above. The produced digital learning game is an ordinary two-dimensional action game. Players move their characters by using the right, left, and space keys, and compete for controlling events in the game (Fig. 5). The game is constituted by 7 stages in the first half and 7 stages in the second half. For all of the stages, a “guide” is displayed so that characters can proceed to the next stage. By effectively using this guide, game players can overcome all of the 14 stages in a short period of time. For the 7 guides used for the 7 stages in the first half, color combinations that are difficult to distinguish for color-blind people are used. For the 7 guides used for the 7 stages in the second half, color combinations that are easy to distinguish for color-blind people are used. Fig. 6 shows one example. Fig. 7 shows the guides used for each stage. These color combinations were determined with reference to “Set of color combinations recommended by Color Universal Design” by the committee for producing the set of color combinations recommended by Color Universal Design. In the guide shown in Fig. 7, the upper guides (a) are difficult for people with color blindness to recognize. On the other hand, the guides at the bottom (b) can be recognized relatively easily by people with color blindness.

Fig. 5. The figure shows a screenshot of the action game. The game is constituted by 7 events in the first half and 7 events in the second half.
Fig. 6. At each stage, a “guide” will be displayed to help the character proceed to the next stage. The guide at the top is easy to see for students with color weakness. However, the guide at the bottom is difficult to see for students with color weakness.

Fig. 7. List of guides used in this action game. The upper guides are difficult to recognize for color-blind people. On the other hand, the lower guides are recognized relatively easily by color-blind people.

Fig. 8. The figure shows what happens when the player advances the character in a different direction from the guide's support. (a): It shows a character falling off a cliff and returning to the start point. (b): It shows the character returning to the road she came to because she found a cliff. (c): It is when the character returns to the path she came to because she found some obstacle.

During game play, a guide moves as a character moves, so there are some cases in which a color-blind person cannot notice a guide and the guide does not function. Fig. 8 shows what happens when the player advances the character in a different direction from the guide's support. Fig. 8 (a) shows a character falling off a cliff and returning to the start.
point. On the other hand, Fig. 8 (b) shows the character returning to the road she came to because she found a cliff. Also Fig. 8 (c) shows a scene in which the character returns to the path she came to because she found some obstacle. In this way, if the player does not use the guide well, the time it takes to reach the goal will increase. If a player repeats this situation without operating mistakes, it is suspected that the player is color blind.

The produced action game was exhibited at a municipality’s event held in the vicinity of our college in Dec. 2019. That event was for citizens, and visitors were composed of mainly local students of elementary and middle schools. Before starting each experiment, we explained the research to subjects (elementary school students) and their guardians in writing and orally and obtained the guardians’ consent, in accordance with the instructions from the Kanazawa Institute of Technology’s committee exclusively for checking the ethics of research targeted at people (approval No. 192102). We had 37 children in the lower grades of elementary school enjoy the game. They evaluated the game highly, and most of them gave positive comments, such as “It’s fun.” They also evaluated the level of difficulty of the game as “suitable.”

In this game, a guide is placed in each event to facilitate the player’s progress in the game, in order to determine color blindness screening based on the time spent for the game alone. Color combinations of the guides are all different in consideration of differences in visibility among color-blind players. Color combinations of the guides for the 7 events in the first half were difficult for players with color blindness, while color combinations of the guides for the 7 events in the second half were easily visible. As for the 7 events in the first half, 3 players spent 60 seconds or less, 17 players spent over 60 seconds and within 120 seconds, 10 players spent over 120 seconds and within 180 seconds, and 5 players spent over 180 seconds and within 240 seconds. However, two players who spent over 240 seconds are excluded here, as there could have been troubles during the game. 86% of the 35 players completed the first half of the game within 180 seconds. In the 7 events in the second half, 16 players spent 60 seconds or less (including the two players who spent over 240 seconds in the 7 events in the first half), 17 players spent over 60 seconds and within 120 seconds, and 4 players spent over 120 seconds and within 180 seconds. Excluding the two players who spent over 240 seconds in the 7 events in the first half, 89% of the 35 players completed the second half of the game within 120 seconds. The time spent by players for the 7 events in the second half is 60 seconds shorter than the time spent for the 7 events in the first half. The factors behind this difference are considered to be “visibility of the guide” and “familiarity with the game operation.” For normal color vision people, the visibility of both the guide that appears in the first half and the guide that appears in the second half is good. Therefore, it is considered that the 60-second reduction was mainly because they got accustomed to the game operation.

In Fig. 9, we further study the 4 players who spent over 120 seconds and within 180 seconds for the 7 events in the second half. 2 out of the 4 players here spent more time for the 7 events in the second half than for the 7 events in the first half. For color-blind people, the guides that appear in the first half would be less visible and they would spend more time for the 7 events in the first half than for the 7 events in the second half, but this was not the case for these two players. The two players seemed to have lost concentration during the 7 events in the second half, which caused them to spend more time for the 7 events in the second half than for the 7 events in the first half. Finally, we examine the remaining two players. These two players spent 224 seconds and 237 seconds, respectively, for the 7 events in the first half, and 141 seconds and 154 seconds, respectively, for the 7 events in the second half. Both of them reduced the spent time by about 80 seconds for the 7 events in the second half. Considering that more than 80% of the players were able to reduce the time spent for the 7 events in the second half by about 60 seconds as they got accustomed to the game operation as mentioned above, it can be predicted that “20 seconds,” which is “80 seconds by these 2 players” minus “60 seconds as a result of getting accustomed to the game operation,” is the time associated with the visibility of the guide for these two players. Color combinations of the guides for the 7 events in the second half are easily visible to people with color blindness. However, not all of the guides for the 7 events in the second half are easily visible for all color-blind people due to individual differences in visibility. Hence, the cumulative time spent for perceiving each guide in the 7 events in the second half is likely to be reflected in these 20 seconds. Therefore, these two players may be color blind, and should be recommend to undergo a formal color vision screening test. It is said that there is one color-blind person in every 20 Japanese males, and we believe that the result of this preliminary screening of two possibly-colorblind persons among these 37 children are within the acceptable range. In summary, although the number of subjects cannot be said to be sufficient, the guiding function in the action game proposed in this paper can be used for the preliminary screening of color-blind people.

V. CONCLUSION

Apps for testing color vision have been already distributed in the market, but they are intended for “checking whether a subject has color weakness,” and lack entertainment. Those who are not interested in color vision deficiency tend to avoid the use of such apps. In this study, we aim to develop a digital learning game that can be enjoyed by anyone from the viewpoint of Color Universal Design and motivate
Why was “color vision screening” resumed in school?

At present, color vision screening for Japanese school children is not conducted unless their guardians request, so it is necessary to educate guardians about color weakness. At a scientific event targeted at citizens, we had children play the game described in this paper after obtaining their guardians’ consent. We expect that this will contribute to the early detection of color weakness among children and the deepening of guardians’ understanding of color vision variation.

Any of elementary, middle, and high schools in Japan does not provide opportunities to actively learn about color blindness, and, as described in this paper, parental understanding and consent are necessary for screening for color blindness. In Japan, generations with no experience of color blindness screening tests will reach the age of parents of elementary school students around the 2030s. At that time, education to promote the understanding of color blindness will be even more important than it is at present, and the progress of this study will be of higher significance. We plan to continue to exhibit at science-related events for the general public to contribute to the early detection of children with color blindness and to promote understanding of color blindness among their guardians.

One possible limitation of this study is that it is difficult to proceed with testing the practicality of the digital learning game we have developed in Japan due to human rights concerns. The most effective solution is to get cooperation from a large number of color-blind people. However, there are only a small number of people in Japan who disclose their color blindness, and it is difficult to find color-blind people in general. Naturally, it is also difficult to gain cooperation in the field of school education. Therefore, we believe that the practicality of this digital learning game can be verified by making the game available online for a large number of users and confirming the emergence of the “tendency related to the delay caused by the visibility of the guide” between the “distribution of people with normal color vision with respect to the time spent” and the “distribution of color-blind people with respect to the time spent,” as shown in Fig. 9 of this paper.

“Set of color combinations recommended by Color Universal Design” suggests “color combinations that are relatively easy to distinguish,” “color combinations that are difficult to distinguish,” and “color combinations that are somewhat difficult to distinguish.” From now on, we would like to study the instant visibility for “color combinations that are somewhat difficult to distinguish” by utilizing this action game.

APPENDIX

To experience the action games in Section IV of this paper, please visit the following URL, http://kanazawa.p-product.net/game/ .

ACKNOWLEDGMENT

During the course of this study, we received valuable information regarding the application development and prior work from Mr. Tsubasa Takeda and Ms. Misa Tanaka. We express our deep gratitude. We would like to thank the former Associate Professor Sumio Nakamura of Kanazawa Institute of Technology and Professor Toshiyuki Yamamoto of Kansai University for their advice when writing this paper.

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Understanding Design Elements of Hindi Coding Application

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Abstract—Skills like logic, reasoning, algorithm formulation for problem-solving, mathematical inferences, application of knowledge and others are independent of language we speak. Using these skills, an individual can solve day to day problems quickly. Art of programming (AOP) is a combinational skill. It is composed of several language-independent skills like logic, reasoning, algorithm design, problem classification and others. However, AOP heavily depends on learners knowledge of the English language because the syntaxes of nearly all important and widely used programming languages were designed using the English language. This introduces a problem before non-English learners (NEL) and learners with English as a second language (ESL) to start coding. In my country India our mother tongue is the Hindi language, and most learners are either NEL or ESL. Due to this, teaching programming becomes challenging. This research is the answer to this challenge. To encounter this problem, we developed a desktop application entitled “Hindi-CNL-Coder”. This application helps naive/beginner NEL or ESL programmers to learn to code using their native Hindi-language, which further helps them to learn to code using traditional programming languages like C, Java, and others. This research presents the complete details associated with the “Hindi-CNL-Coder” version 2 app, along with the technology stack, associated reference architecture and other essential elements used to fabricate the app. This research also presents the usefulness of the proposed application in various learning environments.

Index Terms—Art of Programming, Controlled Natural Language, Desktop Application, English as Second Language, Native Language.

I. INTRODUCTION

The English language serves as a pre-requisite for naive/beginner level NEL and ESL programmers. This happens because most of NEL or ESL programmers have difficulty in understanding the English language and all advance and most widely used programming languages derive their keywords, syntaxes, statements, and other elements from the English language. Moreover, the programming language syntax itself produces complications in understanding the art of coding.

To design an easy AOP learning process for NEL and ESL learners, we have to teach them programming using programming elements designed in their native language rather than in the English language. Moreover, the overall coding elements like language structure, keywords, syntax, and others must be simplified. The essential principles of programming like assigning variable names, declaring functions, creating classes, including header files or importing packages, calling functions using call by reference or call by value, function overloading, function overwriting, default values in parameters, handling arrays, handling conditional statements, handling loops, using jump statements, using structures, object handling, garbage collection functions and others must align with the most widely used or targeted programming languages like C, C++, Java and others.

To achieve these objectives, we engineered a desktop application named “Hindi-CNL-Coder”. This app helps naive/beginner level NEL or ESL Indian coders to code using their mother tongue, which is the Hindi language. Use of this application helps in smooth migration of Hindi coders towards standard programming languages like C, C++, Java, and others. To design programming syntaxes and elements using the Hindi language, we used the concept of controlled natural language (CNL). CNL’s are derived using natural languages (NL) by restricting rules and vocabulary present in NL. So we restricted the use of rules and vocabulary present in the Hindi language in order to obtain HINDI-CNL. As we know that the Hindi language is not a widely used language in the international market and on the internet so nearly no standard Hindi-CNL engine is present in the market. So instead of building the complete Hindi-CNL engine (which is a costly affair), we fabricated a mechanism to handle the problem. Section IV, V and VI discuss in detail issues concerning CNL’s and Hindi-CNL.

Although the Hindi-CNL engine is the core of the system, still, the overall system requires other architectural artifacts and components. Section VII presents the details concerning the reference architecture of the Hindi-CNL-Coder application. This reference architecture helps software developers to design similar applications for other native languages. The tradeoff between various quality attributes heavily depend on the architecture of the system. Due to this system architecture becomes a critical issue.

Section VIII discusses the complete working of the app. This section also presents the step by step procedure of using this application along with its technical details. On the other hand, section IX lists in detail the usefulness and benefits of the app. Whereas section X point toward some critical issues which end users flagged after using the app. Beta testers of the app also pointed out the same set of issues.

We believe that this application help naive/beginner level NEL or ESL coders to understand better the art of programming. We also believe that this application help in smooth migration of naive/beginner NEL or ESL programmers towards the core programming languages like C, C++, Java, and others. This application also provides a native-language based user-friendly environment for learning the art of programming.

II. RELATED WORK

The researches based on theories given by Bloom [1], Pavlov [2], Bandura [3-6], and Webb [7-10] produces, beautiful results in the

Received August 1, 2020, Accepted September 2, 2020, Published online December 6, 2020.

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form of classroom-based teaching models and frameworks. These frameworks and models help course instructors and teachers to teach effectively. Teaching style heavily depends on learning strategies adopted by the students. The issues concerning the depth of knowledge, knowledge points and content complexity rigor help educators to design courses and their structure [11-13]. Programming courses are no exception. All teaching styles, trends and pedagogical issues which applies on standard courses apply to the coding courses as well. Learning styles like learning by doing (LBD), learning by imitation (LBI), learning by teaching (LBT), learning by memorization (LBM) and others helps educators to choose teaching strategy [14-15]. Researchers showed that students retain nearly 25% of what they see, 50% of what they see and listed and more than 75% if they learn using LBD approach [19-22]. Several online educators designed their online learning systems using the approaches mentioned above [16-18]. Researchers also proved that block-based programming and algorithm-based programming are suitable for beginners [23-24]. Researchers also showed that cognitive score serves as better criteria for selecting students in an online course concerning their marks and pre-requisites [26]. Researchers also listed several tradeoffs which exist among various types of learning style [25]. All these researchers provide pedagogical background for the development of Hindi-CNLCoder app.

The core engine of this application works on the concept of controlled natural language (CNL). The CNL based concept of micro-publishing [27], knowledge representation and knowledge bases [28], CNL in business [29], use of CNL for Semantics of Business Vocabulary and Business Rules and CNL for inferences [30-31] are several types of research which clarify the concept of CNL and its application. In our case, we need Hindi-CNLC engine, but no such engine is available, so we constructed one for this application. The overall architecture design for this application handles the quality attribute (QA) tradeoffs efficiently. The layered approach used for designing several components makes the overall design clear and compact. Researchers proposed several ways of handling quality attributes [32-38]. We considered these approaches while designing our app. Software architects talk about architecture patterns for handling QA’s tradeoffs. We used their concept to handle QA’s related tradeoffs while designing this app.

III. PROBLEMS WITH NEL AND ESL LEARNERS

All NEL and ESL learners suffer from several English language-related issues which include problem in (i) understanding English text/instructions (UETI), (ii) writing English text/instructions (WETI), (iii) filling English templates/forms (FETF), (iv) Interpretation (INTP) and (v) communication (COMM). Apart from these five issues listed above, several issues like (a) interspeaker, (b) intraspeaker, (b) socio-linguistic and (d) others are essential from a linguistic point of view. However, they are not necessary for this research, so we are not going to discuss them here.

The complete set of English language grammatical rules, vocabulary, syntaxes and structures amplify all five problems listed above. The NEL and ESL learners suffer a lot in short duration courses where a good knowledge of the English language serves as an unsaid pre-requisite. Due to English based syntaxes programming courses on C, C++, Java and other standard programming languages make learning difficult for NEL and ESL learners. In practice, the course instructor uses his/her experience to overcome these challenges. Teaching using dual language is the most common approach which they follow. This approach works well for offline teaching mode but fails for teaching online courses. It fails because, in online courses, students from different countries can participate which bars course instructor from using dual or multi-lingual teaching approach. The application proposed in this paper is the answer to this problem.

Most Indian teachers and course instructors follow “just enough English” approach for teaching AOP to NEL and ESL learners. This approach uses limited English keywords, syntaxes and other elements to teach programming to the NEL and ESL students. Instructors and teachers use abstraction for teaching English elements to the learners due to which they highlight only essential details of English elements without going into its core grammar. This abstraction based method seems useful, but in reality, it is a crude method because everything is done informally without any proper control over elements of English. We noticed that programmers produced using this approach lack self-confidence because they mugged up several keywords, syntaxes, concepts and other programming elements without understanding them.

The other approach to handle the above-listed problems is to formally teach the NEL and ESL students a limited set of English language rules and vocabulary, which is domain-specific concerning AOP before teaching them programming. This type of English is known as controlled English, and it falls under the category of CNL. This approach is effective concerning the previous approach. However, researchers observed that this process is time taking and AOP requires limited knowledge of the English language, so it is hard to derive a limited set of English language rules and vocabulary for the same.

In this research, we followed the modified version of the second approach discussed above. The second approach is also known as the controlled natural language (CNL) approach. We modified it, considering the pedagogical issues associated with the AOP.

In order to do a course generally, course instructors choose pre-requisites and cumulative grade point average (CGPA) as screening criteria for students. Researchers showed that cognitive score is more effective screening criteria concerning pre-requisites and CGPA. They further showed that the best way to learn to program is through imitation. We considered these researches while fabricating Hindi-CNLC engine. In the next section, we will discuss the basics of CNL and learning by imitation (LBI). These two elements form the conceptual structure for this research.

IV. UNDERSTANDING THE CONTROLLED NATURAL LANGUAGE AND LEARNING BY IMITATION

A controlled natural language (CNL) is a restricted or controlled version of some natural language (NL). A CNL is obtained by extracting a subset of rules and vocabulary from the complete set of rules and vocabulary present in the source natural language. For example, English is a natural language, and several English based CNL’s are attemptito, cleartalk, ASD simplified English, common logic controlled English, E-prime and others. These English CNL engines are available online.

NL’s are used to create CNL’s. On the other hand root of NL is embedded in classic literacy which means the art of reading and writing using native NL’s. Classic literacy is the primary prerequisite for learning courses like science, arts, technology, social science and others. Learning a new concept or technology requires knowledge of the native NL. Researchers showed that all human brains are designed to think and understand using their native NL. It is to be noted that bilingual or multilingual speakers have two or more languages as their native NL’s, respectively.

Initially, CNL’s were created to solve five linguistic problems listed in section III. Later they were used in several automated tasks like knowledge representation, formal logic and others. The
translation of a document written in a particular natural language (say NL1) may result in ambiguous interpretations when translated to some other natural language (say NL2) or when read by different persons using NL1 or NL2. This ambiguity arises because NL’s have inbuilt variations like linguistic, interspeaker, intraspeaker, sociolinguistic and others. These variations affect several aspects of language, including phonemes, morphemes, syntactic structures, meanings and others, resulting in ambiguous interpretations. To overcome such ambiguities, CNL’s are used.

Many multinational companies and government agencies started using controlled natural languages for doing their official work. This eliminates interpretation ambiguity while interpreting documents written using CNL’s. CNL’s provide some beneficial properties to users; these properties are as follows:

- CNL’s are easy to learn.
- Sentences written using a CNL are having unambiguous meanings.
- A document written using a CNL has exactly one interpretation.
- Translating a document written using one type of CNL to another type of CNL is easy and unambiguous.
- Native-CNL’s provide links between two or more natural languages.

So from the above discussion, it is easy to conclude that a CNL is the restricted version of NL. When the use of grammatical rules and vocabulary present in any NL is restricted concerning some domain, then the restricted NL obtained is known as controlled natural language.

Researchers showed that our brains are tuned to think, understand and memorize using native natural languages. When we try to learn concepts written in foreign natural languages, our brain translates them to native natural language, which eases the learning process.

Learning programming is always a painful task for beginners. This pain amplifies when beginners fall under NEL and ESL categories. Is it possible to learn to code using native-controlled natural language? How coding through native controlled natural language help programmers to learn traditional programming languages like Java, C, C++ and others, better? How native-CNL help programmers to enhance their coding skills? This research is the answer to these questions.

The best way to learn a natural language is through imitation. The programming language is no exception. So learning by imitation approach is the most suitable approach for learning programming. In one of our paper, we proposed a model which helps naive programmers to learn to program using LBI, learning by doing (LBD) and memorization. This model produces fantastic results when implemented in online coding platform.

The concept of analogy based learning by imitation is used while designing the Hindi-CNL-Coder application. According to the concept of analogy based LBI coding is done using elements of Hindi-CNL, and these elements are analogous to the elements of standard programming languages like C, C++, Java, Python and others. Due to this migration from coding using the Hindi language towards standard programming languages becomes easy.

V. NO CNL FOR THE HINDI LANGUAGE

Several CNL engines are available online for languages like English, French, Spanish and others but no such engine exists for the Hindi language. After reading several official Hindi documents, we came to know that from several years India is using several Hindi and Urdu language-related official rules, vocabulary and formats for executing the official work. We found that these formats are equivalent to Hindi-CNL and Urdu-CNL, respectively. Based on these official Hindi-CNL documents, we constructed a template-based Hindi-CNL engine. This engine forms the core of Hindi-CNL-Coder desktop application. In the next section, we will discuss issues concerning the designed engine.

VI. TEMPLATE BASED HINDI-CNL ENGINE AND IT’S COMPARISON WITH C PROGRAMMING LANGUAGE

The Hindi-CNL engine consists of Hindi character set, Hindi keywords, rules for creating identifiers and templates equivalent to standard programming concepts. Let us discuss each of them in detail. The standard Hindi character set consist of 13 SWARS, 36 VYANJANS, 10-digits 0 to 9 (see figure 1). The Unicode and digital way of writing Hindi character set is shown in Table I. The rules for creating identifiers in Hindi-CNL program are as follows:

- The first character of an identifier must either be an underscore or SWAR or VYANJAN.
- Any combination of SWAR and VYANJAN can be used to create an identifier.
- An identifier must not start with digit.
- No special character other than underscore can be used to create identifier.
- Digits can be used to create identifiers but underscore or SWAR or VYANJAN must precede them.
- Total length of the identifier must not exceed 32 characters.
- Keywords cannot be used as identifiers.

The keywords are reserved words in Hindi-CNL. The set of selected (total seventeen words are selected) Hindi words constitutes the keywords. Table II shows the complete list of keywords used in Hindi-CNL.

We used the template-based approach for designing the Hindi-CNL engine because this approach reflects analogy based LBI. In this approach, programming concept-based coding templates are designed using Hindi-CNL. These templates are analogous to their equivalent concepts in standard programming languages like C, C++, Java and others. So learning to code using these templates helps in smooth migration of NEL and ESL students from Hindi-CNL based coding towards coding using standard coding languages. Tables III-V shows some sample templates and their equivalent C language code.

Table III shows the concept of variable creation in Hindi-CNL and its equivalent code in the C programming language. In this table, some elements required for creating variables are also given like data types in Hindi-CNL and their equivalent in the C language.

Table IV shows the basic Hindi-CNL program template and its equivalent C code. From Table IV, it’s clear that the basic structure of the C program consists of header file inclusion, followed by the body of the main program. The analogue of this structure is replicated in Hindi-CNL coding template. The first line of Hindi-CNL code tells the computer that the main program is going to start, and lines second and fourth encapsulates the program body. The third line tells the computer to attach all-important header files in the program.

Table V shows the basic looping template used in the Hindi-CNL, and it’s associated equivalent C language code. In the Hindi-CNL code first line initializes an integer variable second line is the loop syntax and lines 3 and 5 encapsulates the loop body. The loop written in table V prints the first ten integers in reverse order. Line 4 represents the Hindi-CNL print statement.

Other similar templates form the core of Hindi-CNL engine.
Now let's have a look at reference architecture of the app.

![Fig. 1. Showing standard Hindi alphabets (SWAR and VYANJAN).](image source: https://images.app.goo.gl/oHFrUrWw414cVRgN8)

### TABLE I
**Showing official Unicode Consortium code chart for Devanagari script.**
(IMAGE SOURCE: HTTPS://EN.WIKIPEDIA.ORG/WIKI/DEVANAGARI_ (UNICODE_BLOCK))

<table>
<thead>
<tr>
<th>Official Unicode Consortium code chart (PDF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Code Chart](image source: <a href="https://images.app.goo.gl/oHFrUrWw414cVRgN8">https://images.app.goo.gl/oHFrUrWw414cVRgN8</a>)</td>
</tr>
</tbody>
</table>

### TABLE II
**Keywords Used in Hindi-CNL**

<table>
<thead>
<tr>
<th>संतलन–यंत्र–तालिकाये।</th>
<th>मुख्य–खण्ड</th>
<th>आरम्भ</th>
<th>समाप्त</th>
</tr>
</thead>
<tbody>
<tr>
<td>धर्म–संस्कृत</td>
<td>अपूर्ण–संस्कृत</td>
<td>वाक्य</td>
<td>यंत्र–दर्शाओँ</td>
</tr>
<tr>
<td>यंत्र–पूर्ण–संस्कृत–लो</td>
<td>वाक्य</td>
<td>भाग</td>
<td>में–रचन–है</td>
</tr>
<tr>
<td>यंत्र–वाक्य–लो</td>
<td>योग</td>
<td>&quot;ो&quot;</td>
<td>&quot;ो&quot;</td>
</tr>
<tr>
<td>यंत्र–अपूर्ण–संस्कृत–ला</td>
<td>धर्म–कौ</td>
<td>समाप्त</td>
<td></td>
</tr>
</tbody>
</table>

### TABLE III
**Showing Variables and Related Elements in Hindi-CNL and Their Equivalent Code in C Programming Language.**

<table>
<thead>
<tr>
<th>Hindi-CNL Code</th>
<th>Equivalent C Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>पूर्ण–संस्कृत</td>
<td>Int</td>
</tr>
<tr>
<td>अपूर्ण–संस्कृत</td>
<td>Float</td>
</tr>
<tr>
<td>संतलन–यंत्र–तालिकाये।</td>
<td>;</td>
</tr>
<tr>
<td>धर्म–संस्कृत</td>
<td>int p;</td>
</tr>
</tbody>
</table>

### TABLE IV
**Showing Basic Hindi-CNL Program Template and Its Equivalent Code in C Programming Language.**

<table>
<thead>
<tr>
<th>Line No.</th>
<th>Hindi-CNL Code</th>
<th>Equivalent C Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>मुख्य–खण्ड</td>
<td>#include&lt;stdio.h&gt;</td>
</tr>
<tr>
<td>2.</td>
<td>आरम्भ</td>
<td>void main()</td>
</tr>
<tr>
<td>3.</td>
<td>संतलन–यंत्र–तालिकाये।</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>समाप्त</td>
<td></td>
</tr>
</tbody>
</table>

### TABLE V
**Showing Basic Loop Concept Using Hindi-CNL Loop Program Template and Its Equivalent Code in C Programming Language.**

<table>
<thead>
<tr>
<th>Line No.</th>
<th>Hindi-CNL Code</th>
<th>Equivalent C Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>पूर्ण–संस्कृत ह=10</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>चक(1)</td>
<td>for(;i&lt;p;i=i-1)</td>
</tr>
<tr>
<td>3.</td>
<td>आरम्भ</td>
<td>printf(&quot;%d&quot;,i);</td>
</tr>
<tr>
<td>4.</td>
<td>समाप्त</td>
<td></td>
</tr>
</tbody>
</table>

### VII. Reference Architecture of Hindi-CNL-Coder App
This section presents the complete reference architecture of Hindi-CNL-Coder desktop app. The reference architecture is composed of three engines, namely (i) User Interface engine, (ii) Hindi-CNL engine and (iii) execution engine (see Figure 2). All engines, along with their core elements, are described next.

#### A. User Interface Engine
The User Interface engine allows users to interact with the application. It is composed of a set of Hindi fonts and Hindi text editor for editing programs using Hindi-CNL. It contains Hindi-CNL palette which helps users to do the editing work speedily. This engine also contains a Hindi I/O error dialog. This dialog displays runtime/compile-time errors/exceptions to the user.

#### B. Hindi-CNL Engine
The layered design pattern is used for designing the Hindi-CNL engine. According to this design pattern, the bottom layer provides services to the layer above it. This engine is the core component of this app. Its modeled using analogy base LBI approach and template-based Hindi-CNL approach discussed in the above sections. This engine is composed of three layers and one translator module. These layers, along with the translator module, are discussed next.
1) Hindi I/O Translator Module
This module helps to translate input text/program to a standard Hindi program format which pre-processor layer can handle. This module translates output generated by the system in user-readable Hindi format because the system generates output in non-Hindi format.

2) Hindi Code Pre-processor
The Hindi-CNL engine cannot directly parse the Hindi code written by the user. So this layer pre-processes the Hindi code making it compatible for processing by the layer above it. This layer pre-processes the Hindi-CNL templates and Hindi code syntax to make processing smooth.

3) Hindi-CNL-IMC Code Parser
This layer generates the intermediate Hindi code. This intermediate Hindi code is optimized and free from certain ambiguities which Hindi programmer may unknowingly insert in Hindi code while typing the code.

4) IMC-Hindi-CNL to Java Parser
This layer parses the intermediate Hindi code generated by Hindi-CNL-IMC Code Parser layer to its equivalent Java code. If during parsing any error occurs then this layer directly contact the “Hindi I/O Error dialog” present in the user interface module and halt the execution till user correct the code and restart the execution. Otherwise, if all is correct, then the equivalent java code is subjected to standard Java compiler and runtime environment.

C. Execution Engine
The execution engine is designed using the modular design approach. This engine helps in executing the user program. The Hindi-CNL engine generates the Java program equivalent to Hindi source code entered by the user. This Java program is compiled and executed by this engine. This engine contains three main components which are discussed below.

1) Java Compiler and Runtime Engine
The Java compiler and runtime engine is composed of the standard Java compiler and Java runtime environment (JRE). This engine takes Java program as the input, compiles it and if correct runs it. If any runtime or compile-time error/exception is generated, then it is sent to the Error Mapping Module. If everything is correct, then using the Hindi I/O mapper module and Error mapping module program is executed.

2) Error Mapping Module
This module helps in handling runtime/compile-time errors/exceptions. This module also uses Hindi I/O mapper to establish proper communication between the execution engine and Hindi-CNL engine. All results generated by Java engine are in English this module along with the Hindi I/O mapper module and Hindi I/O translator module present in Hindi-CNL engine converts them in Hindi-CNL for NEL and ESL users.

3) Hindi I/O Mapper
This module helps in establishing a communication link between the execution engine and the Hindi-CNL engine. This module also coordinates with other modules like Error mapping module and Hindi I/O translator module for the smooth working of the system.

VIII. WORKING OF HINDI-CNL-CODER

Figure 3 shows the complete working of the Hindi-CNL-coder desktop app. The user edits the Hindi code using the coding user interface (see figure 4). Then when the user clicks on the compile button, the Hindi-code is pre-processed. The Hindi-CNL parser parses the pre-processed Hindi program and generates the intermediate Hindi code. This intermediate Hindi code is optimized and subjected to “IMC-Hindi-CNL to Java Parser” this parser parses the intermediate Hindi code to its equivalent Java code. This Java code is compiled and executed by the standard java compiler and runtime environment. As we know that the standard Java engine produces the outputs in the English language, so the Error mapping module, Hindi I/O module and Hindi I/O translator module work in coordination to convert the English output generated by standard Java engine to its equivalent Hindi-CNL output for NEL and ESL users.
We floated an online C programming course from March-2020 to June-2020 for beginner/naive NEL and ESL students. A total of 80 students registered in the course. We used Hindi-CNL-Coder desktop application to teach them coding in Hindi-CNL and then using the concept of analogy based LBI taught them C programming language. We asked them to write algorithms in Hindi for the selected set of programming problems before the course start. This exercise is the pre-test for students. Based on six programming parameters listed later in this section, we scored them. Based on their scores, we clustered them in three groups, namely High performing group (HPG), Moderate performing group (MPG) and Low performing group (LPG). We selected six programming parameters, namely total performance (TP), concept grip (CG), innovation (IN), logic (LO), coding structure understanding (CSU) and problem-solving time (PST) to measure student performance. After the completion of the course, all students were tested and scored on the scale of [0, 10] concerning the selected programming parameters. These scores were compared with the scores obtained at pre-test.

We found a remarkable hike in programming parameter for all three groups. Table VI presents the performance hike results concerning selected programming parameters for all three groups.

From Table VI we can easily see that concerning TP, IN and LO highest hike is observed by MPG group which is \{25%, 27%, 29%\} followed by LPG and MPG groups which is \{17%, 20%, 21%\} and \{13%, 17%, 20%\}, respectively.

We also observed that PST is reduced by 24%, 13%, 11% for MPG, LPG and HPG groups, respectively. The CG hike observed is 30%, 28%, 20% concerning HPG, MPG and LPG respectively. The CSU shows 18%, 33%, 18% hike concerning HPG, MPG and LPG groups.

Apart from this, we asked students to comment concerning the Hindi-CNL-Coder desktop app. Most students gave powerful positive comments. They claimed that this app could enhance their programming capability and programming skills effectively. They loved the concept of analogy based LBI. They also asked to design similar app for other native languages of India.

Few students claimed that this way of migrating from Hindi-CNL code towards the C language code is easy and enjoyable. They also personally told us that they could understand linking concepts easily just by using this application. Many students asked us to configure the application for Java and Python. They suggested us to launch the online version of this application. They also suggested us to find new editing methods for native Indian languages.

In this research, although the application is very successful for naive/beginner NEL and ESL students, still it suffers from two significant problems. The first problem is the Hindi text editing problem. In India, English keyboards are used, so for NEL and ESL students typing become a problematic issue even if we make keys with Hindi alphabets. In reality, Hindi typing is problematic. All students want us to design better Hindi typing or input mechanism. The Hindi-CNL palette provided with the help of the app helps students significantly. However, still, we have to find new ways for Hindi typing. The second problem is with the errors produced by the compiling program. Since all errors/exceptions thrown by Java engine are in English and we only mapped a few important errors/exceptions in Hindi, so in case of non-mapped errors/exceptions system display them in English. To solve this issue, we have to design a complete error mapping system.
XI. Conclusion

This research focuses on architectural issues concerning the Hindi-CNL-Coder desktop application. The paper started by discussing the problems that NEL and ESL users face while learning to code. Then it discusses issues like program syntax, structure, keywords, rules and others, which make coding a frustrating task for beginner level NEL and ESL learners. Then concepts concerning controlled natural languages and their use to teach programming courses to beginner level NEL and ESL students were discussed. With proper references, we presented essential properties concerning CNLs and their application in learning foreign languages unambiguously. We discussed the use of CNL properties for teaching courses concerning programming.

Knowing the fact that one can teach English-CNLL to students using the Hindi-CNLL, the research extended the concept of Hindi-CNLL to learn to code in the Hindi language followed by migration step towards the standard programming languages like C, C++, Java, Python and others. The complete learning approach is termed as analogy based LBI.

This research also discusses the design-related technical issues concerning the Hindi-CNLL engine, because no standard Hindi-CNLL engine is present in the market. So this paper presents in detail the fabrication process of the template-based Hindi-CNLL engine.

Then this research focuses on the reference architecture of the app. This architecture helps software designers to design similar applications for other native languages. This paper further showed the internal components of the app, namely Hindi-CNLL engine, Execution engine and User interface engine while presenting the reference architecture.

Furthermore, this paper explains the complete working of the app in detail. In working the complete flow of control is explained with the help of a diagram. Then the paper discusses usefulness and benefits related to Hindi-CNLL-Coder desktop application. To highlight the benefits we presented the performance hike results for 80 students who used this application for learning coding in C programming language. We also listed their feedbacks to show usefulness and benefits of this application. Then finally, we listed two significant issues faced by students while using this application. The suggestions given by students concerning the issues present in the app will be considered in the next design iteration of the application.

We strongly believe that the development of such systems and applications helps NEL and ESL beginner level students to learn to code productively.

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The Go-Lab ecosystem: A practical solution for school teachers to create, organize and share digital lessons

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Abstract—The Go-Lab ecosystem is an integrated set of digital tools and services aimed at increasing the meaningful use of technology in teaching and learning. Go-Lab offers a free authoring platform to create digital lessons that have been translated into over 30 languages. It also offers a sharing platform to share content or to find ready-made digital lessons and support. This article gives an overview of the diverse possibilities afforded by Go-Lab. We show how one can get started creating and using Go-Lab digital spaces. We then give an example of a complete digital lesson that was made using the pedagogically grounded Go-Lab inquiry cycle. Finally, we show a new and innovative approach to supporting the development of students' collaboration skills based on the use of asymmetric simulations. As the recent coronavirus outbreak has made clear, online teaching can suddenly become mandatory. Go-Lab offers school teachers a practical and useful solution for delivering online digital lessons.

Index Terms—Collaboration, Computer aided instruction, Distance learning, Educational technology, Mobile learning, STEM

I. INTRODUCTION

Imagine that you are a teacher preparing for a lesson about how the earth, sun and moon move with respect to each other in outer space. You want your students to learn how that movement relates to phenomena like the seasons of the year, phases of the moon and solar eclipses. An online search for relevant material provides you with useful pictures and an informative five-minute video. You even find a website with an animated 3D model of the earth-sun-moon system that enables students to actively explore the situation by pausing or slowing down the animation and then navigating around the 3D simulation to look at it from different viewpoints. You are now satisfied with the content you found and begin designing the lesson.

At the start of the lesson you plan to collect ideas students may already have related to this new topic. Instead of just asking a few students to volunteer ideas, you use an online survey to collect responses from everyone (via their personal smartphones or school provided tablets). Then you display the results to everyone and think aloud while organizing them in a way that ties into the new topic. You highlight important questions that remain unanswered. Next you show the introductory video, but before playing it, give the students a list of questions that will direct their attention while they watch it. After the video ends you check their understanding with an online quiz. The quiz gives students immediate feedback and explanations and you see on a digital dashboard how well the class performed overall. Finally, you begin the main activity involving the 3D simulation. You decide to have students work collaboratively in groups and develop tasks accordingly. You share cloud-based documents with groups so that they can record their observations, complete the taskwork and reflect on their experience. The lesson concludes with you discussing the work done by groups and reviewing again the new concepts and skills practiced during the lesson.

The imagined scenario above highlights that teaching in today’s digital age can easily involve organizing a number of digital tools and resources for just a single lesson. Clearly teachers can benefit from an efficient way to organize their digital lessons. The Go-Lab ecosystem arose from a European project originally aimed at promoting the widespread use of innovative digital technologies in the teaching of science and math subjects [1]. Before Go-Lab, science teachers who happened to find an interesting computer simulation would usually create and print worksheets with instructions and questions to guide learning with the simulation. Typically the lesson occurred in a computer classroom and the limited time allotted to use this room meant that the teacher would try to maximize the time students had on the computer at the expense of interacting with them in discussions. Thus, students mainly relied on the worksheets for guidance and support, with occasional individualized attention by the teacher. But in a class with a large number of students, and the not so uncommon situation of the teacher having to deal with unforeseen technical problems, receiving adequate support from the teacher was likely to be sporadic at best.

Learning science with computer simulations is particularly advantageous when an inquiry-based approach is used [2, 3]. Interactive simulations offer students control over some of the variables in a model of a physical system and make it particularly convenient to observe what happens when those variables are changed. Simulations can speed up processes that are too slow to observe on natural time scales, visualize objects that are too large or too small to observe with the naked eye, and simulations allow one to study phenomena too dangerous to handle in a school laboratory. By manipulating variables to discover cause-and-effect relationships,
students engage in an authentic scientific practice. Furthermore, simulations are often intentionally designed with visually appealing cartoon-like and game-like elements to capture the interest of young people. The PhET project repository (https://phet.colorado.edu/) provides free math and science simulations and purposefully designs simulations to encourage exploration, show familiar everyday objects, and utilize visual clues to emphasize pedagogically important concepts [4]. For example, the Balancing Act simulation (https://phet.colorado.edu/en/simulation/balancing-act) allows one to place cartoon-like objects representing different masses on either side of a seesaw at varying distances away from the pivot points. A simple press of a button removes a virtual support underneath the seesaw and reveals whether the seesaw will tilt or balance. A gaming mode option for this simulation offers students the opportunity to test whether they can successfully balance various configurations of a seesaw given only one attempt. The game keeps tracks of successful attempts with a score and progressively increases in difficulty.

Although advantageous in many ways, one challenge with inquiry learning is that students often struggle with certain tasks during an investigation. Woolley et al. [5] describe several common mistakes students can make during scientific reasoning tasks. For example, when designing an experiment, students may confuse independent and dependent variables or fail to control all variables. When predicting results, students may simply rely on prior knowledge rather than drawing conclusions strictly from the data they collected. That is, students often persist in holding pre-existing ideas or beliefs even when confronted with evidence to the contrary. The authors de Jong and van Joolingen [6] classified problems learners encounter during inquiry learning according to the main cognitive and metacognitive processes usually occurring during an inquiry activity: hypothesis generation, design of experiments, interpretation of data, and regulation of learning. The authors emphasized that for learning to be effective these problems must be alleviated. Support, guidance or scaffolding are the general terms used in education research to describe assistance given to learners that simplifies or prescribes the processes required for learning to be successful. A meta-analysis on the effects of guidance in inquiry-based learning concluded that adequate guidance should always be given to assist learners in accomplishing tasks [7]. When adequate guidance is provided, research has consistently shown that inquiry learning is more effective than teaching methods based on more expository forms of instruction [8, 9].

The Go-Lab (Global Online Science Labs for Inquiry Learning at School) learning environment was developed as a free online educational resource to provide teachers with not only a platform to create digital lessons, but also provide pedagogically designed support tools to assist students in the learning process. Support tools in Go-Lab are called apps. The Hypothesis Scratchpad app (https://www.golabz.eu/app/hypothesis-scratchpad) is an example of a Go-Lab app designed to assist students in formulating a hypothesis during an inquiry investigation. Figure 1 shows an example Hypothesis Scratchpad app configured to assist students in forming a hypothesis related to studying the time it takes for sugar to dissolve in water. The app displays a set of words or phrases that the student can drag-and-drop into place to form a complete hypothesis. Although not directly prescribing a hypothesis, the app constrains the selection of terms and suggests possible relationships that one should consider. For a novice learner, the support provided by this app can significantly help to overcome difficulties in generating a useful hypothesis that can be tested later empirically.

More generally, we note that an app which allows a teacher to create a set of words or phrases and have students arrange them into a meaningful order has potential beyond just supporting scientific inquiry learning. The Hypothesis Scratchpad app, if applied appropriately, has potential as a support tool for language teachers.

The aim of the present article is to broadly consider the usefulness of Go-Lab as an all-purpose digital teaching and learning resource. Educators in many nations are increasingly expected to exhibit digital competence [10]. The sudden and abrupt move to a temporary period of online teaching due to the coronavirus outbreak highlights the need for educators to be prepared to delivery digital lessons. The Go-Lab ecosystem offers a practical solution to meet these expectations. Figure 2 shows a screenshot of the main webpage from which a beginner can find information about getting started using Go-Lab.

Although the original motivation for developing Go-Lab was for online STEM (science, technology, engineering, and mathematics) teaching, we will see that Go-Lab actually offers teachers of any subject a practical way to create, organize and share digital lessons. This article is organized as follows. In Section II we describe the basic technical aspects of the Go-Lab learning environment and show how one can quickly get started using it. An important distinction is made between the authoring platform where a teacher puts together different components of a digital lesson and the standalone or student view where a user interacts with the lesson. Section III introduces the Go-Lab inquiry cycle as a pedagogically grounded approach to structuring a complete digital lesson. An example related to the biology topic of natural and sexual selection is used to illustrate this inquiry cycle. Section IV discusses the potential of Go-Lab to support...
the important 21st century skill of collaboration. We present a new type of interactive simulation for developing students’ collaboration skills. Finally, we conclude the article with some thoughts on where Go-Lab may be headed in the future.

II. A Basic Go-Lab Digital Space

A. The Student and Teacher Views

It is instructive to look at a simplified example of a Go-Lab digital space before considering an example of a complete Go-Lab digital lesson. A Go-Lab digital space behaves like an interactive webpage when accessed by students. It is formally called an ILS. The acronym ILS stands for Inquiry Learning Space, but for our purposes it is better to think of it as an online digital space, since from our general considerations an ILS need not be directly related to inquiry learning. Figure 3 shows the student view of an ILS with four phases labeled ‘Introduction’, ‘Guppy Simulation’, ‘Seesaw version A’ and ‘Seesaw version B’. Here the term ‘phase’ refers to the links appearing in the left-hand navigation bar. Clicking on different phases causes the content in the main area of the student view to change. In Fig. 3 the ‘Introduction’ phase is currently active and displays two elements: (i) a text document that begins with the words ‘Hello world!’ and (ii) an embedded video from the online video-sharing platform YouTube. A student or online user can access this ILS by opening the web address https://graasp.eu/s/kehtdb on any internet-enabled device. When the ILS first opens, there is a prompt to enter a login name. Afterwards the login name appears in the upper right-hand corner of the student view. Identification via login names is how the author of an ILS can monitor the activities or progress of users who access their digital space. The view presented in Fig. 3 is called the student or standalone view because it represents what a user sees when they open the ILS. This view is different from what the author sees in the Go-Lab authoring platform.

Figure 4 shows the teacher view for the aforementioned ILS. It displays what an ILS author or coauthors see in the Go-Lab authoring platform, which is called Graasp. We will shortly introduce the Graasp platform in more detail, but for now we just want to highlight how the various elements we previously saw in the student view appear in the teacher view. In the teacher view the four phases are represented as purple colored folders. The title of the ILS is ‘My first ILS’ and is prominently displayed at the top. A green button labeled ‘Show standalone view’ is displayed at the bottom in a panel called ‘Sharing’. Clicking this button opens the student view shown previously in Fig. 3.

So just to repeat, a Go-Lab digital space (or more formally ILS) is created by a teacher or author using the Graasp platform. In this platform a teacher creates and arranges various components together. For example, a science teacher might begin by adding a simulation. Then he or she creates a text document to write instructions explaining how to use the simulation. The teacher also might also want to include questions that can be interactively answered in the ILS. This can be done using the Input Box app. We will soon see an example describing how to use the Input Box app.

After a Go-Lab digital space has been prepared in the authoring platform and is ready for use by students, a link to the student view must be retrieved. This can be done by clicking on the ‘Show standalone view’ button at the bottom of Fig. 4 and copying the url of the web page that is opened. A short link can be obtained using the ‘Get short link’ option underneath the button. Alternatively, to the right of the show standalone view button is an icon that generates a QR code. When students are using smart devices, then distributing links as visual barcodes avoids students having to type in long links and allows them to quickly open a Go-Lab digital space by simply scanning a QR code.

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Fig. 3. A screenshot of the student or standalone view of a Go-Lab ILS with four phases labeled ‘Introduction’, ‘Guppy Simulation’, ‘Seesaw version A’, and ‘Seesaw version B’. Links to these phases are displayed in the left-hand navigation bar. The first phase is currently active and displays text followed by an embedded YouTube video. See https://graasp.eu/s/kehtdb.

Fig. 4. A screenshot of the teacher view for the example ILS presented above in student view. The four phases appear here as purple colored folders. Not shown are two components inside the ‘Introduction’ phase: a text document starting with ‘Hello world!’ and a YouTube video element.
B. The Input Box App for Collecting Student-Generated Data

One of the most useful Go-Lab apps is the Input Box app (https://www.golabz.eu/app/input-box). It enables a teacher to collect text-based data from students. Let us see how this is done.

Figure 5 shows, in student view, the second phase of the example ILS we have been looking at. In this phase the Input Box app has been used to prompt a user for information. The app appears as a rectangular area with the text ‘Type here’ inside it. The app automatically saves the text typed inside it and associates this data with a user’s login name. A teacher retrieves this data in the teacher view of the Input Box app. Figure 6 shows the teacher view after the Input Box app has been opened in Graasp. We see the login names of students, their input data, and a date/timestamp displayed in a table. The Input Box app is a particularly convenient way to collect text-based data from students in Go-Lab.

C. Basic Components in the Go-Lab Authoring Platform

The Go-Lab authoring platform Graasp (https://graasp.eu) resembles a typical graphical user interface in which folders can be hierarchically organized. What one usually considers to be a folder is called a ‘space’ in Graasp. At its most basic level Graasp is simply an online web service in which one can store digital data in the cloud. But Graasp is also a powerful tool to create digital lessons for students, and this is its unique and defining feature. We previously mentioned that an ILS is a particular kind of space in Graasp that is viewable to students as an interactive website. An ILS is distinguished from a regular space by an icon that looks like an ancient Greek temple (see Table I).

It is important to be aware that only an ILS can be viewed in student view. Within an ILS are usually a number of phases. Phases look like spaces in Graasp but are referred to differently because they function in the student view as navigation bar links. Within phases are the core components of a Go-Lab digital lesson (i.e., text, images, files, apps, embedded web content, simulations, etc.).

A teacher has the ability to ‘hide’ phases in Graasp using a menu option (see ‘Menu for a space or ILS’ in Table I). This is a convenient feature when a teacher does not want to display to students all of the content at once. The lesson can then be paced according to a tempo set by the teacher. When the teacher is ready to reveal a phase, he or she unhides it and tells students to refresh their web browsers, thereby revealing it in student view.

More information and even video tutorials for getting started in the Go-Lab authoring platform are available online, and we next discuss how one can access such support material.

D. The Go-Lab Sharing Platform

The Go-Lab sharing platform (https://www.golabz.eu) is a website where one can find resources and support related to creating and using Go-Lab digital spaces. It was originally aimed at helping science teachers find online labs and inquiry learning applications appropriate for their class. Golabz currently lists more than 600 online labs and 45 inquiry apps. In addition, there are more than 1200 digital lessons (i.e., ILSs) listed on Golabz. A teacher can search through and read descriptions of the labs, apps or spaces to see if they can be useful in creating their own digital lesson.

Golabz also offers a support page (https://support.golabz.eu) for beginners to learn how to get started with Go-Lab. There is a glossary explaining the terms and definitions used in Go-Lab, a step-by-step guide, online training modules, and video tutorials. The videos include a detailed look at how to create an ILS and the specific actions one must make in Graasp to add multimedia elements. There is also information on Golabz about ‘Developing an Inquiry Lab’ (i.e., ILS, text, images, files, apps, embedded web content, simulations, etc.).

Learning Space together with a colleague’. Collaboratively creating digital lessons can help motivate teachers who are less confident in their digital skills. For schools that use Go-Lab extensively there is an option to receive additional services and functionality via the Go-Lab Premium Membership. This is one possibility for schools to have their teachers receive training with the Go-Lab ecosystem and learn best practices for using it.
III. The Go-Lab Inquiry Cycle

Inquiry learning is often discussed in terms of a cycle. Learners start with a question, seek and find an answer, and at the end of this process generate a new question which restarts the cycle. The Go-Lab inquiry cycle was developed from a systematic literature review of inquiry processes described in psychology and education research [11]. It consists of five general phases labeled as Orientation, Conceptualization, Investigation, Conclusion, and Discussion. In addition, there are various subphases in some general phases and it is possible to move between phases in different ways.

<table>
<thead>
<tr>
<th>Graphic</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Home" /></td>
<td>Home tab</td>
<td>The “root” or top-most container for viewing all of your Go-Lab spaces.</td>
</tr>
<tr>
<td><img src="image" alt="Joined spaces" /></td>
<td>Joined spaces</td>
<td>Used for viewing the content in your Home directory or within a particular Go-Lab space.</td>
</tr>
<tr>
<td><img src="image" alt="Settings icon" /></td>
<td>Settings icon</td>
<td>Used to change settings in the platform such as your login password or email.</td>
</tr>
<tr>
<td><img src="image" alt="Members icon" /></td>
<td>Members icon</td>
<td>Used to view the users who have logged in to your space and retrieve their data.</td>
</tr>
<tr>
<td><img src="image" alt="Sharing icon" /></td>
<td>Sharing icon</td>
<td>Used to retrieve the student or standalone view link of an ILS.</td>
</tr>
<tr>
<td><img src="image" alt="Grid view" /></td>
<td>Grid view</td>
<td>Visually organizes content into a grid view so that components can be ordered by dragging-and-dropping.</td>
</tr>
<tr>
<td><img src="image" alt="Create item" /></td>
<td>Create item</td>
<td>Enables the creation of new spaces and ILSs. Also enables you to add text, images, links or other multimedia components to an ILS.</td>
</tr>
</tbody>
</table>

**Example space**

**Example ILS**

**Orientation**

**Phase**

**Hidden phase**

**Content name**

**Menu for a space or ILS**

**Standalone view button**

An ILS (i.e., a Go-Lab digital space) can be accessed in student view by clicking on this button.

**Table 1**

**Basic Components in the Go-Lab Authoring Platform**

*Fig. 7. The Go-Lab inquiry cycle consisting of five general inquiry phases: Orientation, Conceptualization, Investigation, Conclusion, and Discussion. There are also several subphases and various pathways for traversing phases. Note that the conclusion of an inquiry can always generate new questions which serve as the start of a new inquiry (hence the term cycle). Adapted from Fig. 3 of Ref. [11].

Figure 7 illustrates the Go-Lab inquiry cycle and its various pathways. The Orientation phase is described as a stage for stimulating curiosity about a topic and leads to a problem statement. Conceptualization involves understanding the concepts belonging to a stated problem and also generating scientific questions and/or hypotheses. The Investigation phase is where students perform a study in a systematic way and gather evidence for testing their hypothesis or answering their question. The Conclusion phase is an interpretation of the evidence. The Discussion phase involves communicating to others about one’s inquiry process or its outcomes, as well as reflecting on one’s learning processes. The Conclusion phase elicits both transformative and regulative learning processes.

Figure 8 gives an example of a complete self-contained Go-Lab digital lesson that follows the five-phase inquiry cycle structure. This example is based around the simulation Sexual Selection in Guppies (https://www.golabz.eu/lab/sexual-selection-in-guppies-html5), which is an online interactive simulation that allows users to recreate the classic experiments performed by the biologist John Endler when he first investigated the balance of natural and sexual selection in guppy fish in the 1970s. Traits which increase an animal’s success in obtaining mates can sometimes decrease their chances at survival. The simulation deals with this evolutionary trade-off. In guppy fish, females prefer to mate with males that have lots of colorful spots. But those males are more easily noticed by predators.
Fig. 8. Layout and screenshots of the Go-Lab digital lesson ‘Is it good to be beautiful?’ (https://www.golabz.eu/ils/is-it-good-to-be-beautiful) designed according to the five phases of the Go-Lab inquiry cycle. Notable design components in this lesson include: 1 – Text document, 2 – Padlet wall, 3 – YouTube video, 4 – Concept Mapper app, 5 – Image file, 6 – Table, 7 – Question Scratchpad app, 8 – Hypothesis Scratchpad app, 9 – Virtual laboratory Sexual Selection in Guppies (https://www.golabz.eu/lab/sexual-selection-in-guppies-html5), 10 – Observation Tool app, 11 – Conclusion Tool app, 12 – Input Box app, and 13 – Input Box app. Four important design components used in this digital lesson have been magnified. Adapted from Fig. 2 of Ref. [12].

The guppy fish simulation allows students to manipulate the strength of female preference for spotted male guppies and the number of predators in the environment to observe what happens to the average number of spots per male guppy over time. We do not have space in this article to go through all of the details of this example Go-Lab digital lesson. It can be previewed at https://www.golabz.eu/ils/is-it-good-to-be-beautiful. We refer to Ref. [12] for additional information. But we would like to point out a few
IV. SUPPORTING COLLABORATION SKILLS WITH ASYMMETRIC SIMULATIONS IN GO-LAB

Collaboration is an important characteristic in today’s workplace as well as in knowledge production. Wuchty, Jones, and Uzzi [14] found that in the past half-century there has been a dramatic increase of publications by teams of two or more authors across all academic fields. The ability to successfully collaborate is regarded as essential in solving the increasingly complex problems society faces.

In order to prepare young people with useful collaboration skills, it is necessary to understand how such skills can be taught and assessed. The assessment of collaborative problem-solving skills was studied by the ACT21S project [15] as well as part of the PISA 2015 study [16]. Both assessments identified that collaborative problem solving involves an interaction between a cognitive dimension (problem-solving) and a social dimension (collaboration). The challenge for the developers of these assessments was to create tasks that reliably and accurately measure these dimensions. Both ACT21S and PISA 2015 arrived at the conclusion that collaborative problem solving involves a condition where a person relies on and learns from another person or persons during the course of solving a problem. The ACT21S project developed what are called asymmetric tasks. These tasks involved computer simulations and are based on the presumption that getting students to collaborate requires that they initially have different information. Researchers studying preliminary ACT21S tasks had observed that “Our students tended not to collaborate on tasks where they and their partners were presented with the same information” [17]. Solving an asymmetric task requires students to collaboratively pool together different information. The term asymmetric derives from the asymmetric distribution of information among collaborators.

Tasks involving asymmetric collaborative simulations are similar to the hidden profile task [18]. The hidden profile task describes a situation in which a decision-making group has been provided with two types of information: shared information that is common to all members of the group and unique information that is initially only available to particular individuals. When the group gets together to begin discussing what decision to make, then if they rely mainly on shared information, a less than optimal decision will be made. In contrast, if the group considers all of the information equally, that is, unique information is shared by individuals to the rest of the group and it is duly considered, then an optimal decision can be reached. Research on the hidden profile task finds that groups rarely choose the optimal decision because they tend to concentrate on mostly shared information at the expense of considering unique information [18-20]. Research also shows that performance on the hidden profile task improves when people are encouraged to communicate any relevant information they have, even if it contradicts the consensus view.

An example task developed by the ATC21S project to assess collaborative problem-solving involved two students working remotely on computers. They could communicate using a text messaging application and they shared a virtual beam balance. However, each student could see and place masses on only one side of the balance. The other side was hidden from view and under the control of the other person. Thus, this task established a condition of interdependence, meaning that the only way the students could balance the beam was by sharing information and coordinating their actions. Johnson and Johnson [21] introduced the term ‘positive interdependence’ to describe a condition where people rely on one another for success. They defined positive interdependence as “the perception that we are linked with others in a way so that we cannot succeed unless they do.”

Similar to the simulations used in tasks developed by the ATC21S project, Go-Lab offers asymmetric collaborative simulations [22]. This type of simulation comes in two variations so that different functionalities are offered to students working in the different variants. Figure 9 shows an example of an asymmetric collaborative simulation called the ‘Collaborative Seesaw Lab’ (https://www.golabz.eu/lab/seesaw-lab). A student in one variation (version) of this simulation is able to place masses on only the left side of the seesaw. But this student cannot balance the seesaw by him- or herself because he or she lacks the functionality to place masses on the right side of the seesaw. A second student working with the second version of the simulation places masses on the right side, but not on the left side. In this way the two students are dependent upon one another to solve the task of balancing the seesaw. Students can exchange masses using a “sharing” box located in the lower right-hand corner of the simulation.

When a Go-Lab asymmetric simulation first opens a student sees an input field labeled “Enter a chat room number” and a “Join”
button. A pair of students who enter the same number in their respective versions of the lab are then able to control variables and see the effects in the same simulation. Assigning different chat room numbers to pairs of students is done by the teacher.

A study by Rannastu et al. [23] revealed that students’ collaboration skills for successfully completing tasks with a Go-Lab asymmetric simulation are weak and require further support and development. Moreover, the sudden move to online teaching due to the coronavirus outbreak revealed that supporting collaboration online is particularly difficult for teachers [24]. New and innovative approaches to digital collaboration may be one way to foster the development of students’ collaboration skills.

V. Conclusion

Go-Lab is a powerful online platform for teachers to create, organize and share digital lessons. Teaching in today’s digital age requires a well-designed organization of digital content and Go-Lab is ideally suited for this task. Although originally aimed at science teachers, Go-Lab enables teachers of all subjects to enhance their teaching with digital content, tools and learning support applications. For this article, the constraints of space limited us to describing the essentials of creating and using digital spaces in Go-Lab, as well as one innovative application for supporting students’ collaboration skills. More advanced uses of Go-Lab, such as teacher co-creation of digital spaces, were not discussed. In a time when online teaching may suddenly become mandatory, it is important that school teachers are able to find a pedagogically grounded digital environment. Go-Lab was developed as part of a European funded education research project and its unique affordances for educators are based on a clear and comprehensive understanding of pedagogy. As more and more teachers begin to realize the benefits of using Go-Lab, we hope that a community of collaboration will develop. As an open educational resource, Go-Lab encourages the sharing of digital resources. The Go-Lab sharing platform (https://www.golabz.eu) currently offers over 1000 contributor-made digital lessons in a range of different languages for free use by anyone. This growing source of open digital lessons is a valuable place where educators can easily find inspiration and ideas, freely remix or adapt digital lessons as they please, and use them to enhance their own teaching.

References

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Handbook on Facilitating Flexible Learning During Educational Disruption: The Chinese Experience in Maintaining Undisrupted Learning in COVID-19 Outbreak

Yihong Shi

Abstract—This paper is an in-depth review of the Handbook on Facilitating Flexible Learning During Educational Disruption: The Chinese Experience in Maintaining Undisrupted Learning in COVID-19 Outbreak. Aiming to investigate to what extent this handbook can contribute to the teaching and learning of countries suffering from the pandemic, this paper analyzes the goal and strategies of flexible learning, which are presented in the handbook. It is concluded that the handbook provided comprehensive knowledge and practical strategies for educators and parents to facilitate learning beyond the restrictions of space and time, and that the handbook demonstrated clear criteria for educators to choose educational tools and resources in order to implement flexible learning. Based on these findings, it is suggested that all stakeholders should consider flexible learning from six aspects: infrastructure, learning tools, learning resources, teaching and learning methods, services for teachers and students, and cooperation between schools, governments, and enterprises. To further strengthen the adaptability of flexible learning, future researches on this subject should pay more attention to the adaption of flexible learning in culturally and politically different context, the assessment and evaluation of learning experiences and outcomes of flexible learning, and teachers’ competency building in the era of flexible learning.

Index Terms—Book review, COVID-19, Flexible learning, technology

I. INTRODUCTION

Due to the covid-19 pandemic, thousands of schools worldwide have closed, where over one billion students could not go back to their schools [1]. Therefore, to maintain education from home, Open and Distance Learning (ODL) have been applied. ODL aims to provide open access to education, by removing learning constraints, such as time and place, and offering flexible learning opportunities to individuals and groups of learners. ODL is one of the most rapidly growing fields of education, and its potential impact on all education delivery systems has been greatly accentuated through the development of Internet-based information technologies, and in particular the World Wide Web [2]. In the same context, several researchers have reported many challenges in terms of adopting ODL by both students and teachers during this pandemic, including lack of ICT skills and online isolation [3, 4].

To address the ongoing covid-19 outbreak and the provided educational responses in crises and emergencies, the Smart Learning Institute of Beijing Normal University (SLIBNU) in collaboration with UNESCO International Research and Training Centre for Rural Education (INRULED) and UNESCO Institute for Information Technologies in Education (IITE) have published the Handbook on Facilitating Flexible Learning During Educational Disruption: The Chinese Experience in Maintaining Undisrupted Learning in COVID-19 Outbreak [5]. Therefore, this study aims to review this handbook to provide insights on how to maintain education in crises and emergencies. These insights could help in preparing readers for future crises.

II. BOOK REVIEW


As the most important notion of this handbook, flexible learning is well explained and elaborated in Chapter 1. Drawing on the theoretical frameworks from Lewis [6], Gordon [7], Ryan and Tilbury [8], and other scholars, this handbook re-conceptualizes flexible learning and pedagogy as a learner-centered educational strategy that can be featured at both individual and institution level. Chapter 2 serves as a transition from concept to practice and contextualizes flexible learning in an online learning environment. The handbook considers online learning as a vehicle to support flexible learning, as it brings along diverse learning tools and facilitates active learning experiences. This chapter specifically introduces the most used online learning platforms and the core elements of supporting “Disrupted Classes, Undisrupted Learning”, an initiative carried out by the Chinese Ministry of Education. With vivid stories and thorough descriptions of the current state of flexible learning in China, this chapter delineates flexible learning as both an innovative concept and an applicable approach.

Chapter 3 demonstrates the importance of the reliable network infrastructure in flexible learning. The chapter lists different scenarios where network infrastructure plays a vital role, including attending video meetings, accessing digital resources, etc. Drawing on the case of a mobile communication operator, this chapter also indicates that government and private sectors should work closely and collaboratively to maintain the continuity of education during the pandemic.

Chapter 4 continues to introduce another important key related to flexible learning. The precise criteria of selecting learning tools is of immense importance for curriculum creators and teachers when it
comes to flexible learning design. It highlights the mixed usage of various tools in aiding communication among teachers and students, managing virtual classes, as well as facilitating students’ cognitive development and collaborative construction of knowledge.

Chapter 5 helps readers walk through the suitable digital learning resources required to implement flexible learning. It notifies readers to evaluate digital learning resources before using them, pointing out that suitable learning resources should meet criteria like licensing, accuracy of content, cultural relevance and so on. Therefore, Chapter 5 prepares teachers and parents to facilitate flexible learning with necessary knowledge in choosing and providing learning resources for children.

Following these chapters, the handbook steers the focus toward the teaching and learning in Chapter 6. This chapter centers the autonomy of students, hence the handbook reiterates the learner-centered characteristics of flexible learning, by providing multiple learning strategies including case study, debate, discussion, student-led discovery, and so on.

Chapter 7 summarizes the support services for teachers and students. What differentiates this chapter from the former ones is that Chapter 7 demonstrates the goals of utilizing the support services for both teachers and students, and introduces the services by presenting substantial real-life examples, where teachers successfully conducted learning activities, designed feedback and assessment systems, and students actively engaged in learning while producing impressive learning outcomes.

The last chapter focuses on the collaborative support from governments, enterprises and schools to ensure the high-quality content, diverse process and effective outcomes of flexible learning. Holding governments, enterprises and schools accountable in this uncertain time is a vital message this handbook hopes to convey. Story by story, Chapter 8 shows that the collaboration between governments and schools, governments and enterprises has contributed greatly to students’ effective learning.

III. READING REFLECTION

While reading this handbook, readers will admire that this handbook not only reports theoretical knowledge, but also practical case studies and vivid stories shared by teachers from different Chinese Universities during the covid-19. These studies and stories can be adopted by other teachers in their contexts to facilitate ODL in times of crises. Additionally, after reading this handbook, the following conclusions can be identified to support education in times of crises.

(1) Flexible learning is one of the common approaches in ODL that can be applied in crises via key elements, namely: (a) reliable communication infrastructure, (b) suitable digital learning resources, (c) friendly learning tools, (d) effective learning methods, and (e) instructional organizations, (f) effective support services for both teachers and learners, and (g) close cooperation among schools, governments, and enterprises.

(2) Teachers and students should pay attention to the quality of learning materials published online, as thousands of resources are published online without knowing the reliability of the publishers/authors. Therefore, they can use several criteria to select the suitable ones, including: (a) licensing: is the resource open-licensed and can be reused by others; (b) ease of adaptability: can the resource easily be adapted (mixed or modified) to different contexts (e.g., PowerPoint presentations can be good resources as they can be easily modified); (c) cultural relevance & sensitivity: educators should choose educational resources that do not report any offensive information to any given race or culture.

(3) Different online instructions, such as collaborative learning, social networks and hands-on learning activities, can significantly enable students to learn, communicate and interact beyond the limitations of space and time, and enormously promote students’ autonomy in learning and constructing knowledge [9].

(4) The learning assessment of students can also be realized during flexible learning in a more effective and flexible way. Project based assessments, such as assessing the written reports or the prepared presentation by students, can be used instead of paper-based assessments to assess the learning performance of students in ODL. Moreover, flexible learning enables teachers to capture the learning traces through real-time computer-based tools, which advances the accuracy of assessments.

(5) To ensure inclusive education as too many students might not have Internet especially in rural and remote areas, flexible learning should not rely only on online mediums but also on offline mediums to deliver courses, such as tele-courses (courses via TV). The courses can be presented both synchronously and asynchronously in accordance with students’ study schedule and pace.

In summary, amid this unprecedented health crisis, a handbook regarding the subject of flexible learning in response to the crisis is much needed in the current literature, given that abundant literature has conveyed the idea that learning should not be disrupted during such emergencies.

To summarize, there are three main highlights that are noteworthy of this handbook. First, it described and classified different learning tools in flexible learning, which caters to different learning scenarios. The handbook presented several popular learning repositories that teachers can visit to find different learning and teaching materials. The criteria to select learning tools and resources provided in the handbook are also useful for practices, in that it is simple and detailed. Second, the handbook introduced a framework [5] that hold society, school, and government accountable regarding flexible learning especially amid emergencies and crisis. For each subject, using simple diagrams, this handbook helped readers identify different priorities. Third, vivid stories presented in this handbook significantly improve readers’ understanding on flexible learning, which can better instruct them to implement and facilitate learning and teaching.

While finishing reading the handbook, some questions can be raised, and need to be answered in order to better serve readers in a global context. As readers may find out in the handbook, the concentrated support from the national government greatly promoted the successful implementation of flexible learning in China. This is due to the characteristics of China’s education system. It’s state-run and little private providers are involved in school sector [10]. The state heavily steers and implements education in such an immense education system through financial subsidies and using laws and regulations. However, to what extent can such strategies be applied to a context where the government cannot leverage resources this easily and quickly? UNESCO’s call to support learning and knowledge sharing through Open Educational Resources (OER) [11] has drawn public’s attention to OER, as it plays a vital role in eliminating the gaps of unequal distributions of educational resources [12]. Hence providing countries that are unlike China with instructions on how to access to and utilize abundant learning resources is important in the sense of expanding flexible learning beyond national borders. Thinking “flexible” from this perspective may enrich the discussion and allow flexible learning to be more applicable.

Additionally, cultural differences should be considered when providing flexible learning to learners. Hofstede [13] pointed out that culture is a crucial factor impacting students’ learning behaviors. The Chinese students’ learning experience and performance may differ
from those of students from other cultures, due to their perception of individualism, power distance, and uncertainty avoidance, which are hugely impacted by the culture they live in. Therefore, in order to implement flexible learning in broader and diverse contexts, besides assuring the content is culturally relevant, how to make the teaching and learning of flexible learning culturally flexible is another path for educators to probe into.

Besides, this handbook did not discuss the impact of the provided flexible learning experiences on the students' learning outcomes. Therefore, more investigation should be conducted to understand how students perceived these learning experiences. Researches [14] have indicated that an online environment may have a negative impact on students’ learning outcomes, including lowering students’ performance and retention of knowledge. How to generate a reliable assessment and evaluation to address these problems emerging in a flexible learning environment remains a major concern for flexible learning.

In terms of emerging technologies, the handbook barely touched on technologies other than Artificial Intelligence, overlooking some other powerful technologies that can be utilized to provide better learning experiences. For instance, Augmented Reality (AR) and Virtual Reality (VR) are frequently discussed to enhance immersive learning [15], which can also adapt to more complicated learning contexts [16].

Last but not least, the handbook does not mention teacher education and preparation in terms of flexible learning. According to a research conducted in China, scholars found that teachers’ utilization of network resources is very low and the advantage of OER is not fully played [17]. Scholars [18] indicated that empowering and building teachers’ competencies in online teaching is vital to promoting teaching quality. Therefore, more information should be provided to enhance teachers’ ability to integrate technology into pedagogical practices in flexible learning.

REFERENCES
Issues in Designing Learning Frameworks for Visually Impaired Learners


Abstract— Learning by Imitation (LBI) is the most natural way to learn a natural language and classic literacy. When LBI is doped with learning by doing (LBD) and learning by memorization (LBM), then this combination help learners to master courses based on arts, science, technology and others. Researchers from pedagogy claimed that teaching strategies used for classroom/online teaching depend heavily on learning style adopted by the learners. But they do not talk about visually impaired learners. This paper highlights some solved as well as some unsolved issues associated with the application of skill-based learning concerning visually impaired learners (VIL). The prime focus of this research is to propose a framework entitled “VIL Framework” which uses LBI, LBD and LBM learning styles and help educators in designing course contents, physical learning games, audio-based learning games, psychomotor skills-based teaching aids, skills-based learning environment and teaching environments for visually impaired learners. The proposed framework includes mock drills as a core component which reflects LBD and LBI. Apart from this, we will highlight some issues on which we are working, and we will be working in the near future associated with VIL's in this research. We believe that the study of this kind help psychologists and educators to design quality educational games, courses contents and learning environments covering different dimensions for visually impaired learners.

Index Terms— Learning By Doing, Learning By Imitation, Learning By Memorization, Visually Impaired Learners, Educational Games, Mock Drill.

I. INTRODUCTION

The art of designing course content and learning environments for non-visually impaired students follows standard frameworks and theories developed around Bloom’s taxonomy [19]. These theories superbly handle parameters like content complexity, depth of knowledge and others concerning non-visually impaired students. Nevertheless, when it comes to designing the same infrastructure for visually impaired students/learners, then these theories fail to achieve their goals. So the modifications in these theories are required for developing contents and learning environments for VIL learners/students.

The content and learning environment designing process for VIL learners heavily depends on natural psychomotor skills possessed by VIL learners. So all contents and concepts must be modeled around teaching aids and instruments specially designed to teach the targeted contents, concepts and skills to the VIL learner’s. The designing principals concerning teaching aids and instruments must focus on learner’s psychomotor skills.

This research presents a framework for designing courses, audio-based learning games, learning tools, learning systems and environments for VIL learners. The complete detail of this framework, named VIL framework, is given in section III. The proposed framework can be viewed from two points of views, namely (a) VIL learner’s point of view and (b) course designers and educators point of view. These two views or perspectives help readers to understand the core crux associated with the learning environment design concerning VIL learners. These views are discussed in detail in section III.

Further, in section IV of this paper, we discussed the use of the proposed framework for designing the solution to self-first aid problem concerning visually impaired students. This section gives an insight to readers and collaborators regarding our expectation. In the very same section, we listed some other sample problems on which we are working. This highlights our expectations concerning framework, system, instruments and other learning environment designs for VIL learners. Through this research, we ask collaborators to develop (a) frameworks, (b) course content designing guidelines, (c) audio-based learning games, (d) learning systems and (d) other tools for VIL learners which help them to learn and shape their skills in order to live a better life.

II. RELATED WORK

The pedagogical issues associated with the development of educational audio games, physical games, and mock drills concerning VIL learners are critical. Online educational game designers pay nearly no attention for the development of games for VIL. Several HCI researchers are trying to make guidelines for designing audio-based games [1-9] for regular players. However, the guidelines they proposed can be extended concerning design issues related to VIL’s. On the other hand, researchers from the field of psychology are trying to understand the impact of game-based learning on overall mental and psychological development for the students. These psychologists do not genuinely concern issues related to VIL learners. On the other hand, many researchers tried to develop methods and approaches for collaborative play between VIL and non-VIL students [10]. They also showed that coordination between non-VIL and VIL learners helps in the development of learning echo-system, which helps VIL learners to shape their skills. Their study further showed that such interaction has a strong positive psychological effect on VIL students [11-14]. Many researchers also talked about pedagogical aspects concerning VIL learners [15]. They presented several theories and conceptual frameworks which help in the improvement of teaching and related pedagogical issues concerning VIL learners. We also developed several frameworks for non-VIL learners. The modified versions of these frameworks can easily be used for VIL learners [16-18].

Researches done based on Bloom’s taxonomy [19-21] allow offline as well as online educators to design effective systems for non-VIL learners. However, these researches fail to design the same systems for VIL learners. Hence, they require up-gradation and fine-tuning so they
can easily model real needs for VIL learners.

III. THE VIL FRAMEWORK

The art of teaching depends on learning styles adopted by learners/students. This theory works perfectly well for teaching non-VIL learners but fails when learners are visually impaired. Instead of the single, simple and standard way of teaching, the VIL learners requires a dynamic, innovative and effective way of teaching. VIL learners are sophisticated towards psychomotor skills. Hence requires designing of the learning exercises, which involves the use of psychomotor skills. All course instructors must design their course contents using teaching aids which somehow relates to psychomotor skills concerning VIL learners.

This section presents the VIL framework. This framework help educators and course designers to design courses, psychomotor skill-based teaching aids, learning games, learning environments and other learning systems for VIL learners. The proposed framework (see Figure 1) contains eight essential elements, namely LBD, LBM, LBI, VIL learners, Instruments, Algorithm, Instructions and Mock Drill. In figure 1, the stepwise flow is represented by black lines and conceptual flow by bold orange lines. When we follow the stepwise flow, then the starting point is instructions. Otherwise, when we follow logical/conceptual flow, then the starting point can either be instructions or algorithm or instruments. The complete framework can be viewed from two points of views, namely (a) VIL learners point of view and (b) course designer and educators point of view. We will be discussing both views of points in this section.

A. VIL Framework from the VIL Learners point of View

From the VIL learners point of view, stepwise flow is considered the best. According to this point of view a course, exercise, game, learning environment and other learning features designed using this framework help VIL learners to learn new things. The learning process starts by using LBM style to learn some basic instructions concerning the targeted task, followed by LBD and LBM to understand the application of instructions on instruments/teaching-aids. These instruments help VIL learners to execute some critical tasks. Once learners are exposed to instruments and trained accordingly, then LBM is used to teach them the process/algorithim which uses instructions and instruments to accomplish the targeted task. This allows learners to get a clear conceptual view of the procedure to accomplish the targeted task. Then LBD and LBI styles are used to train students using mock drills. Doing so induces practical problem-solving patterns in VIL learners.

B. VIL Framework from the Course Designers and Educators point of View

The VIL framework from the course designers and educators point of view consists of strongly coupled modules, namely (a) instructions, (b) algorithm, (c) instruments and (d) mock drill. The VIL learners can start the learning process using learning styles as shown in figure 1, from either module (a), (b) or (c) then once all three modules are covered (as all three modules are interconnected) then only the final (d) module is covered.

This view treats each module as an independent unit having high coupling among them. This allows course designers and educators to independently design course content and concerning policies for the modules mentioned above. Then the course content and policies are coupled with each other using coupling elements. The pedagogical tools help in designing coupling elements.

IV. SELF-FIRST AID DRILL FOR VISUALLY IMPAIRED STUDENTS AND OUR EXPECTATIONS FROM COLLABORATORS

During COVID-19, when my country India was locked down, we faced first aid related issues in visually impaired students living in private hostels. Due to the scarcity of human resources, these hostels failed to provide night attendants. Due to this, when many visually impaired students suffered from health problems like fever, headache, loose motions and indigestion at night, then there was no one to give them first aid. This section discusses how we solved this problem of first aid at night.

To overcome this problem, we used the proposed VIL framework. First, we designed an instrument which is a Braille script encoded medicine box. This medicine box contains four sections, and each section contains three sub-sections. This box can hold four basic types of medicines for four common health problems, namely fever, headache, loose motions and indigestion. The first subsection of each section contains medicine name, its use and dose details written using the Braille script. The second subsection of each section contains the allopathic medicine, and the third subsection of each section contains the equivalent Ayurvedic medicine.

Then we trained each student to measure the rough intensity of fever using pulse rate. Then we taught them how to use the box and medicines. The 4 Ayurvedic herbs placed in the third subsection are of different aroma and taste. We intentionally did this, so visually impaired students who do not know Braille script can take correct Ayurvedic medicine or equivalent allopathic medicine by tasting Ayurvedic medicine.

Then we trained each student concerning the use of the medicine box, the art of measuring fever through pulse rate, and procedure to take correct medicine. After the accomplishment of training, a mock drill was conducted to clarify the concept and complete procedural protocol associated with the self-first aid problem to the visually impaired students. This is how the problem of self-first aid is solved. We want to solve several problems associated with visually impaired students. The highlights of these problems are as follows.

We want to develop procedures and frameworks for teaching Braille script and associated Braille based classic literacy to VIL learners in their native language. We want to do this because India has
more than 22 official spoken languages. Moreover, 19500 unofficial languages and dialects are spoken by Indians. So developing guidelines for assigning Braille codes for all native Indian languages helps VIL learners to learn in their native language.

We further want collaborators to suggest some changes in government policies, forms and procedures which help visually impaired person to perform complex daily life tasks like banking, railway ticket booking, accounting, and others without depending on another person.

Our co-author Mr. Akash Verma suggested one such policy change concerning Indian voting system. This change allows visually impaired voters to vote without any attendant. We encourage collaborators to come up with more such innovative ideas.

We are also working on gadgets and their training procedures which allow the visually impaired person to do clerical work in offices. This helps them to become socially active and earn their living. We welcome ideas which make the life of visually impaired person easy, happy and socially active. We are doing this work for the service of humanity and want our collaborators to collaborate with us with the same spirit.

We welcome researchers, students, teachers and other stakeholders of society to give their valuable ideas concerning the development of systems and policies for helping visually impaired persons.

Fig. 2. Showing the expected workflow from the collaborators.

Now let us discuss the workflow which we are expecting from our collaborators to follow. Figure 2 pictorially shows the complete workflow. We want our collaborators to come up with innovative ideas concerning VIL learners. Then we want to conduct a discussion concerning two aspects as follows.

(a) The set of advantages VIL learners gain from the proposed idea.

(b) Number of user stories derived from the proposed idea.

Then based on aspects mentioned above, user stories will be prioritized in the form of a list known as story list. Then one user story (i.e. story with the highest priority in the story list) is taken at a time, and prototype system/product/policy concerning the selected user story will be fabricated for the same.

Then we will be conducting mock drills using VIL learners in order to obtain feedbacks concerning fabricated prototype. On analyzing feedbacks if they meet the requirements of the VIL learners, the next user story is taken into account. Otherwise, we will refine the designed plan and do changes in the designed prototype accordingly. The VIL learners will be validating the changes done in the prototype using mock drill-based testing.

This process is repeated until all user stories in the story list are not considered, and the resulting final prototype which satisfies the needs of the VIL users is not achieved.

Then using the final prototype, the final system/product/policy is crafted, and final mock drill is conducted. Then the final system/product/policy is given to the VIL learners for use and maintained/refined as per need.

V. CONCLUSION

In this paper, we talked a lot on different types of learning’s and their role in choosing appropriate teaching style. We discussed that standard learning theories fail to fulfill their goals when learners are visually impaired. So standard theories must be tuned concerning VIL learners. Considering this in mind, we proposed a framework named VIL framework. This framework helps content designers and educators to design learning systems for VIL learners. These learning systems include audio-based learning games, psychomotor skills-based training instruments, course contents, learning policies, learning processes and others.

After discussing the core elements of this framework namely (a) LBI, (b) LBD, (c) LBM, (d) Instrument, (e) Instructions, (f) algorithm and (g) Mock Drill, we showed an application of this framework for solving the self-first aid problem. Then we presented our point of view concerning future work and our expectations from the collaborators. To present our expectations, we explained some scenarios and highlighted work done by our co-author Mr. Akash Verma to accomplish our aim.

We genuinely believe that the highlights given in this research help future researchers to come up with very effective frameworks, audio-based learning games, learning policies, learning procedures, learning tools, learning instruments and gadgets for VIL learners. This help visually impaired person to live a socially active, self-sufficient, self-motivational, confident, mentally stable and independent life.

We welcome researchers, students, teachers and other stakeholders of society to give their valuable ideas concerning the development of systems and policies for helping visually impaired persons.

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Taiwan Pedagogy and Practice in Technology-Enhanced Language Learning Association and PPTELL 2021
(28-30 June 2021)

Yu-Ju Lan, Kao Chia-Ling Gupta

I. OVERVIEW
Taiwan Pedagogy and Practice in Technology-Enhanced Language Learning Association (PPTELL Association) was founded in July 2020 with Prof. Yu-Ju Lan as the first Chairman and Prof. Meei-Ling Liaw as the first Vice-Chairman. It aims to promote the collaboration between researchers in the fields of Technology-Enhanced Language Learning (TELL) and Computer-Assisted Language Learning (CALL) for the purpose of making a greater contribution to the research in the globe.

II. HISTORY AND DEVELOPMENT
The PPTELL Association originated from one of the nine Special Interest Groups under the Division of Information Education, Ministry of Science and Technology—The Technology Enhanced Language Learning Special Interest Group (TELL SIG). TELL SIG was established by Prof. Kuo-En Chang in 2007. Over the past decade, it has recruited members not only from Taiwan but also from Singapore, Hong Kong, Macau, New Zealand and Australia. It aims to bring together researchers to examine and solve problems encountered in TELL. With its fruitful research outcomes published in well-known international journals, TELL SIG has remained influential.

In 2017, in order to promote the research outcomes and enhance the impact of TELL SIG, the Chairperson of TELL SIG, Prof. Yu-Ju Lan discussed with Prof. Meei-Ling Liaw and Prof. Nian-Shing Chen and confirmed the following three areas to work on: (1) boosting Taiwan’s academic synergy in the fields of TELL, (2) closely connecting with communities outside of Taiwan, (3) promoting Taiwan’s academic influence in the world, and (4) allying with the other TELL communities to develop opportunities for international collaboration.

III. PREVIOUS PPTELL CONFERENCES
Up to now, three PPTELL conferences were held. At that time, before the Association was formed, the first PPTELL Conference 2018 was held at National Taiwan Normal University (NTNU) Heping campus, and then the second in 2019 at NTNU Linkou campus, and the third in 2020 by NTNU in collaboration with University of North Texas (UNT), U.S.A. Thanks to the funding from the Ministry of Science and Technology and Office of Research and Development, NTNU, these conferences were held successfully.

The themes of each PPTELL conference aim to realize the contemporary requirement of competency-oriented and contextualized language learning. Modern technologies have been used to inspire unlimited innovations. Thus, in line with the rising trends mentioned above, since 2018, the PPTELL conferences have connected researchers, educators, and the front-line teachers to have conversations on the huge potential of integrating language learning theories and advanced technologies for cultivating learners’ critical competencies for pursuing success in the 21st century. Rich and diverse topics were presented and discussed in PPTELL conferences 2018, 2019 and 2020, including smart learning environments, AI, robotic technology, augmented/virtual reality, big data, mobile computing, and educational games.

Most notably is the third PPTELL conference held during the COVID-19 pandemic. Unlike the first and the second ones, PPTELL 2020 was conducted solely online, with the great support of many researchers and scholars, marking a breakthrough in the face of challenges when many were bound by time and space. Thus, similar to the previous PPTELL conferences, PPTELL 2020 received a notable success. Following the third PPTELL conference comes the fourth, which will be held in 2021 in a hybrid mode. It will be co-hosted by PPTELL Association and Chinese Language and Technology Center, NTNU. The details are listed in the following section.

IV. PPTELL 2021
PPTELL 2021 sincerely invites abstract submission that shows originality based on theoretical or practical works focusing on global connectivity in technology-enhanced language learning with the topics related to the theme—Contextualized multimodal language learning (CMLL).

The PPTELL 2021 conference features three types presentations: Oral presentation, Poster presentation, and Technology showcase. A submitted abstract is restricted to 500 words. Prior to submission, please read and follow the conference templates (PDF version / MS Word version) carefully. Submissions must not be published previously. All the submissions will be double-blind peer-reviewed. The review will focus on whether the work is original and is of good quality through theoretical and empirical methods. Below are the important dates of PPTELL 2021 conference.

- Deadline for Abstract Submission: February 20th, 2021
- Notification of Abstract Acceptance: March 15th, 2021
- Deadline for Early Registration: April 15th, 2021

For questions regarding this submission, please contact PPTELL 2021 at pptell2021@gmail.com.

We look forward to seeing you at PPTELL 2021.