Does learner mindset matter while learning programming in a computer-based learning environment?

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***Abstract*—Computer programming has gained significant attention in recent decades. However, concerns persist regarding students' learning outcomes and success rates in programming courses. It is established that learner interaction influences learning outcomes in a computer-based learning environment (CBLE). Many factors influencing learning interaction with a CBLE have been analysed in this context, except the learner mindset. The term "learner mindset" refers to an individual's beliefs regarding the potential for their abilities to change and improve. Those with a fixed mindset believe their abilities are set in stone, whereas individuals with a growth mindset believe learning can enhance capabilities. This study examines how different learner mindsets (fixed versus growth) affect interaction patterns in a computer-based learning environment (CBLE) designed explicitly for teaching Python programming. We collected the log data along with learners' self-report to mindset questionnaire. We aim to identify learners' interaction patterns and behaviour by analysing log data and utilising process-mining techniques. Based on their reported mindsets, we have reported the differences in the behaviour of learners' interaction patterns within the CBLE observed.**

***Index Terms*—Learner mindset, learner behaviour, learning path, process mining for learning behaviour**

I. Introduction

Over the past few decades, computer programming has garnered significant attention due to its potential to foster vital skills such as logical thinking, problem-solving, creativity, and technological advancements [1], [2]. Despite the surging demand for computer programming skills, concerns persist regarding learning outcomes and student success rates. Aho and Lanski argue that traditional computer science education does not prepare students for workforce success [3]. This causes significant concern for computer science educators worldwide. Moreover, understanding why students fail in computer science education research remains a crucial issue in computer science education [4]. Developing an inclusive and effective learning environment to teach introductory programming courses so that dropout rates and learner performance improves remains a problem in CS education [5], [6].

Factors such as student self-efficacy [7] levels of readiness and computer literacy [8], age and ethnicity [9], learning styles [10], cultural diversity [11], social interactions with peers [12] etc. have been reported to influence students' interaction with the learning environment. Increased learner interaction with the learning environment has been reported to result in positive learning outcomes [13]. Through classroom-based studies, it has been shown that learners with different mindsets behave differently while learning [14]–[18]. But learners' mindset has not yet been investigated in this context for computer-based learning environments.

It is established from the literature that learners' interaction with the learning environment and other students plays a crucial role in improving learning outcomes [13], [19]–[22]. Therefore, investigating the factors influencing learners' interaction is considered highly important. However, there is a paucity of research investigating the difference in the interaction behaviour of learners of a different mindset in a computer-based learning environment. To fill this lacuna, we propose to look into the following research goal- 'To assess the effect of learners' mindset on their behaviour in a computer-based learning environment.'

There are two mindsets based on beliefs in abilities - one with fixed abilities that must be demonstrated and another with abilities that can be developed through learning [23]. A person's mindset decides motivation and actions while learning, influencing learner behaviour. This, in turn, can influence learning programming skills. A growth mindset, which is the belief that skills and abilities can develop through

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hard work, trying challenging things, learning from failure, and adjusting strategies to accomplish goals, can help students succeed in programming. Students with a growth mindset tend to see mistakes as a chance to grow and seek out challenges to improve themselves. This mindset can help students develop problem-solving skills essential for programming.

For this research, we used the PyGuru- a computer-based learning environment [24] to collect the data from 38 first-year undergraduate students. Students responded to the mindset questionnaire [25], [26] and the demographic survey. We applied descriptive and diagnostics analytics to highlight the differences in the interaction behaviour of fixed and growth mindsets learners. The results show that individuals with a Growth mindset pay attention to the information that can help them expand their knowledge. In contrast, individuals with a fixed mindset aspire to effortless perfection and get discouraged by failure. Similarly, individuals with Growth Mindset are not afraid of failures but look forward to learning. Contrary to this, individuals with a Fixed Mindset give their best in assessments and aim to achieve higher grades.

The paper is organized as follows: In Section II, we discuss related work, and in Section III, we provide context for the data. Section IV describes our methodology, including the prepossessing of click stream data, and we present our results in Section V. Finally, we conclude in Section VI.

II. Related Work

In order to understand the basis of our work, in this section, we first describe the term "Mindset" and then provide the details about the various studies done around this construct. We also discuss various techniques for analyzing learner behaviour in CBLEs reported in the literature.

A growth mindset is a belief that personal characteristics, such as intellectual abilities, can be developed, and a fixed mindset is the belief that these characteristics are fixed and unchangeable [26]–[29]. Research on these mindsets has found that people who hold more of a growth mindset are more likely to thrive in the face of difficulty and continue to improve, while those who hold more of a fixed mindset may shy away from challenges or fail to meet their potential [26]. In other words, based on the beliefs in abilities, two kinds of mindsets exist - one with fixed abilities that need to be proven and the other with changeable abilities that can be developed through learning [23].

The difference in Table I indicates that people with growth and fixed mindsets have different behavioural dynamics. Students with a Growth mindset have reported better performance [30]. While the influence of domain is stronger for undergraduate students, the mindset differs for different subjects. For complex topics, primarily STEM subjects, the mindset tends to shift from growth to a fixed mindset [18]. In programming where problem-solving and tackling errors (Both logical and syntactical errors) are important while achieving a certain level of mastery [31], [32]. Kench et al. 2016 reported no significant correlation between learners' performance and their mindset, but learner mindset played a role when learners developed their

TABLE I
Difference between Fixed and Growth Mindset (based on Dweck, 2017)

	Fixed Mindset	Growth Mindset
1.	The belief that your abilities cannot be changed	The belief that your abilities can be developed through learning new things
2.	Individuals with a fixed mindset are generally only interested in the feedback concerning their abilities	Individuals with a growth mindset pay attention to the information that could expand their knowledge base
3.	Individuals with a fixed mindset believe that if someone needs to work hard for something, they must not be good at it	Individuals with a growth mindset believe that even geniuses have to work hard for their achievements
4.	Passing the chances for learning, shying away from something which requires effort, and easily getting discouraged by failure	Learning from failure happens; continuous efforts are taken whenever challenges are encountered
5.	They aim to give their best in the assessment and achieve higher grades	They find success in doing their best, constantly learning and improving themselves

problem-solving strategies [33]. Learning strategies learners employ can better understand if we analyze learners' behaviour or actions in a learning environment.

To comprehend how learners engage with the CBLE, various analytical and mining techniques can be utilized [34]. By analyzing the temporal connections between actions taken by high and low-performing learners, discrepancies can be highlighted, identifying areas where learners may require additional support or scaffolding [35]. Two methods commonly employed for such analyses are Sequential Pattern mining (SPM), Differential Sequence Mining (DSM) and Process Modelling (PM). SPM gives us emerging patterns from the ordered actions performed by the learners. SPM gives us the sequence of meaningful actions out of all the actions of learners from log data [36]. While DSM focuses on revealing less common and distinct behaviour patterns exhibited by different learner groups [37], PM involves organizing all the learner actions in a temporal sequence, which can be interpreted as the learners' problem-solving model over time [35]. Visualizing learners' action sequences through PM can help illustrate the actions performed by learners while learning introductory programming and try to solve the programming assignment problems. As PM considers the individual learners' log data in its entirety, it can give a comprehensive view of learners' actions in contrast with the SPM and DSM techniques which focus on the subset of the actions performed by the learners. Many studies have reported using process mining to understand learning processes in CBLEs better [35], [38], [39].

Literature has been scarce on the role of the learner mindset in affecting learner behaviour in the CBLE. This makes a compelling case to consider the study for understanding the influence of learner mindset on learner's actions in CBLE.

To gain insights into the learning path opted by the learners with different mindset use of Process Modelling as an analysis technique will be useful.

III. Learning Environment

PyGuru is an interactive computer-based learning environment that aims to facilitate the learning and teaching of Python programming skills. PyGuru comprises four key components: a book reader, video player, code editor, and discussion forum. Learners interact with these elements in various ways. We have captured these learner actions in the log data. Description of these actions in detail and corresponding entries in the log are discussed below.

The book reader component of PyGuru, as depicted in Fig. 1, allows learners to read (Read) and annotate digital text. Highlighting text involves selecting a section of the text and adding colour to it (Highlight). The annotation feature allows learners to comment on the text and attach tags for better organization (Annotate). The video player component of PyGuru, as shown in Figure 1(b), provides an interactive video-watching platform for learners. Learners can use basic video player features such as play, pause, seek, and speed enhancement (Play, Pause, Seek video). In addition, instructors can embed questions into the videos, which pause the video and wait for learners to respond (Video Question attempted). The code editor component of PyGuru is crucial for learners to practice coding. PyGuru offers two kinds of code editors to facilitate learning. The first code editor is embedded into the book reader to allow learners to practice coding immediately after learning about the concept. This code editor includes a coding window and an execute button. As depicted in Figure 1(c), the second code editor is more advanced and used to assign programming questions to learners. It evaluates the learners' code against test cases and allows learners to verify their program for errors and test cases before submitting (Verify). This code editor comprises four panels, including the instruction panel, input panel, coding panel, and output panel. Learners can verify their code against the test cases, view errors, and check the messages (See errors, View messages).

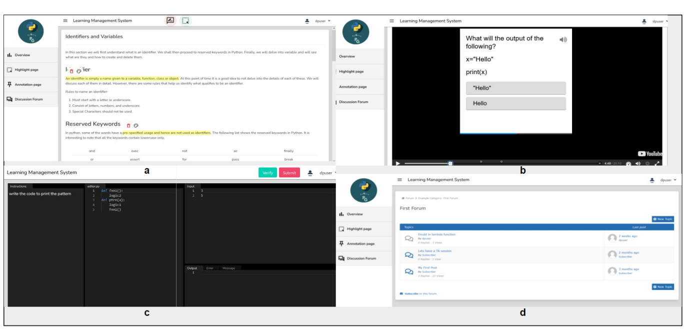

Fig. 1. PyGuru Environment (a) Book Reader (b) Video Player (c) IDE (d) Discussion Forum.

IV. Research Questions

For this paper, we had the following broad research goal: *"To investigate the effect learner mindset has on learner interaction while they interact with CBLE to learn computer programming."* This led us to the following research question:

- RQ1. What are the differences in the number of actions performed by learners with different mindsets in a CBLE for computer programming?
- RQ2. What are the different interaction strategies or learning paths in a CBLE for computer programming for cohorts of learners with different mindsets?

V. Study Design

The study was conducted with first-year undergraduate students enrolled for the Bachelor's in Information Technology course between 18-19 years. All the students interacted with the CBLE for 2 hours daily during the two days in the workshop-like mode. We followed a volunteer sampling process and conducted the study with students who responded to our call for participation in the workshop for learning Python through Introduction to Python workshop. All participants were enrolled in a Bachelor's program in Information Technology and provided informed consent to participate in the study, which was approved by the Institute Ethics Committee (IEC). The learners' participation did not impact their assessment and/or grades of their course, and no monetary compensation was provided. Participants were asked to respond to mindset questionnaire, demographic survey. In addition, the study collected log-interaction data from PyGuru for two sessions and administered a pre-and post-test to assess the programming knowledge of the participants.

We used the questionnaire developed by Dr Dweck [25], [26], [40] to get information on their mindset. This questionnaire is validated and accepted as a valid instrument to measure the mindset in adults [40], [41]. Therefore this short questionnaire was chosen as an instrument for this study. The questionnaire has statements about one's intelligence. Everyone differs in their ability to understand complex ideas, learn from experience, adapt effectively to the environment, and engage in reasoning to overcome obstacles and solve problems. This ability is often referred to as "Intelligence". Intelligence encompasses attention, memory, perception, planning, etc. [42]. Mindset is measured concerning this definition coined by the American Psychological Association through the report on 'Intelligence.' The questionnaire asks whether the person agrees or disagrees with those statements. It uses a 6 - point scale from 'Strongly agree' (6) to 'Strongly disagree'(1) to measure how much the respondents agree or disagree with those statements. The score was calculated by adding the numbers corresponding to the option selected by the respondent and dividing it by the number of questions. The respondents scoring less than 2.75 were classified as learners with a Fixed Mindset, and learners with a score greater than 3.25 were classified as learners with a Growth mindset.Total 42 students responded to our call for participation. Out of which, 15 have a Fixed Mindset (39.5%), and 23 have a Growth Mindset (60.5%). There were 4 students had mindset scores between 2.75 and 3.25, so their data was not considered for the analysis and hence not reported and our sample size for analysis was 38 students. Cronbach's Alpha was calculated for the mindset score of the learners, and it was to be 0.731, which is greater than 0.5 and hence acceptable. This was decided based on their responses to the questionnaire.

The study included a demographic survey that obtained information on the participants' age, gender, and proficiency with various programming languages and a survey on student mindset. The sample included a balanced representation of gender, with 18 females and 20 males. All the students reported to have no prior programming experience with Python and identified as 'beginners'. Although peer interaction was not restricted, it was observed to be related to queries regarding difficulties in log-in to the CBLE. Hence was not noted. Instructor interaction was also limited to the directions to log in and logistics of pre and post-tests.

Based on the student's responses to the self-report questionnaire, we divided the students according to their mindset based on their mindset score. This metric was used to divide the log data as well. We analysed the log data for the frequencies of various actions taken by learners. The log data of learners with a fixed mindset and those with a growth mindset were processed separately to create the process model.

TABLE II
AVERAGE COUNT OF ACTIONS PERFORMED BY THE LEARNERS WITH GROWTH MINDSET AND LEARNERS WITH FIXED MINDSET.

Actions	Average Count (Fixed Mindset learners)	Average Count (Growth Mindset learners)
Count of learners	15	23
Average of total actions	83.13	81.96
Average of Total time	0.05	0.08
Average of Execute (In-page IDE)	25.64	25.52
Average of avg act per session	28.63	31.34
Average of execute for programming assignment	1.2	2.13
Average of Assessment	2.47	2.48
Average of Verified	1.47	2.48
Average of See Errors	0.2	1.13
Average of success frequency	8.6	10.17
Average of error frequency	16.4	17.39
Average of Reading	13.2	12.04
Average of Video watching actions	6.8	6.13
Average of Pause Video	1.07	2
Average of Play Video	1.6	2.43
Average of Continue - Video watching	0.27	0.61
Average of invideo question attempted	1.67	0.91
Average of Quiz	1.6	0.52

VI. Results and Discussion

In this section, we present the differences in the actions performed by learners with Growth Mindset and Fixed Mindset while using the CBLE to learn Python programming. The discussion based on the average action counts for learners with Growth and Fixed mindset is followed by the discussion on process models generated using learners' log data.

A. Quantifying Learners' Actions

In this sub-section, we present the differences in the actions performed by learners with Growth Mindset and Fixed Mindset while using the CBLE to learn Python programming. We analysed the data by counting the frequencies of various actions performed by the students and attempted to answer RQ1. The frequency of different actions for both groups (fixed and growth) is presented in Table II. The data analysis showed that the learners with the Fixed mindset have a higher average for the count of navigational actions like - Reading, Videos compared to those with the Growth mindset (Refer to Table II). However, even with the greater count of clicks for videos, learners with a Fixed mindset have fewer click counts for Paused, Play, and Continue_video (while attempting the in-video questions). Such actions of "Paused", "play", and "continue_ video" indicates active video-watching behaviour and are linked to deeper engagement [43]. This is supported by the general characteristic of people with the Growth mindset that individuals with a growth mindset pay attention to the information that could expand their knowledge base [23]. Interestingly, learners with a Growth mindset frequently checked errors they encountered while executing their Python codes in the assessment component. Even though the average error frequency was higher for learners with a Growth mindset, the average success frequency was also higher. This suggests that learners with a Growth mindset tried to rectify the errors they encountered while testing their codes, which indicates their focus on developing themselves. Individuals with a Growth mindset pay attention to the information that could expand their knowledge base. People with fixed mindsets aim to give their best in the assessment and achieve higher grades [23]. This is supported by the frequency of attempting the quiz and answering the in-video questions. For learners with a Fixed mindset, the average number of times the quiz (1.6) was attempted is higher than that of the learners with a Growth mindset(0.52). The average number of in-video questions attempted is 1.67, and the average number of correct answers is 1.2 for learners with a fixed mindset. While the average number of in-video questions attempted is 0.91, and the average number of correct answers is 0.57 for learners with a Growth mindset. The average learning gain observed for the students with the Fixed mindset (0.933) was higher than that of students with the Growth mindset (0.652).

Our findings suggest that learners with different mindsets have performed different actions (Table II). Even though learners with a Fixed mindset spend more time clicking on content pages, they spend less time in the CBLE. The average error frequency and the number of incorrect answers are not very different for both cohorts. Still, looking at errors is observed mainly in learners with a Growth mindset. Not so

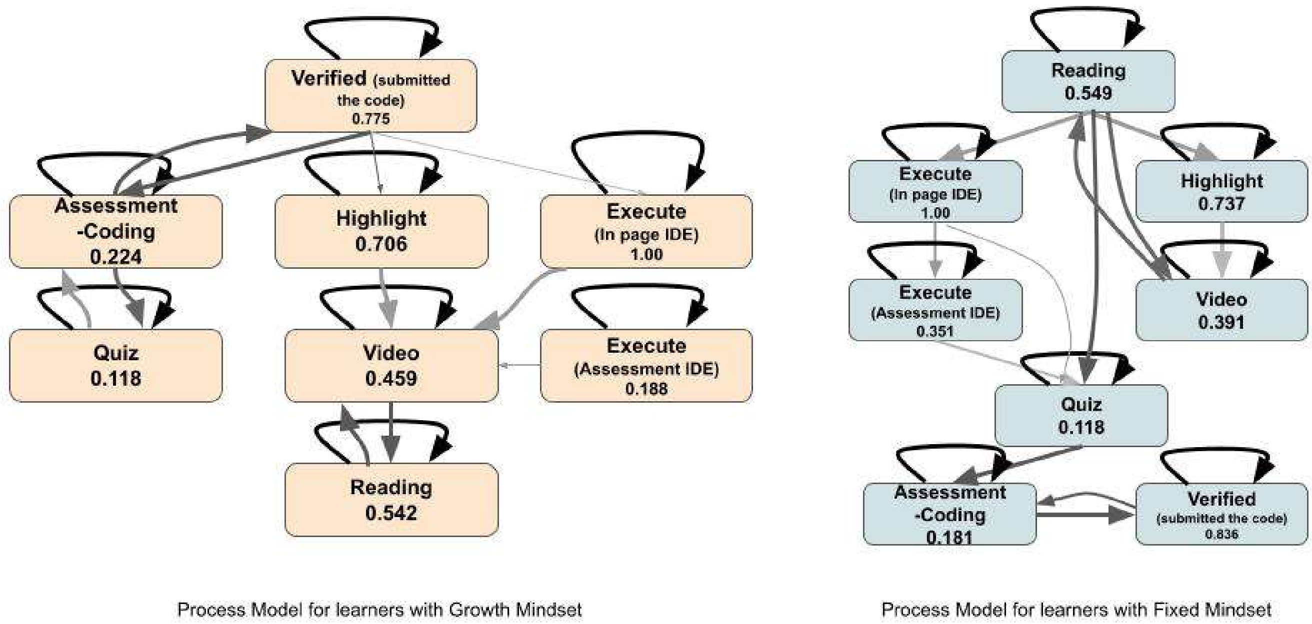

Fig. 2. The Process Models for Learners with Growth Mindset and Fixed Mindset.

surprising that the frequency of running the program without errors is higher for learners with a Growth mindset. Since no statistically significant difference was observed for the average action=4 counts for both cohorts, we analysed the log data to investigate the difference further. The same is discussed in the following subsection.

B. Learners' Process Models

We used the log data to create the temporal pictorial depiction of the action sequences performed by the learners in PyGuru. We tried to find answers to RQ 2 using process models for learners with a Growth Mindset and a Fixed Mindset. Process Models (PM) will give us a comprehensive view of actions performed by the learners. PMs will help us understand the learning path or strategies taken by learners with fixed and Growth mindsets. The details of the same are discussed in this section. The log data was used for ProM Tool- an open-source process mining tool (https://www.promtools.org/) to make the process models using the Fuzzy mining algorithm. The parameters for all the process models were - node cut-off = 0 (to keep all the nodes/actions) and utility ratio = 0.5 (to give equal weightage to significance and correlation). In all the PMs, the node represents the actions performed by learners, and the edge represents the transition from one activity to another. Each node has a significance value (between 0 and 1), and each edge has thickness indicating significance, while darkness depicts the correlation [44].

Figure 2 shows the process models for learners with the Growth Mindset and learners with Fixed Mindset. The node of "Execute," which corresponds to the execution of the code via the in-page IDE window, has a significance of 1 for both the cohorts - learners with the Growth mindset and learners with the Fixed mindset. The common action sequence for both groups is Quiz $\rightarrow$ Assessment $\rightarrow$ Verified.

But learners with a Growth mindset have both ways to transition for all three nodes, while learners with a Fixed mindset have only a one-way transition between Quiz and Assessment. In the CBLE, the component of Quiz and Assessment is placed after the content/ topics. Verifying the code is part of the Assessment component, where learners can verify their code against the test cases. For learners with a Growth mindset, the transitions from the most significant node - Execute, is - Execute $\rightarrow$ Videos $\rightarrow$ Reading. All these actions are related to checking the content. Another similar action sequence is observed for learners with a Growth mindset- execute $\rightarrow$ Videos. This transition also corresponds to checking the content. The Reading $\rightarrow$ Videos link is observed for both the learner groups viz—learners with a Growth Mindset and learners with a Fixed mindset. However, the link has stronger significance for learners with a Growth mindset than learners with a Fixed mindset. The action of Highlighting is not observed to be linked with the content navigational actions for the learners with the Growth mindset. However, it was observed to be linked with the content navigation actions for the learners with the Fixed mindset with the sequence

TABLE III
AVERAGE COUNT OF ACTIONS PERFORMED BY THE LEARNERS WITH GROWTH MINDSET AND LEARNERS WITH FIXED MINDSET.

Action sequences for learners with Growth Mindset	Action sequences for learners with Fixed Mindset
execute → Videos → Reading	Reading → Highlighted → Videos
Verified → Assessment → Quiz	Reading → Execute → execute → Quiz → Assessment → Verified
Verified → Highlighted → Videos → Reading	Reading → Quiz → Assessment → Verified
Verified → Execute → Videos → Reading	

as Reading → Highlighted → Videos. For learners with the Growth mindset, it was Verified → Highlighted → Videos → Reading. The differences in the process models for learners with a Growth Mindset and learners with a Fixed mindset can be observed in the unique action sequences observed for each cohort. These differences are shown in Table III.

The prominent difference between action sequences for both cohorts is that learners with a Growth mindset are going back to the content after verifying their codes in the assessment task. At the same time, learners with a Fixed mindset are going to assessment tasks after going through the contents. The cyclic action sequences observed for the learners with a Growth mindset are mainly concerned with the navigation between the assessment components - Coding Assessment and Quiz, which is - Quiz ⟷ Verified ⟷ Assessment. For the learners with a Fixed mindset, cyclic actions were found for the navigation, like - Reading ⟷ Highlight ⟷ Videos. Another cyclic action sequence observed was - Quiz ⟷ Execute ⟷ execute, but this sequence does not correspond to any meaningful click - result and mostly implies random clicks. The different learning paths taken by learners with Growth and Fixed mindset differed from what we had expected. The action sequences in the process models confirmed the observations made for average action counts. The action nodes observed for learners with Fixed Mindsets are aligned with the linear navigation sequence in PyGuru. Whereas the process model of learners with a Growth mindset clearly showed that they verified/ crosschecked the content. Process models clearly showed the different strategies used by learners with different mindsets. The learning strategies observed for learners with a Growth Mindset and learners with a Fixed Mindset are congruent with their characteristics mentioned in the literature [17], [23], [25].

VII. CONCLUSION

We aimed to assess the effect of learners' mindsets on their behaviour in a computer-based learning environment. The results revealed the differences in the interaction pattern of the learners with fixed and growth mindsets using their action counts and process models. Learners with a fixed mindset showed a greater average count of navigational actions, such as reading and watching videos. Still, they had fewer active video-watching behaviours like pausing, playing, and continuing. On the other hand, learners with a growth mindset actively checked errors encountered while executing Python codes, demonstrating their focus on self-improvement. They also had higher success frequencies and engaged in actions like executing, verifying, and reviewing errors. Furthermore, learners with a fixed mindset tended to attempt quizzes and answer in-video questions, indicating their aim to achieve higher grades. In contrast, learners with a growth mindset had lower participation in quizzes and in-video questions but exhibited a focus on content review and checking. Comparing average values per learner gave us insights into their learning behaviour and encouraged us to explore their learning strategies further. The study also identified distinct action sequences and transitions in the learning process for each mindset group using process models. The visual depiction of action sequences clearly showed that learners with a Growth mindset cross-checked the content after attempting the programming assignment and assessment questions. Another distinct learning strategy observed for learners with a Growth mindset was checking the errors and messages while completing the programming assessment tasks. This learning strategy was not observed for learners with a Fixed mindset. We could see the differences in the action counts of the learners with Fixed and Growth mindsets, which meant that they had followed different learning strategies. This was proven with the help of Process Models for learners with Fixed mindsets and learners with Growth mindsets. Process Models based on learners' entire log data gave us a comprehensive view of all the actions performed by the learners. They helped us identify the different learning strategies for learners with Fixed and Growth mindsets.

Acknowledging the limitations of this work because of the small sample size, there is a need for future studies with larger sample sizes. Overall, the findings underscore the importance of understanding learners' mindsets and their impact on learning behaviours. These insights can inform the design of interventions and instructional strategies to support learners in achieving their learning goals in CBLEs. Further research in this area can enhance computer science education by addressing the different needs and preferences of learners with different mindsets. This can potentially result in sustained engagement and better performance in programming courses. Since performance and engagement in the courses are highly correlated with the dropout rate [45], such an improved design of CBLE may even result in high retention rates for CS courses or any course taught using CBLE.

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