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The challenges of pre-calculus in times of change

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ABSTRACT

Sustainable science, technology, engineering, and mathematics (STEM) education rests not only on gender equity in educational opportunities but also on the academic attainment of female students. In Saudi Arabia, women enrolled in engineering and computer science are both newcomers and a minority. The present study compared the performance of female undergraduate students in pre-calculus (a prerequisite for STEM programs) before and after the pandemic. It also examined changes in students' perceived difficulty and value of pre-calculus, the stress experienced in it, and their determination to pursue STEM. In this study, pre-calculus performance declined after the pandemic. Furthermore, the course was perceived as more difficult and stressful, as well as less valuable. Nevertheless, students' determination to continue in STEM was undeterred. After the pandemic, students reported mostly utilitarian motives for pursuing STEM degrees (i.e., career opportunities), and concerns about their ability to balance work and personal lives in STEM professions. The key challenge was a personal issue (i.e., balancing professional and personal lives) rather than a social issue (e.g., the persistent gender imbalance in STEM fields). These findings suggest that interventions supporting intrinsic motivation are key to students' engagement and persistence in academic pursuits and thus to their ability to be academically and professionally successful in STEM.

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1. INTRODUCTION

A disruptive event is an experience that alters an individual's conditions so profoundly to cause a substantial departure from habitual activities and expectations [1]. Its impact may be confined to the micro-level, affecting particular individuals and their immediate entourage, or may extend to the macro-level, affecting large geographic areas and populations. The COVID-19 pandemic can be considered a disruptive event with micro- and macro-level impacts [2], [3]. Within the extant literature, its specific impact on learning in the post-pandemic environment is yet to be clarified. In our work, we take the view that understanding the impact of the pandemic on learning requires that the periods preceding and following the pandemic be compared. At the very minimum, such a comparison allows one to determine the extent to which performance after a return to on-campus instruction replicates that of the pre-pandemic period. Namely, it answers the question of whether the post-pandemic educational environment can be defined as a return to the 'old normal' or as an adjustment to a 'new normal' with uncertain opportunities and challenges. This selective comparison can offer insights into whether students face particular post-pandemic challenges, which can shape interventions intended to promote teaching and learning. In the extant literature though, the bulk of the evidence involves comparisons of performance before and during the pandemic [4]–[7]. That is, the evidence collected mostly reflects students' responses to instructional modality changes (i.e., from face-to-face to online teaching) in a variety of institutional settings. Comparisons of this nature not only have led to mixed findings but also are moot as to whether education attainment has changed after such a disruptive event.

The evidence of comparisons between before and after the pandemic is both mixed and scarce. For instance, Pilotti *et al.* [8] reported that performance in particular general education courses (e.g., written communication and statistics) after the pandemic improved relative to that before the pandemic. Instead, Zheng [9] found a decline in information technology and management (ITM) courses. To delve into this issue, in the present study, we focus on an understudied population of female college students pursuing a degree in the field of engineering or computer science. They are citizens of a country that only recently opened such fields to both women and men. The country is Saudi Arabia. Its programmatic plan, named Vision 2030, has included a restructuring of the entire educational system to promote not only gender equity in education but also curricula and instruction that meet international standards [10]. As a result of offering equal educational opportunities to both women and men, Saudi Arabian women are newcomers in the fields of science, technology, engineering, and mathematics (STEM). In engineering and computer science, they are also a distinct minority [11]. Furthermore, women not only are underrepresented in these particular STEM occupations but also face steep challenges when trying to accommodate personal and family expectations to their professional aspirations [12], [13]. Thus, it is especially important to determine their post-pandemic performance in STEM fields, such as engineering and computer science, to ensure that suitable remedies are introduced if declines are found.

In STEM fields, pre-calculus is the gateway to calculus, which is a requirement for all STEM majors. Thus, we chose this course as an index of whether the performance of female undergraduate students in engineering and computer science changed from the pre-pandemic era. Added to the performance data are opinions about the course, and more broadly their lives in the post-pandemic world. The disparate impacts of the pandemic have been chronicled in a multitude of studies. Of interest here is the purported impact of stress responses on brain functioning [14]. The pandemic has been characterized by stress produced by the uncertainties of the situation, disruptions in people's routines and social interactions (including physical isolation), and feelings of helplessness arising from the loss of significant others [15], [16]. Stress is known to impact learning and memory in a variety of ways [17]. Although stress may enhance memory formation, leading to durable memories, it can impair retrieval of memory records, depressing academic performance. Stress can also disrupt the updating of long-term memory records (i.e., the integration of new information with preexisting knowledge) and promote rigid, habit-like actions, thereby depriving learning of flexibility and adaptability. Long-term memory is not the only cognitive function to be disrupted by stress. Working memory is another likely fatality. Working memory is a system that allows learners to temporarily preserve and actively manipulate information for planning, making decisions, and executing a variety of tasks. Worrying upsets executive functioning, slows processing speed, depletes the cognitive resources of working memory, and reduces the amount of information available to learners for task execution [18], [19]. Thus, it is not surprising that a likely outcome of the disproportionate apprehension that accompanies stress is impaired decision-making processes [19], [20]. Over time, disruptions of working memory may acquire stability, become more severe, and be linked to an overall sense of exhaustion [21].

Evidence that the pandemic may have changed brain functioning [14] begs the question of whether students' performance before the pandemic reported by several researchers [5]–[7] would be reproduced or changed after such a disruptive event. In this context, the residuals of the stress related to the pandemic are likely to add to the stress arising from common academic circumstances (e.g., exams) and readjustments to on-campus classes. Indeed, the task of performing well on exams requires that students retrieve information from long-term memory, and then manipulate it in working memory to generate answers to questions. Exams exemplify how students deal with uncertainty. When uncertainty is present, stress affects working memory [22]. It specifically weakens the resources required to make adjustments to information held in working memory. As such, it forces learners to rely heavily on automatic response tendencies, and to reduce their use of controlled cognitive processes [23], thereby affecting performance on exams. Similarly, a return to face-to-face classes requires re-adaptation to commuting and adjustments of study routines, all involving controlled processes that demand cognitive resources that may be scarce at present. Yet, as noted earlier, the few comparisons available in the literature concerning pre- and post-pandemic learners' performance have yielded mixed evidence [8], [9].

Interestingly, for Saudi Arabian learners who have been under intense pressure to succeed since before the pandemic, stress lingering from this disruptive event and that arising from adjustments to post-pandemic on-campus demands and common academic challenges are not isolated occurrences. They may merely add to the underlying stress induced by the persisting pressure to succeed [24]. For Saudi Arabian learners, such pressure has specifically come from the neo-liberal economic plan of their country, called

Vision 2030, which heavily relies on a college-educated workforce to rapidly convert the economy from one based on fossil fuels and its byproducts to one that is knowledge- and service-based [25], [26]. The plan has compelled the allocation of vast amounts of resources to revamp the entire educational system, from elementary school to college and beyond, to meet international standards [26]–[28]. Gender equity is one key aspect of the plan, according to which educational programs before reserved to men, such as engineering and computer science, are now open to women [29]–[31]. As a result, the pressure to succeed is particularly high for female college students who are newcomers to many educational programs as well as a minority struggling with the relics of a patriarchal society (e.g., gender stereotypes). The plan's goal of quickly developing a skilled and educated workforce has required the use of incentives, such as generous scholarships and plum professional opportunities, administered to meritorious students. Tangible indices of good performance, such as cumulative grades, have been mostly used to measure merit. As a result, students have been struggling to find a balance between a grade/performance orientation (i.e., studying to obtain good grades and a degree) and a learning/goal orientation (i.e., acquiring knowledge that is necessary for future professional success) [32]. Grade/performance orientation, however, is often associated with negative emotional states, such as anxiety and stress [32]–[34]. Thus, after the pandemic, in Saudi Arabian female college students, a confluence of sources of stress may be at work, including those arising from the aftermath of the pandemic [35], readjustment to on-campus demands, common academic challenges, and the persistent intense need to produce tangible signs of good performance. According to the Yerkes-Dodson law, excessive autonomic arousal harms performance [36].

One way to counteract stress is through self-regulation, which refers to strategies that learners use to monitor and control their cognitive performance before, during, and after studying [37]. Another way is presented by the learning environment. External regulation of learning is fostered by a student-centered approach to teaching that promotes positive emotions [38], [39], as well as reliance on problem-driven learning strategies rather than emotion-driven strategies. Yet, stress can easily disrupt learners' self-regulation and appreciation of external sources of regulation, thereby impairing academic performance [40]–[42]. It was thought that for Saudi Arabian female learners, the convergence of different types of stressors might limit their ability to cope with the academic demands of the post-pandemic world with its face-to-face classes and added time-management challenges (e.g., commuting times, increased socialization, and participation in extra-curricular on-campus activities). Thus, the likely fatalities of these stressors would be academic performance and motivation. The two variables were viewed as interconnected. Indeed, if motivation is the drive to initiate academic activities, broaden their scope, and persevere when difficulties arise, performance is the outcome variable of interest. Performance measurement involved either strictly timed or loosely timed assessments. Exams, as exemplified by either a formative assessment measure (e.g., midterm test) or a summative assessment measure (e.g., final test), were selected as they reflected settings where performance is timed and outcome uncertainty is high. Thus, stress would likely be experienced at a level above and beyond that arising from the common challenges of a student's undergraduate life. As such, the chances of stress impairing performance would be increased. Indeed, stress is known to be accompanied by a sense of uncertainty which induces learners to perform less-than-ideal actions to reduce it [43]. Time constraints, such as during exams, bolster such actions. For instance, in a strictly timed exam, evidence exists that high stress causes learners to move inefficiently or slowly through the text of the exam and make careless mistakes [44]–[46]. Learners' failure to answer all exam questions and generate correct answers then leads to poor grades and a host of erosive emotive effects [47].

In this study, performance in class activities was selected because it was a formative assessment measure that would encompass a variety of regularly scheduled (i.e., predictable) activities completed under more flexible time constraints independently or collaboratively at home or in class. That is, it reflected a context that elevated students' perception of control over the learning process [39]. Yet, both before and after the pandemic, college students would be expected to juggle multiple demands and thus experience time scarcity. The experience of time scarcity would arise when the unwavering multitasking demands of college life lead to the belief that one might never catch up. It is conceptualized as a distraction that drains cognitive resources and impairs executive functions, thereby lowering learners' ability to plan, think clearly, and engage in effective multitasking [48]. Among the factors that could reduce the feeling of time scarcity in college students is the predictable rhythm of loosely timed academic activities, such as the assignments and quizzes of the selected pre-calculus course [49]. Another factor might be the sense of relatedness, support, and control that arises from the participative instructional environment exemplified by collaborative activities [50]. As such, performance entailing class activities was thought to be less sensitive to disruptions due to stress. Based on these assumptions, the following hypotheses were formulated for performance on the midterm and final exams (H1) as well as performance involving class activities (H2):

- H1: if challenges in the adjustment to on-campus instruction and residues of the stress arising from the pandemic added to the stress induced by tests, post-pandemic exam performance, including midterm and final tests, would be lower than pre-pandemic exam performance.

- H2: if the experience of time scarcity arising from the unwavering multitasking demands of college life is experienced more intensely during the post-pandemic period, adding to the challenges of the adjustment to on-campus instruction, grades related to class activities would decline in the post-pandemic period. However, because such grades included collaborative and independent activities with more flexible time constraints, the magnitude of the decline would be less than that observed for exams.

In this study, performance assessment was accompanied by the measurement of the emotive responses that define students' motivation. It was thought that for Saudi Arabian female learners, the most likely fatality of the convergence of different types of stressors would be motivation. According to the theory of self-determination [51], motivation in a course or, more broadly, in the pursuit of a STEM degree may fall on a continuum from intrinsic motivation to amotivation. Intrinsic motivation applied to pre-calculus may be characterized as interest, enjoyment, and satisfaction in the pre-calculus curriculum and related instructional activities along with the recognition of the value of such curriculum and activities. Amotivation is the exact opposite. According to the theory of self-determination, extrinsic motivation exists between these two extremes. Actions driven by rewards or penalties (i.e., external regulation) or by the recognition of the practical utility and value of particular activities (i.e., identified regulation) exemplify extrinsic motives. To assess students' perceptions of pre-calculus that could provide insights into their academic motivation, we measured: i) their views of the difficulty of the course; ii) the practical value (i.e., utility) attributed to learning pre-calculus; and iii) their self-reported level of stress experienced while completing the course. We also asked whether the course made them more or less likely to continue their studies in the chosen STEM degree. The following prediction was made:

- H3: if challenges in the adjustment to on-campus instruction in the post-pandemic period were perceived by the students as pronounced, indices of intrinsic motivation (e.g., interest, enjoyment, satisfaction, and recognition of the value of the pre-calculus curriculum and activities) would not be detected. Such challenges would be reflected in students' opinions of the difficulty of pre-calculus and the stress level experienced in the course. That is, students enrolled in pre-calculus during post-pandemic times would judge the course as more difficult and more stressful than students enrolled in pre-calculus before the pandemic. They would also be more likely to attribute less practical value to pre-calculus learning (discounting its worth) and indicate a change of academic major as a possibility.

More broadly, to understand students' attitudes towards not only a particular course but also their pursuit of an engineering or computer science degree in the post-pandemic era, we inquired about their views of such degrees. Three areas were considered: i) reasons for choosing a STEM degree; ii) anticipated challenges in pursuing it; and iii) their views of women's representation in STEM. H4 rested on extant evidence linking stress to learners' adoption of an egocentric perspective [43].

- H4: if challenges in the adjustment to on-campus instruction in the post-pandemic period were perceived by the students as pronounced, such challenges would be reflected in the adoption of an egocentric perspective. Egocentric lenses would lead to the following pattern of students' responses: i) Personal reasons (e.g., a struggle to balance personal and academic demands) would be selected more often than sociocultural reasons (e.g., gender stereotypes) as the main difficulty of pursuing a STEM degree; ii) External (mostly utilitarian) reasons for pursuing a STEM degree would be prevalent; and iii) Evidence of women's lower representation in STEM would be minimized. The latter prediction was based on evidence that stress tends to be accompanied by an enhanced reliance on self-knowledge when inferring others' conditions, resulting in more egocentric inferences [43]. If so, the recognition that the participants were themselves women in STEM fields would lead them to infer adequate representation of women in such fields.

2. METHOD

2.1. Study participants

The participants were 472 undergraduate students who were pursuing STEM programs (engineering or computer science). All were females whose ages ranged from 18 to 25. Arabic was their first language and English their second language. Before admission to their selected undergraduate program, students were deemed competent users of the English language through standardized English tests (test of English as a foreign language (TOEFL)≥83; or international English language testing system (IELTS)≥6). They were enrolled in a pre-calculus course consistently taught by one instructor since before the pandemic. Due to a gender-segregated campus, all classes were composed of female students taught by female faculty. There were 176 students enrolled before the pandemic (4 semesters), and 296 after the pandemic (4 semesters). Important to note that 163 students were enrolled in the course during the online pandemic period (3 semesters). These latter students are mentioned to demonstrate continuity in our data collection, although only the data from the pre-pandemic and post-pandemic periods were analyzed to test our hypotheses.

Also important is to note that the increased number of students in the period after the pandemic reflected the enrollment trend of female students in STEM programs from 416 before the pandemic to 993 during the pandemic and 1,084 after the pandemic. Admission criteria remained unchanged during these periods. Based on these reference groups, the sample sizes of the two periods were deemed adequate assuming $\alpha=0.05$ and $\beta=0.20$ levels of risk [52], [53].

2.2. Pre-calculus

At the selected academic institution, pre-calculus is preceded by the successful completion of an intermediate algebra course. Pre-calculus is a prerequisite for calculus, which is a college-level course. Thus, pre-calculus is considered a preparatory course without college credits. A final grade of 70% or better is required to pass the course and enter calculus. A placement algorithm, which considers Scholastic Assessment Test (SAT) scores, and high-school mathematics courses and grades, determines whether a student will be enrolled in intermediate algebra, pre-calculus, or calculus I. All courses are taught in English. Their curriculum complies with US standards as determined by the Texas International Education Consortium (TIEC).

Pre-calculus instruction generally entails meetings three days a week within a 15-week semester followed by an exam week. Each meeting consists of two sessions of 50 minutes each. Class size ranges from 15 to 30. Calculators are required tools. Teaching faculty are available after class and during office hours to help students. Additional instructional support is offered by mathematics tutors.

A student-centered, active-learning pedagogy is applied to all instruction [54]. Thus, the course is taught through a variety of methods to foster engagement. Methods focus on learning mathematics through understanding and not through memorization. Class meetings may begin with a brief lecture introducing students to new material. Students are then given time to work individually or in groups on some problems, present their solutions to the class, and answer questions from peers and the instructor. The latter is available to answer questions by walking around the room when students are at work. After each class meeting, homework assignments feature questions similar to in-class problems along with additional applications of the concepts covered in the class. Loosely timed quizzes are included in many class meetings. Both homework assignments and quizzes are intended to reiterate materials and procedures discussed in class as well as foster additional applications. That is, sometimes, students practice skills and knowledge they have just learned. At other times, they work on guided discovery problems.

2.3. Procedure and materials

Across all selected periods, instructional materials were posted on Blackboard. During the pandemic, however, instruction and assessment materials for exams and quizzes were delivered online. Instruction was synchronous. It entailed reliance on Blackboard Collaborate, a tool that allowed the instructor to interact with students in real-time via voice and audio functions along with a chatbox for written communications. Before and after the pandemic, instruction was delivered face-to-face. Paper-based exams were administered. Although the mode of instruction and assessment changed during the pandemic, the assessment protocol remained consistent across time. It entailed a midterm exam (20%), and a final exam (40%). Intermixed across the entire semester, there were regularly scheduled but loosely timed quizzes and in-class or homework assignments (40%), which were intended to prepare students for the midterm and final examinations. Along with the midterm exam, quizzes, and assignments were forms of formative assessment, whereas the final exam was an instance of summative assessment.

The instructor anonymized grades and made them available to the research team at the end of each period. In addition to performance data, two sets of emotive response data were collected. First, the research team examined whether there were changes in the degree to which the selected course was perceived as challenging. Thus, a subset of STEM female students who had completed the course either before (n=30) or after the pandemic (n=30) was selected through convenience sampling. They were asked to describe the extent to which the course yielded challenges using a 5-point scale including very difficult, difficult, neutral, easy, and very easy. They were also asked to indicate the degree to which they experienced stress in the course on a 5-point scale including no stress at all, mild stress, moderate stress, high stress, and extreme stress. After these two questions, students were instructed to consider their pre-calculus activities and performance. Then, they indicated how useful they found what they learned in the course for their future academic and professional activities on a 5-point scale, including very useful, useful, neutral, useless, and very useless. They also reported whether they planned to continue their studies in the selected STEM major on a 5-point scale including very unlikely, unlikely, neutral, likely, and very likely. All responses were anonymized.

Second, the research team questioned a group of 101 STEM female students enrolled in a pre-calculus or intermediate algebra course taught by the same instructor during the post-pandemic period. They were asked in a written format to indicate their views in three broad areas: i) motivation to pursue a STEM degree; ii) anticipated challenges; and iii) view of women in STEM fields. For each area, they were to mention what was most relevant to them. Because all responses were anonymized, it was not possible to link attitudinal and performance data.

Preceding survey administration, the judgment of two independent educators in the field of assessment examined all selected questions to determine face validity [55]. Cohen's Kappa index (CKI), which was used to determine face validity, was 0.84. It indexed substantial interrater agreement in the context of binary decisions. The minimal acceptable value of Kappa is 0.60. Instead, participants' open-ended answers were submitted to thematic analysis [56], [57]. The guidelines of thematic analysis included familiarization with the content of students' answers and coding according to conceptual categories. Raters were instructed to approach coding as a descriptive enterprise. Namely, they aimed to remain as close as possible to the content of students' intended meaning. The interrater agreement was 0.82. If disagreement existed, then the method of negotiated agreement was adopted to reconcile the remaining differences [57], [58].

3. RESULTS

Results are organized by the question they are intended to answer. Table 1 displays the descriptive statistics (mean (M) and standard error of the mean (SEM)) of students' grades in three time periods: before, during, and after the pandemic. The data from the pandemic period are displayed to illustrate the continuity of the data collection process but were not included in the set submitted to inferential statistics.

The grades considered are those of the midterm exam (formative assessment measure), the final exam (summative assessment measure), and class activities (also formative assessment measures). The last column of Table 1 illustrates significant differences between the periods before and after the pandemic, both of which entail face-to-face instruction. The last rows illustrate the course failure rates and withdrawal rates. In the table, inferential statistics are considered significant at the 0.05 level. Based on the standards of the selected university, failures in pre-calculus were deemed to be grades below 70% (D or F). Because in-class quizzes and assignments could sometimes entail work with other students (pairs or groups), their grades were not considered unadulterated work of individual students. Thus, they were analyzed separately.

Table 1. Descriptive statistics of grades by type of assessment

Grades	Before		During		After		Sign.
	M	SEM	M	SEM	M	SEM	
Midterm exam	58.70	(1.85)	83.97	(1.36)	56.40	(1.29)	B=A
Final exam	60.77	(2.16)	84.52	(1.00)	54.42	(1.17)	B>A
Class activities	77.80	(1.35)	71.79	(1.13)	73.35	(0.88)	B>A
Failure rates	25.00%		66.26%		31.77%		B=A
Withdrawal rates	1.7%		4.91%		19.93%		B<A

Note: >or< indicates that values before the pandemic were significantly different from those after it; =indicates no significant differences

3.1. Has performance changed between before and after the pandemic?

To assess the impact of the pandemic on comparable instructional modes, we examined performance indices before and after the pandemic, which were the result of entirely face-to-face classes. The midterm exam grades, final exam grades, and class-activity grades were submitted to a one-way ANOVA with period as the independent variable. Final grades [$F(1, 470)=7.96$, $MSE=558.09$, $p=0.005$, partial $\eta^2=0.017$], and class-activity grades [$F(1, 470)=8.29$, $MSE=263.54$, $p=0.004$, partial $\eta^2=0.017$] were higher before the pandemic. No difference emerged on the midterm exam, a formative assessment measure [$F=1.10$, ns].

A Chi-squared test was used to determine whether the course failure rate after and before the pandemic differed. Failure rates did not differ between these two time-based periods [$\chi^2(1)=3.18$, ns]. However, withdrawal rates [$\chi^2(1)=25.90$, $p<0.001$] were substantially higher after the pandemic.

In summary, if exam performance is considered in isolation, the distinction between formative and summative assessment is relevant. Formative assessment performance was equally poor during the two time-based periods of face-to-face instruction, but students' performance in summative assessment deteriorated even more after the pandemic. Deterioration also involved class activities, such as assignments and quizzes, that were performed under less stringent time schedules. On average, final exam grades suffered from a 6.35% decline, whereas class activities exhibited a 4.45% decline. Thus, H1 was supported. Although both performance indicators decreased, the magnitude of the declines was rather similar, partially supporting H2 ($F=1.55$, ns).

Although failure rates were equivalent, withdrawal rates from the course were higher after the pandemic. If students who withdrew are assumed to be those whose course performance is irreparably damaged, the combined picture is that of students who are not doing well after the pandemic. Namely, students tended to give up in greater numbers. Yet, when they persisted in pre-calculus, they appeared to manage the demands of pre-calculus a little better when given activities that were less constrained by time and more participatory in nature.

3.2. Did students' emotive responses to pre-calculus change from before to after the pandemic?

A subset of STEM students who had completed the course either before or after the pandemic was selected through convenience sampling. They were asked to describe the extent to which the course yielded challenges on a 5-point scale, from very difficult to very easy. All students described the course as either difficult or very difficult. However, 23.33% of the students before the pandemic, and 76.67% of the students after the pandemic designated the course as very difficult.

Before the pandemic, students described the course as entailing either moderate (50.00%) or high stress (50.00%). After the pandemic, 80.00% of the students chose high stress while 20.00% chose moderate stress. When asked to clarify their answers, students admitted that stress was driven by doubts about whether they could satisfy the demands of the course given their knowledge base and available time. Most students spontaneously reported that they felt anxious about all math courses. Often conveyed was the realization that a return to on-campus classes required commuting to and from the university, which deprived them of useful study time. Another observation often reported was students' return to the habit of cramming for exams and assignments. Attempts to preserve a more continuous approach to class demands, which had been adopted during the pandemic, were reported to have failed.

When asked about the utility of their learning of pre-calculus materials for their future academic activities and professional life, most of their answers tended to fall into the useful slot before the pandemic (90.00%) and into the neutral slot after the pandemic (93.33%). When students were asked about their intentions to persist in the selected STEM major based on their performance in pre-calculus, no student selected very unlikely, unlikely, or neutral. Before the pandemic, students selected likely (56.67%) or very likely (43.33%). The same pattern was uncovered after the pandemic. Thus, students' determination to continue in the program they chose before completing pre-calculus was unbending even in cases in which they admitted that their performance was less than optimal. They were aware though that this determination might lead to difficulties in the courses that follow it if remedial actions were not explored. Their uncertainty in recognizing the value of pre-calculus learning suggested that determination to persist in STEM in the post-pandemic world might reflect extrinsic motives (e.g., rewards, such as a desired job).

3.3. What are students' post-pandemic views of their STEM choices?

Table 2 contains descriptive statistics. Specifically, it illustrates the responses produced in the post-pandemic era by a selected group of students in three emotive-response areas related to STEM: motivation to pursue a STEM degree, anticipated challenges in STEM, and view of female representation in STEM. In this table, the choice deemed most relevant by each participant is listed.

Female students' answers to the question about their motivation to pursue a STEM degree tended to prioritize career opportunities. The programmatic plan labeled Vision 2030 of Saudi Arabia offers career opportunities that young women perceive as desirable, including financial independence. Thus, the preponderance of answers involving career opportunities might reflect the recognition of the current and future impact of Vision 2030. Yet, it confirmed the weight of extrinsic motives in these young women's decision-making practices, which was suggested by the answers to the pre-calculus course. The other choices underscored female students' recognition either that their intrinsic interests are key to their ability to succeed in STEM, or that STEM fields are impactful and thus beneficial to their country's future. Interestingly, only a few women mentioned family or peer influences as a motive. When they did so, the choice of a STEM degree was reported as less genuine in post-survey debriefings.

In response to the question about the anticipated challenges of a STEM degree, many students reported their current difficulty in balancing the demands of school and home. Other students noted the negative impact of gender biases in the pursuit of a STEM career or mentioned the fear of being unable to gain practical experience in a professional world that only recently accepted them as equals. A few others expressed concern about keeping pace with technological advances in a world that is changing fast.

Table 2. Views about STEM

Motivation to pursue a STEM degree	%	Anticipated challenges in STEM	%	View of women's representation in STEM	%
Passion for STEM subjects	17.82	Balance academic demands and personal life	35.65	Underrepresented	12.87
Career opportunities	46.54	Overcome gender biases in STEM fields	19.80	Fairly represented	31.68
Impact on society	24.75	Gain practical experience	25.74	Equal representation of sexes	39.61
Family or peer influence	5.94	Keep up with evolving technology	16.83	No opinion	15.84
No opinion	4.95	No opinion	1.98		

The question about their views of the role of women in STEM fields received some ostensibly counterintuitive answers. A large number of female students reported that women were either fairly represented or equally represented in STEM fields even though their fields were engineering and computer science. Only a meager 12.87% recognized the reality of women's underrepresentation in the STEM fields of engineering and computer science. The former answers might reflect an aspirational goal taken from Vision 2030. Indeed, it is undeniable that Vision 2030 gives prominence to the employment of women, especially in STEM fields. Although this programmatic plan aspires to gender equity in education and employment, and progress has been made, the aspirations of the plan have yet to be fully realized [12], [13]. Alternatively, these answers might underscore the fact that female university students are overrepresented relative to men (62% in 2016) [11] and that there has been an increase in the enrollment of women in STEM. Because the campus where classes are held is gender segregated, female students mostly see other female students whose numbers have steadily increased. Thus, misperceptions of the extent to which women are represented in STEM fields could be the result of the daily experiences of female students on the female side of the university campus. However, these answers along with those expressing no opinion might also reflect female students' reticence to criticize the unfulfilled aspects of a plan that benefits them.

4. DISCUSSION

The results of the present study can be summarized into three interconnected sets of data involving face-to-face pre-calculus classes. First, compared to the pre-pandemic period, most assessment measures after the pandemic indicated lower pre-calculus performance. The course was also reported to be more stressful and difficult. Notwithstanding their less-than-desirable performance, female students did not convey any intentions to change academic majors. On one side, the determination of female students to pursue a STEM degree spells good news for the gender-equity goal of the programmatic plan named Vision 2030. As gender equity is one of the key pillars of a sustainable ecosystem [59], it is also good news for the sustainability of this plan. Yet, female students' unwavering determination flies in the face of their declining performance. If the withdrawal rates and failure rates are combined, the picture that emerges is one of students who are not doing particularly well in pre-calculus, a foundational course in engineering and computer science. Determination to persist in a field notwithstanding poor performance may indicate that these women are contemplating remedies (e.g., further tutoring) before enrolling in calculus, a course for which success relies on knowledge and skills acquired in pre-calculus. Alternatively, it may indicate the influence of the so-called optimism bias according to which students may overestimate future performance in calculus even though current evidence suggests otherwise [60], [61]. In the present study, we did not measure the extent to which this bias was operative. Indeed, we did not ask students to predict their performance in calculus and then measure the obtained outcome after calculus was completed. Thus, we are unable to objectively determine whether this bias was present. Nevertheless, the most likely outcome of this finding is that students will find calculus an even harder course with challenges that may appear unsurmountable. The future of students whose performance is poor will tell whether before enrolling in calculus they have chosen remedies or have remained unrealistically optimistic, thereby facing likely failures.

Second, the emotive responses to a math course (pre-calculus) and a field (STEM) were examined through the lens of the self-determination theory of motivation [62]. According to this theory, learners' motives can be described along a continuum. At one end of the continuum, learners are intrinsically motivated, thereby finding learning activities interesting, enjoyable, personally valuable, and sources of satisfaction. At the opposite end of the continuum, learners are unmotivated, a condition experienced by those who find no value or desirable outcomes in learning activities. Learners who are externally motivated are located between these two extremes. Their learning activities are prompted by external outcomes (i.e., rewards or penalties) or by the perceived value, importance, or usefulness of such activities (i.e., identified regulation motives). Intrinsic motivation is often linked to engagement, persistence, and desirable learning outcomes [63]–[65]. Learner's identified regulation motives are also linked to performance, but for such learners, well-being is contingent on performance [66]. Self-identified regulation refers to learners who see good performance as rewarding and poor performance with a strong sense of disappointment, thereby experiencing a decline in well-being.

If the pre-calculus course is viewed as the harbinger of students' future academic and professional attainment, some concerns emerge for the post-pandemic era. Intrinsically motivated learners would be expected to express not only interest but also enjoyment, and satisfaction in the pre-calculus curriculum and related instructional activities along with the recognition of the value of such curriculum and activities. In the post-pandemic period, students appeared uncertain regarding the utility of pre-calculus and saw it as more difficult and stressful than students did before the pandemic. Taken together, the emotive responses of our participants indicated that female students in the post-pandemic era might be trending towards amotivation when responses to particular courses are examined (e.g., pre-calculus) and external motivation when responses to STEM programs are considered. The former is a situational-level motive, which describes responses to particular activities, whereas the latter describes a context-level motivation, which refers to responses to a particular domain [62]. In the extant literature, anxiety is often associated with math performance [67], [68]. Here, self-reported stress appeared to be linked to amotivation for pre-calculus and external motivation when STEM fields were considered.

Third, in the post-pandemic period, two sets of primary motives seemed to prevail in the female students who chose to pursue STEM fields. Almost half of the female students (46.54%) selected career opportunities, an external motive, as their main incentive for pursuing a STEM degree. It is undeniable that the currently low representation of women in computer science and engineering professions makes a degree in such fields likely to lead to ample job opportunities. However, this type of extrinsic motive may not be sufficiently strong to withstand all the challenges that such a degree brings forth. Not surprisingly, our students were aware of such challenges, albeit they disagreed on which obstacle was the most relevant. They listed challenges such as balancing academic and personal demands, difficulty in gaining practical experience in fields dominated by men, and gender biases. In sum, they recognized that the transition to a more gender-equitable society is in the making but yet to be fully realized.

Interestingly, if students' choices of STEM due to passion (an intrinsic motive) or recognition of STEM as impactful (an identified regulation motive) are combined (42.57%), a different picture emerges. According to Burton *et al.* [66], intrinsic motives promote a focus on learning activities, yielding emotions that energize learners, such as interest and excitement. Identified regulation motives keep learners oriented toward the importance of such activities even when these activities may be relatively uninteresting to them. Thus, both motives can foster persistence in STEM, although intrinsic motives are more sensitive to the extent to which the learning environment matches learners' interests. In this study, if students' intrinsic and identified regulation motives are combined, 42.57% of the students could be said to have selected goals that are much more likely to help them withstand all the challenges that such a degree brings forth. Of course, we do not imply that motives are mutually exclusive. Individuals may express multiple types of motives at any given time toward a particular activity. For instance, students may be determined to get a good grade in a course activity and find interest, enjoyment, and value in the activity. Yet, when asked to prioritize motives, what they choose is an insight into their hierarchy of drives.

Scarce are studies that compare variables such as performance and attitudes before and after the pandemic. Indeed, researchers have by and large focused their work on comparisons before and during home confinement. Within this context, the evidence is mixed. Some studies have reported pandemic-related improvements in grades [6], [69], [70]. Other studies have reported either performance declines or no change [71], [72]. Researchers have also addressed the teaching of math in the post-pandemic world as requiring changes compared to the pre-pandemic world [73]. Others have examined subjective variables, such as anxiety, in the post-pandemic period. A case in point is the study of Dios and Charlo [74], which reported that high levels of anxiety were related to impairments in students' capacity to solve mathematical problems.

An exception to this pattern of empirical evidence is the study of Pilotti *et al.* [75], which examined the performance and enrollment of STEM and non-STEM female students before and after the pandemic. They reported that both student groups yielded lower post-pandemic performance (as measured by grades). Specifically, STEM learners completed fewer general education courses and their grades worsened in courses dedicated to communication, math, and professional competencies. Nevertheless, in post-pandemic times, more female students enrolled in STEM fields. These findings agree with Pilotti *et al.* [75] and complement them. Indeed, they suggest that despite lower performance, female learners' preference for STEM programs may have increased after the pandemic due to utilitarian reasons (professional opportunities).

4.1. Implications and applications

The implications of the findings for the institution where data collection was performed are clear. They suggest that change is in order. Sokolowski *et al.* [76] believe that understanding that concepts of mathematics are abstractions from the physical world can make such concepts meaningful to students. More broadly, they argue that students benefit from being presented with realistic scientific problems that give meaning to abstract mathematical representations as well as offer opportunities for testing hypotheses and computational models. Thus, they propose the use of computer simulations and realistic data sets that reflect real phenomena, instead of textual descriptions. Making problems realistic and thus meaningful may counteract the tendency to memorize concepts instead of understanding them [77]. When students focus their study efforts on memorization, they are unlikely to be able to understand mathematical algorithms and adequately apply them to novel problems.

A course is a package that students evaluate through three criteria, including their sense of competence, relatedness (i.e., the presence of positive interpersonal relationships), and autonomy (i.e., the feeling of being in control). These ingredients tend to be associated with desirable academic performance, engagement, and persistence [78]. The theory of self-determination agrees. It predicts that learners will be intrinsically motivated if they feel competent, experience a sense of choice and control, and establish positive interpersonal connections. As a result, they see learning goals as their own, which makes such goals easier to maintain. Although the selected course relies on a student-centered pedagogy that fosters active learning activities, and other math courses purport to do the same at the selected institution, evidence from the extant literature demonstrates that further strengthening each of these ingredients is necessary. Empirical research aligns several pedagogical techniques with each of these criteria and desirable academic outcomes. They include experiences building self-efficacy (i.e., confidence in one's abilities to perform), and emotional support [79]–[81].

4.2. Limitations

One of the limitations of the current study is its exclusive reliance on female college students. As such, it is unclear whether male students would yield the same patterns. Yet, it is important to consider that both female and male undergraduate students are the objects of the workforce of the Vision 2030 plan. Through the plan, the patriarchal system of their country has been progressively weakened to the point at which the privileges and visibility upon which males had relied in the past have largely faded. Thus, it is reasonable to assume that male students would also be subjected to the same pressure to succeed. Another limitation of our study is the successive independent-group design, which prevents us from examining changes across time in individual students or merely their progression from pre-calculus to calculus.

A related limitation is that our study offers a one-time window into the performance and views of female undergraduate students. Changes in their society, fostered by the Vision 2030 plan, may impact their views in ways that need further study. Of course, the students selected for our study were all second-language learners. Albeit before admission, standardized tests deemed students' competent users of the English language, reading comprehension and production of course materials in English might still offer some challenges. The students were mostly exposed to an inquiry learning approach, according to which educators guide learners to understand concepts through applications in a context of peer collaboration. Furthermore, the educator selected for our study and her instructional staff (e.g., teaching assistants) were competent in both English and Arabic, thereby providing insightful language support if particular difficulties were encountered [82]. Such a supportive environment might reduce students' anxieties toward the English medium [83]. It is unclear though whether other methods, such as a flipped classroom methodology, might be more effective [84].

5. CONCLUSION

This research is a call to action for math educators who are asking themselves whether the post-pandemic environment merely demands that their students readjust to the "old normal" or requires a rethinking of instruction and curriculum to accommodate a "new normal" with its uncertainties and challenges. The answer seems to be the latter when the student population entails female learners from a society that is restructuring itself to serve a knowledge and service economy. Yet, a similar answer may apply to students from other countries as the psychological and practical readjustments to on-campus instruction are likely to take time. Most importantly, if rethinking STEM instruction is considered, it is clear that math courses can benefit from the enhancement of active pedagogies, including inquiry learning and project-based learning, which are known to promote intrinsic motivation.

This call to action is relevant to the aims of sustainable education. At its core, sustainable education consists of academic standards that reconcile concerns for excellence with equity norms. It addresses the needs of all learners through the sensible use of educational resources and makes learners ready to meet the demands of the future. Sustainable education applied to the pre-calculus course that we selected for our study means rethinking instruction to address the needs of female students in the post-pandemic era (fostering stress reduction and intrinsic motivation to learn) as well as their particular dispositions. For instructors, it also means utilizing materials and relying on activities that help female learners appreciate the relationships between current learning and future professional endeavors. Appreciation of such relationships can enhance the value of what they are learning in pre-calculus. It can also help them internalize and identify with the chosen STEM fields, thereby making it easier, as time goes by, to maintain their academic and professional choices. In general, a focus on the process of learning (how to think), rather than the accumulation of knowledge (what to think) is desirable to ensure that such learners are ready and able to face the challenges that the Vision 2030 has set for them. Because the latter heavily relies on STEM students' contribution to the economic engine of Saudi Arabia, its success is their success.

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This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
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O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

Informed consent was obtained from all participants. Any potentially identifying information was deleted after matching the different data sources. Thus, no identifying information was present in the data set submitted to statistical analyses.

ETHICAL APPROVAL

The research was conducted under the purview of the Deanship of Research of the hosting institution. The data-collection process was approved by the Deanship of Research (PMU-DoR-2021-2024-001) as complying with the guidelines of the Office for Human Research Protections of the U.S. Department of Health and Human Services.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author [MAEP], upon reasonable request.

REFERENCES

[1] T. Aquino, J. E. Brand, and F. Torche, "Unequal effects of disruptive events," *Sociology Compass*, vol. 16, no. 4, p. e12972, Apr. 2022, doi: 10.1111/soc4.12972.
[2] M. Burchard, "The Need for Philosophy in Times of Trauma," *Public Philosophy Journal*, vol. 2, no. 2, pp. 1–4, 2019, doi: 10.59522/MQCE7860.
[3] C. Mutch, "The role of schools in disaster preparedness, response and recovery: what can we learn from the literature?" *Pastoral Care in Education*, vol. 32, no. 1, pp. 5–22, Jan. 2014, doi: 10.1080/02643944.2014.880123.
[4] A. T. Capinding, "Analysis of Learning and Academic Performance of Education Students Before and During the Coronavirus Disease Pandemic," *European Journal of Educational Research*, vol. 10, no. 4, pp. 1953–1962, Oct. 2021, doi: 10.12973/eu-jer.10.4.1953.
[5] C. Chisadza, M. Clance, T. Mthembu, N. Nicholls, and E. Yitbarek, "Online and face-to-face learning: Evidence from students' performance during the COVID-19 pandemic," *African Development Review*, vol. 33, no. S1, pp. S114–S125, Apr. 2021, doi: 10.1111/1467-8268.12520.

[6] T. Gonzalez *et al.*, "Influence of COVID-19 confinement on students' performance in higher education," *PLOS ONE*, vol. 15, no. 10, p. e0239490, Oct. 2020, doi: 10.1371/journal.pone.0239490.
[7] S. Iglesias-Pradas, Á. Hernández-García, J. Chaparro-Peláez, and J. L. Prieto, "Emergency remote teaching and students' academic performance in higher education during the COVID-19 pandemic: A case study," *Computers in Human Behavior*, vol. 119, p. 106713, Jun. 2021, doi: 10.1016/j.chb.2021.106713.
[8] M. A. E. Pilotti, K. El Alaoui, H. M. Abdelsalam, and R. Khan, "Sustainable Development in Action: A Retrospective Case Study on Students' Learning Before, During, and After the Pandemic," *Sustainability*, vol. 15, no. 9, p. 7664, May 2023, doi: 10.3390/su15097664.
[9] Y. Zheng and S. Zheng, "Exploring educational impacts among pre, during and post COVID-19 lockdowns from students with different personality traits," *International Journal of Educational Technology in Higher Education*, vol. 20, no. 1, p. 21, Apr. 2023, doi: 10.1186/s41239-023-00388-4.
[10] D. Varshney, "The Strides of the Saudi female workforce: Overcoming constraints and contradictions in transition," *Journal of International Women's Studies*, vol. 20, no. 2, pp. 359–372, 2019.
[11] S. I. Islam, "Arab Women in Science, Technology, Engineering and Mathematics Fields: The Way Forward," *World Journal of Education*, vol. 7, no. 6, p. 12, Nov. 2017, doi: 10.5430/wje.v7n6p12.
[12] H. Al-Ahmadi, "Challenges facing women leaders in Saudi Arabia," *Human Resource Development International*, vol. 14, no. 2, pp. 149–166, Apr. 2011, doi: 10.1080/13678868.2011.558311.
[13] D. Varshney, "Expatriates Go, Let Us Grow," *African and Asian Studies*, vol. 17, no. 4, pp. 340–370, Oct. 2018, doi: 10.1163/15692108-12341379.
[14] D. Bzdok and R. I. M. Dunbar, "Social isolation and the brain in the pandemic era," *Nature Human Behaviour*, vol. 6, no. 10, pp. 1333–1343, Oct. 2022, doi: 10.1038/s41562-022-01453-0.
[15] M. F. Al-Qahtani and A. S. R. Alsubaie, "Investigating Stress and Sources of Stress Among Female Health Profession Students in a Saudi University," *Journal of Multidisciplinary Healthcare*, vol. 13, pp. 477–484, May 2020, doi: 10.2147/JMDH.S255781.
[16] L. Panther, K. A. Allee-Herndon, K. Perrotta, and S. Cannon, "I Can Tell You Stories: Teacher Education during Educational Disruption," *The Teacher Educator*, vol. 56, no. 3, pp. 327–345, Jul. 2021, doi: 10.1080/08878730.2021.1918302.
[17] S. Vogel and L. Schwabe, "Learning and memory under stress: implications for the classroom," *npj Science of Learning*, vol. 1, no. 1, p. 16011, Jun. 2016, doi: 10.1038/npjscilearn.2016.11.
[18] M. Beckwé, N. Deroost, E. H. W. Koster, E. de Lissnyder, and R. de Raedt, "Worrying and rumination are both associated with reduced cognitive control," *Psychological Research*, vol. 78, no. 5, pp. 651–660, Sep. 2014, doi: 10.1007/s00426-013-0517-5.
[19] K. da Silva Castanheira, M. Sharp, and A. R. Otto, "The impact of pandemic-related worry on cognitive functioning and risk-taking," *PLOS ONE*, vol. 16, no. 11, p. e0260061, Nov. 2021, doi: 10.1371/journal.pone.0260061.
[20] A. J. Porcelli and M. R. Delgado, "Stress and decision making: effects on valuation, learning, and risk-taking," *Current Opinion in Behavioral Sciences*, vol. 14, pp. 33–39, Apr. 2017, doi: 10.1016/j.cobeha.2016.11.015.
[21] K. Trezise and R. A. Reeve, "Worry and working memory influence each other iteratively over time," *Cognition and Emotion*, vol. 30, no. 2, pp. 353–368, Feb. 2016, doi: 10.1080/02699931.2014.1002755.
[22] P. Morgado, N. Sousa, and J. J. Cerqueira, "The impact of stress in decision making in the context of uncertainty," *Journal of Neuroscience Research*, vol. 93, no. 6, pp. 839–847, Jun. 2015, doi: 10.1002/jnr.23521.
[23] K. Starcke and M. Brand, "Decision making under stress: A selective review," *Neuroscience & Biobehavioral Reviews*, vol. 36, no. 4, pp. 1228–1248, Apr. 2012, doi: 10.1016/j.neubiorev.2012.02.003.
[24] R. Beiter *et al.*, "The prevalence and correlates of depression, anxiety, and stress in a sample of college students," *Journal of Affective Disorders*, vol. 173, pp. 90–96, Mar. 2015, doi: 10.1016/j.jad.2014.10.054.
[25] Y. H. A. Amran, Y. H. M. Amran, R. Alyousef, and H. Alabduljabbar, "Renewable and sustainable energy production in Saudi Arabia according to Saudi Vision 2030; Current status and future prospects," *Journal of Cleaner Production*, vol. 247, p. 119602, Feb. 2020, doi: 10.1016/j.jclepro.2019.119602.
[26] M. Nurunnabi, "Transformation from an Oil-based Economy to a Knowledge-based Economy in Saudi Arabia: the Direction of Saudi Vision 2030," *Journal of the Knowledge Economy*, vol. 8, no. 2, pp. 536–564, Jun. 2017, doi: 10.1007/s13132-017-0479-8.
[27] P. Le Ha and O. Z. Barnawi, "Where English, neoliberalism, desire and internationalization are alive and kicking: higher education in Saudi Arabia today," *Language and Education*, vol. 29, no. 6, pp. 545–565, Nov. 2015, doi: 10.1080/09500782.2015.1059436.
[28] B. M. Tayan, "The Saudi Tatweer Education Reforms: Implications of Neoliberal Thought to Saudi Education Policy," *International Education Studies*, vol. 10, no. 5, p. 61, Apr. 2017, doi: 10.5539/ies.v10n5p61.
[29] A. S. Alshalawi, "A Review of Women and Higher Education in Saudi Arabia," *Journal of Contemporary Scientific Research*, vol. 4, no. 3, pp. 116–130, 2020.
[30] A. Hamdan, "Women and education in Saudi Arabia: Challenges and achievements," *International Education Journal*, vol. 6, no. 1, pp. 42–64, 2005.
[31] F. Kayan-Fadlelmula, A. Sellami, N. Abdelkader, and S. Umer, "A systematic review of STEM education research in the GCC countries: trends, gaps and barriers," *International Journal of STEM Education*, vol. 9, no. 1, p. 2, Jan. 2022, doi: 10.1186/s40594-021-00319-7.
[32] K. Eum and K. G. Rice, "Test anxiety, perfectionism, goal orientation, and academic performance," *Anxiety, Stress & Coping*, vol. 24, no. 2, pp. 167–178, Mar. 2011, doi: 10.1080/10615806.2010.488723.
[33] J. A. Eison, H. R. Pollio, and O. Milton, "Educational and personal characteristics of four different types of learning- and grade-oriented students," *Contemporary Educational Psychology*, vol. 11, no. 1, pp. 54–67, Jan. 1986, doi: 10.1016/0361-476X(86)90012-3.
[34] M. Ironsmith, J. Marva, B. Harju, and M. Eppler, "Motivation and Performance in College Students Enrolled in Self-Paced Versus Lecture-Format Remedial Mathematics Courses," *Journal of Instructional Psychology*, vol. 30, no. 4, pp. 276–284, 2003.
[35] A. N. AlHadi and A. M. Alhuwaydi, "The mental health impact of pandemic COVID-19 crisis on university students in Saudi Arabia and associated factors," *Journal of American College Health*, vol. 71, no. 6, pp. 1854–1862, Jul. 2023, doi: 10.1080/07448481.2021.1947839.
[36] R. M. Yerkes and J. D. Dodson, "The relation of strength of stimulus to rapidity of habit-formation," *Journal of Comparative Neurology and Psychology*, vol. 18, no. 5, pp. 459–482, Nov. 1908, doi: 10.1002/cne.920180503.
[37] J. Li, H. Ye, Y. Tang, Z. Zhou, and X. Hu, "What Are the Effects of Self-Regulation Phases and Strategies for Chinese Students? A Meta-Analysis of Two Decades Research of the Association Between Self-Regulation and Academic Performance," *Frontiers in Psychology*, vol. 9, p. 2434, Dec. 2018, doi: 10.3389/fpsyg.2018.02434.

[38] J. de la Fuente, P. Sander, J. M. Martínez-Vicente, M. Vera, A. Garzón, and S. Fadda, “Combined Effect of Levels in Personal Self-Regulation and Regulatory Teaching on Meta-Cognitive, on Meta-Motivational, and on Academic Achievement Variables in Undergraduate Students,” *Frontiers in Psychology*, vol. 8, p. 232, Feb. 2017, doi: 10.3389/fpsyg.2017.00232.
[39] J. de la Fuente, F. J. Peralta-Sánchez, J. M. Martínez-Vicente, P. Sander, A. Garzón-Umerenkova, and L. Zapata, “Effects of Self-Regulation vs. External Regulation on the Factors and Symptoms of Academic Stress in Undergraduate Students,” *Frontiers in Psychology*, vol. 11, p. 1773, Aug. 2020, doi: 10.3389/fpsyg.2020.01773.
[40] N. L. Foster, C. A. Was, J. Dunlosky, and R. M. Isaacson, “Even after thirteen class exams, students are still overconfident: the role of memory for past exam performance in student predictions,” *Metacognition and Learning*, vol. 12, no. 1, pp. 1–19, Apr. 2017, doi: 10.1007/s11409-016-9158-6.
[41] K. W. Khan, M. Ramzan, Y. Zia, Y. Zafar, M. Khan, and H. Saeed, “Factors Affecting Academic Performance of Medical Students,” *Life and Science*, vol. 1, no. 1, p. 4, Feb. 2020, doi: 10.37185/LnS.1.1.45.
[42] J. K. Knight, D. C. Weaver, M. E. Peffer, and Z. S. Hazlett, “Relationships between Prediction Accuracy, Metacognitive Reflection, and Performance in Introductory Genetics Students,” *CBE—Life Sciences Education*, vol. 21, no. 3, p. ar45, Sep. 2022, doi: 10.1187/cbe.21-12-0341.
[43] A. R. Todd, M. Forstmann, P. Burgmer, A. W. Brooks, and A. D. Galinsky, “Anxious and egocentric: How specific emotions influence perspective taking,” *Journal of Experimental Psychology: General*, vol. 144, no. 2, pp. 374–391, 2015, doi: 10.1037/xge0000048.
[44] M. H. Ashcraft and E. P. Kirk, “The relationships among working memory, math anxiety, and performance,” *Journal of Experimental Psychology: General*, vol. 130, no. 2, pp. 224–237, 2001, doi: 10.1037/0096-3445.130.2.224.
[45] S. L. Beilock, “Math Performance in Stressful Situations,” *Current Directions in Psychological Science*, vol. 17, no. 5, pp. 339–343, Oct. 2008, doi: 10.1111/j.1467-8721.2008.00602.x.
[46] M. W. Eysenck and M. G. Calvo, “Anxiety and Performance: The Processing Efficiency Theory,” *Cognition & Emotion*, vol. 6, no. 6, pp. 409–434, Nov. 1992, doi: 10.1080/02699939208409696.
[47] J. C. Cassady and R. E. Johnson, “Cognitive Test Anxiety and Academic Performance,” *Contemporary Educational Psychology*, vol. 27, no. 2, pp. 270–295, Apr. 2002, doi: 10.1006/ceps.2001.1094.
[48] J. Larsson, D. Andersson, and J. Nässén, “Subjective temporal well-being: Defining, measuring, and applying a new concept,” *Cogent Social Sciences*, vol. 3, no. 1, p. 1306201, Jan. 2017, doi: 10.1080/23311886.2017.1306201.
[49] M. Holmes, “Time Scarcity and Student Performance: Instructional Strategies for Busy Adult Online Students,” *Canadian Journal of Learning and Technology*, vol. 48, no. 3, pp. 1–14, Apr. 2023, doi: 10.21432/cjlt28357.
[50] K. J. Kinkead, H. Miller, and R. Hammett, “Adult Perceptions of In-Class Collaborative Problem Solving as Mitigation for Statistics Anxiety,” *The Journal of Continuing Higher Education*, vol. 64, no. 2, pp. 101–111, May 2016, doi: 10.1080/07377363.2016.1178057.
[51] E. L. Deci and R. M. Ryan, “The ‘What’ and ‘Why’ of Goal Pursuits: Human Needs and the Self-Determination of Behavior,” *Psychological Inquiry*, vol. 11, no. 4, pp. 227–268, Oct. 2000, doi: 10.1207/S15327965PLI1104_01.
[52] M. A. Kastenbaum, D. G. Hoel, and K. O. Bowman, “Sample size requirements: one-way analysis of variance,” *Biometrika*, vol. 57, no. 2, pp. 421–430, 1970, doi: 10.1093/biomet/57.2.421.
[53] M. Noordzij, G. Tripepi, F. W. Dekker, C. Zoccali, M. W. Tanck, and K. J. Jager, “Sample size calculations: basic principles and common pitfalls,” *Nephrology Dialysis Transplantation*, vol. 25, no. 5, pp. 1388–1393, May 2010, doi: 10.1093/ndt/gfp732.
[54] D. Rodríguez-Luna, O. Rubilar, M. Alvear, J. Vera, and M. Z. Riquelme, “Implementation of Environmental Engineering Clinics: A Proposal for an Active Learning Methodology for Undergraduate Students,” *Sustainability*, vol. 16, no. 1, p. 365, Dec. 2023, doi: 10.3390/su16010365.
[55] V. Ahmed, A. Opoku, A. Olanipekun, and M. Sutrisna, *Validity and Reliability in Built Environment Research*. London: Routledge, 2022, doi: 10.1201/9780429243226.
[56] V. Braun and V. Clarke, “Conceptual and design thinking for thematic analysis,” *Qualitative Psychology*, vol. 9, no. 1, pp. 3–26, Feb. 2022, doi: 10.1037/qup0000196.
[57] K. Roberts, A. Dowell, and J.-B. Nie, “Attempting rigour and replicability in thematic analysis of qualitative research data; a case study of codebook development,” *BMC Medical Research Methodology*, vol. 19, no. 1, p. 66, Dec. 2019, doi: 10.1186/s12874-019-0707-y.
[58] M. Belotto, “Data Analysis Methods for Qualitative Research: Managing the Challenges of Coding, Interrater Reliability, and Thematic Analysis,” *The Qualitative Report*, vol. 23, no. 11, pp. 2622–2633, Nov. 2018, doi: 10.46743/2160-3715/2018.3492.
[59] J. A. Prieto-Saborit, D. Méndez-Alonso, J. A. Cecchini, A. Fernández-Viciana, and J. R. Bahamonde-Nava, “Cooperative Learning for a More Sustainable Education: Gender Equity in the Learning of Maths,” *Sustainability*, vol. 13, no. 15, p. 8220, Jul. 2021, doi: 10.3390/su13158220.
[60] L. Bortolotti, “Optimism, Agency, and Success,” *Ethical Theory and Moral Practice*, vol. 21, no. 3, pp. 521–535, Jun. 2018, doi: 10.1007/s10677-018-9894-6.
[61] E. R. Tenney, J. M. Logg, and D. A. Moore, “(Too) optimistic about optimism: The belief that optimism improves performance,” *Journal of Personality and Social Psychology*, vol. 108, no. 3, pp. 377–399, Mar. 2015, doi: 10.1037/pspa0000018.
[62] J. D. Stolk, M. D. Gross, and Y. V. Zastavker, “Motivation, pedagogy, and gender: examining the multifaceted and dynamic situational responses of women and men in college STEM courses,” *International Journal of STEM Education*, vol. 8, no. 1, p. 35, Dec. 2021, doi: 10.1186/s40594-021-00283-2.
[63] W. S. Grolnick and R. M. Ryan, “Autonomy in children’s learning: An experimental and individual difference investigation,” *Journal of Personality and Social Psychology*, vol. 52, no. 5, pp. 890–898, 1987, doi: 10.1037/0022-3514.52.5.890.
[64] L. G. Pelletier, M. S. Fortier, R. J. Vallerand, and N. M. Brière, “Associations among perceived autonomy support, forms of self-regulation, and persistence: A prospective study,” *Motivation and Emotion*, vol. 25, no. 4, pp. 279–306, 2001, doi: 10.1023/A:1014805132406.
[65] M. Vansteenkiste, E. Sierens, B. Soenens, K. Luyckx, and W. Lens, “Motivational profiles from a self-determination perspective: The quality of motivation matters,” *Journal of Educational Psychology*, vol. 101, no. 3, pp. 671–688, Aug. 2009, doi: 10.1037/a0015083.
[66] K. D. Burton, J. E. Lydon, D. U. D’Alessandro, and R. Koestner, “The differential effects of intrinsic and identified motivation on well-being and performance: Prospective, experimental, and implicit approaches to self-determination theory,” *Journal of Personality and Social Psychology*, vol. 91, no. 4, pp. 750–762, Oct. 2006, doi: 10.1037/0022-3514.91.4.750.
[67] R. Hembree, “The Nature, Effects, and Relief of Mathematics Anxiety,” *Journal for Research in Mathematics Education*, vol. 21, no. 1, pp. 33–46, Jan. 1990, doi: 10.5951/jresematheduc.21.1.0033.
[68] X. Ma and J. Xu, “The causal ordering of mathematics anxiety and mathematics achievement: a longitudinal panel analysis,” *Journal of Adolescence*, vol. 27, no. 2, pp. 165–179, Apr. 2004, doi: 10.1016/j.adolescence.2003.11.003.

[69] J. Pócsová, A. Mojžišová, M. Takáč, and D. Klein, “The Impact of the COVID-19 Pandemic on Teaching Mathematics and Students’ Knowledge, Skills, and Grades,” *Education Sciences*, vol. 11, no. 5, p. 225, May 2021, doi: 10.3390/educsci11050225.

[70] D. Doz, “Students’ Mathematics Achievements: A Comparison between Pre- and Post-COVID-19 Pandemic,” *Education & Self Development*, vol. 16, no. 4, pp. 36–47, Dec. 2021, doi: 10.26907/esd.16.4.04.

[71] S. Andersen, G. Leon, D. Patel, C. Lee, and E. Simanton, “The Impact of COVID-19 on Academic Performance and Personal Experience Among First-Year Medical Students,” *Medical Science Educator*, vol. 32, no. 2, pp. 389–397, Apr. 2022, doi: 10.1007/s40670-022-01537-6.

[72] G. Al-Zohbi, M. A. E. Pilotti, K. Barghout, O. Elmoussa, and H. Abdelsalam, “Lesson learned from the pandemic for learning physics,” *Journal of Computer Assisted Learning*, vol. 39, no. 2, pp. 591–602, Apr. 2023, doi: 10.1111/jcal.12768.

[73] J. Engelbrecht, M. C. Borba, and G. Kaiser, “Will we ever teach mathematics again in the way we used to before the pandemic?” *ZDM – Mathematics Education*, vol. 55, no. 1, pp. 1–16, Feb. 2023, doi: 10.1007/s11858-022-01460-5.

[74] M. T. C. Dios and J. C. P. Charlo, “Mathematical Anxiety among Primary Education Degree Students in the Post-Pandemic Era: A Case Study,” *Education Sciences*, vol. 14, no. 2, p. 171, Feb. 2024, doi: 10.3390/educsci14020171.

[75] M. A. E. Pilotti, K. El Alaoui, H. M. Abdelsalam, and O. J. El-Moussa, “Understanding STEM and non-STEM female freshmen in the Middle East: a post-pandemic case study,” *Cogent Education*, vol. 11, no. 1, p. 2304365, Dec. 2024, doi: 10.1080/2331186X.2024.2304365.

[76] A. Sokolowski, B. Yalvac, and C. Loving, “Science modelling in pre-calculus: how to make mathematics problems contextually meaningful,” *International Journal of Mathematical Education in Science and Technology*, vol. 42, no. 3, pp. 283–297, Apr. 2011, doi: 10.1080/0020739X.2010.526255.

[77] A. M. Nasir, N. A. B. Omar, E. S. B. Sarudin, S. Masrom, and N. H. Ahmad, “Teaching and learning of pre-calculus: an insights of educators,” *Journal of Fundamental and Applied Sciences*, vol. 9, no. 6S, pp. 452–467, Feb. 2018, doi: 10.4314/jfas.v9i6s.35.

[78] A. E. Black and E. L. Deci, “The effects of instructors’ autonomy support and students’ autonomous motivation on learning organic chemistry: A self-determination theory perspective,” *Science Education*, vol. 84, no. 6, pp. 740–756, Nov. 2000, doi: 10.1002/1098-237X(200011)84:6<740::AID-SCE4>3.0.CO;2-3.

[79] B. A. Greene, R. B. Miller, H. M. Crowson, B. L. Duke, and K. L. Akey, “Predicting high school students’ cognitive engagement and achievement: Contributions of classroom perceptions and motivation,” *Contemporary Educational Psychology*, vol. 29, no. 4, pp. 462–482, Oct. 2004, doi: 10.1016/j.cedpsych.2004.01.006.

[80] E. A. Ruzek, C. A. Hafen, J. P. Allen, A. Gregory, A. Y. Mikami, and R. C. Pianta, “How teacher emotional support motivates students: The mediating roles of perceived peer relatedness, autonomy support, and competence,” *Learning and Instruction*, vol. 42, pp. 95–103, Apr. 2016, doi: 10.1016/j.learninstruc.2016.01.004.

[81] M.-T. Wang and J. S. Eccles, “School context, achievement motivation, and academic engagement: A longitudinal study of school engagement using a multidimensional perspective,” *Learning and Instruction*, vol. 28, pp. 12–23, Dec. 2013, doi: 10.1016/j.learninstruc.2013.04.002.

[82] R. El Mouhayar, “The Role of Languages in the Process of Objectification in Pattern Generalization in a Multilingual Mathematics Classroom,” *International Journal of Science and Mathematics Education*, vol. 20, no. 5, pp. 999–1020, Jun. 2022, doi: 10.1007/s10763-021-10174-1.

[83] Y. Teimouri, J. Goetze, and L. Plonsky, “Second language anxiety and achievement: A meta-analysis,” *Studies in Second Language Acquisition*, vol. 41, no. 2, pp. 363–387, May 2019, doi: 10.1017/S0272263118000311.

[84] N. Karjanto and L. Simon, “English-medium instruction Calculus in Confucian-Heritage Culture: Flipping the class or overriding the culture?” *Studies in Educational Evaluation*, vol. 63, pp. 122–135, Dec. 2019, doi: 10.1016/j.stueduc.2019.07.002.

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