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Mathematical tools for understanding a complex world: designing adult courses for critical thinking development

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Abstract. Adult learners often stop engaging in mathematics after formal school education, but existing literature on adult education contains limited work on mathematic courses centered on critical thinking rather than career or examination-based goals. This study tested the specific teaching methods of gamification and emotional triggering context and their relationship with the motivation to join in with online mathematical courses for adults. A questionnaire survey was conducted, and 89 participants aged 20 and above were recruited through convenient sampling. The survey tool adopts a funnel shaped layout. Quantitative analysis indicates that the perceived value of adult mathematics thinking courses by participants does not directly translate to their willingness to participate. Based on these empirical models, two illustrative adult course cases were constructed with the core principles of real-world relevance and moderate gamification. This study provides actionable design insights for online adult mathematics education.

Keywords: learning motivation, gamification, adult education, questionnaire study, andragogy

1. Introduction

As a mandatory course from primary school through senior high school, mathematics has long been a familiar discipline to all students. However, upon graduating from high school and pursuing non – mathematics related college course, many students disengage from mathematics education as an adult.

According to Gal "Even within the 15 journals that cater to the concerns of the field of adult education and lifelong learning, empirical research on adult numeracy education is hardly visible" [1]. Even when adults say they want to regain their motivation for learning mathematics, there are still few high-quality mathematics courses designed for adults and tied to clear aims such as career development or improving their CVS, rather than mainly focusing on critical thinking skills. Research on adult mathematics education is also still limited, and this leaves aside a sizeable group of adults willing to study mathematics for knowledge and purposes that are not exam oriented.

2. Research hypothesis

Adults can regain the motivation to study math and logic related courses if specific learning and teaching methods are used, and they would benefit from these lessons.

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3. Research design

This investigation uses a questionnaire as the main research instrument for collecting empirical data. The questionnaire examines the relationship between different personal characteristics of adult participants aged 20 and above and their motivation for enrolling in online mathematic courses. In this study, a questionnaire survey was a practical method. It made it easier to reach adult respondents from different age groups, collect standardized quantitative data, and prepare the data for later statistical analysis.

The numerical results from the questionnaire may also provide a practical basis for improving and revising online mathematical courses for adults so they better match actual needs in the adult online education market.

3.1. Sampling

This investigation relies on a convenient sample consisting of 89 adult participants aged 20 years or older. Research data were collected through questionnaires distributed as an online survey link. The age threshold was set deliberately. Although adulthood is often defined as beginning at the age of 18 years old, and this generally fits the target demographic of online mathematics courses, the lower age limit in this study was adjusted to 20 years old to allow for differences in individual life timelines.

For example, people may begin primary school at different ages or complete high school at different times, which means that people of the same chronological age may still be at quite different life stages. By setting the minimum participant age at 20, the study assumes that respondents have gained at least a basic level of adult life experience. This does not remove every confounding factor, but it may blueuce variation linked to limited maturity and life exposure, which could improve the reliability of the collected results.

3.2. Example questions

The questionnaire uses a funnel-style question sequence. It begins with short and general demographic items, including respondents' gender, age and occupational background. These opening questions are simple and help participants settle into the online questionnaire format before moving on to the main part of the survey.

The core research questions use a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). This allows psychological perceptions and motivational tendencies to be recorded as numerical data that can be analyzed statistically. For example:

To what extent do you agree: if there is an adult math thinking class, I would be willing to know more.

To what extent do you agree: I would be attracted to this title for an online mathematic course.

To what extent do you agree: I think this type of online course would be helpful for me.

The Likert rating system turns subjective attitudes into numerical values for later quantitative analysis. After the scaled questions, the questionnaire ends with open-ended questions, where respondents can give personal feedback, explain their opinions, or provide relevant examples.

Strict confidentiality protocols are implemented throughout the research. All survey outcomes will be compiled and analyzed anonymously, and no identifiable personal information of participants will be included in the final research document. Before the survey began, the introductory preamble of the online survey stated the research objectives clearly and specified that all collected data would be used exclusively for the compilation of this academic report.

4. Data analysis

4.1. Data processing and sample preview

Before formal analysis, data cleaning was conducted to ensure research quality. A three-step cleaning procedure was applied. First each submission was checked for completeness. Secondly ordinal Likert scale responses were converted from categorical labels into numerical data on a 1 to 5 scale, where 1 represents strongly disagree and 5 representing strong agreement. Thirdly, response duration was computed from the time stamp difference between submission start and completion. The mean completion time was 3.54 minutes, with a median of 2.20minutes and the standard deviation of 3.99, which is consistent with the length of the questionnaire; six responses were completed in under one minute and were flagged as potential low-effort submission but retained in the main analysis, with their influence addressed in the bias discussion below.

4.2. Descriptive statistics of the sample

Descriptive statistics refers to "Techniques that allow one to generalize from one group to a larger group are known as tests of statistical significance and fall within the body of knowledge called inferential or inductive statistics" [2]. In this study a total of 89 valid adult responses were retained for final data analysis. The valid sample consists of participants aged 20 and above with diverse gender, age and occupational backgrounds, ensuring basic population diversity for exploring adult learning motivation. This preliminary data screening guarantees the integrity and accuracy of subsequent statistical analysis.

The sample comprised 89 adults aged 20 and above. Females accounted for 55 participants (61.8%) and males for 34 (38.2%). The age distribution was concentrated in the middle to older adult range: the 36-40 band was the largest (n = 19, 21.3%), 20-25 (n = 11, 12.4%),31-35(n = 10, 11.2%), and 26-30 (n = 7, 15.7%); the remaining participants were spread across technology, public service, business management, consulting, healthcare and manufacturing.

As the start of the questionnaire, introductory questions were implied. Two background variables are particularly relevant to the research question. Regarding feelings towards mathematics and schooling, 34 participants (38.2%) reported enjoying mathematics and finding problem-solving pleasurable, 33 (37.1%) described it as a plain ordinary subject with no particular emotion, 16 (18%) felt slightly pressured and often found it difficult, the remaining 6 (6.7%) participants felt rather fearful or anxious about mathematics during schooling years.

Regarding self – reported school mathematics performance, 41 participants (46.1%) placed themselves in the top 25% of their class, 27 (30.3%) in the 25-50 band, 14 (15.7%) around the 50th percentile, 6 (6.7%) in the 50-75% band and 1 (1.1%) in the bottom 25%. The over-representation of participants with positive mathematics academic scores is an important sampling characteristic and is discussed as a source of self-selection bias in section 4.7.

4.3. Likert scale results

Four – five-point Likert items measured adults' attitudes toward an adult oriented mathematical course were done and the results are summarized below.

Item 1 – the willingness to learn more about the course. The mean score presented was 3.35 with a standard deviation of 0.99 and a median of 3. This result shows that the majority of adults hold a neutral attitude towards adult oriented online mathematic courses, this shows that there is a demand in the market, and the subsequent courses have promising prospects for development. The standard deviation of 0.99 demonstrates that data points deviate from the mean by average of 0.99 units, reflecting moderate variability within the

sample. In terms of the context in this investigation, on the positive side 44.9% of participants expressed willingness to learn more and 38.2% chose the neutral point with 16.9% left felling onto the disagree side of the Likert scale.

Item 2 – concerns the appeal of the model class titled "Using 10 minutes to rescue you as a child once trapped by mathematic questions". This emotionally framed title yielded a mean score of 3.46 (SD = 1.14, median 4) with 52.8% of participants on the positive side, 28.1 neutral and 19.1% negative. When comparing the two titles presented to the participants, this title received a more favorable feedback, with its median falling within the positive range. This indicates that narratives connecting adult learning to the resolution of childhood associated emotions carry tangible appeal. The concept of rescuing one's childhood self is likely to evoke recollections of the respondents' own past experience, memories of peers in the former classrooms, or even images of their children (for participants that are parents) sitting in front of their desk, struggling to solve a particular question.

Item 3 – relating to the topic of solving classical escape room problems received a less favorable result statistically, but in the previous question of "in daily life or leisure activities, in which of the following situations do you feel your logical/reasoning skills are lacking" the top two answers chosen by the participants were "having a hard time figuring out clues when playing escaping rooms or murder mystery games" and "tends to rely on intuition when analyzing problems and lacks a habit of structured thinking" which shows the high demand that adults would want to improve their structured thinking skills and one of the application scenarios could be escape rooms.

This result shows that such affective resonance may be particularly potent for adult learners, who often carry unresolved feelings of anxiety and inadequacy stemming from past mathematical education. Unlike titles that emphasize practical vocational benefits or curriculum objectives, this framing reframes adult mathematical upskilling not merely as skill acquisition, but as an act of emotional repair. It transforms mathematics from a source of past stress into a tool for self-compensation which may lower the psychological barrier for adults to engage with mathematical content voluntarily. Furthermore, this finding implies that promotional materials for adult mathematics programs could leverage nostalgic, child-centered emotional narratives to boost enrolment interest, rather than relying exclusively on pragmatic spelling points such as career advancement or resume enhancement.

Item 4 – measured participant's perceived helpfulness of this type of online adult education course. It was the most positively related item, yielding a mean of 3.73, a standard deviation of 0.94 and a median of 4. Fully 70.8% of participants agreed that such a course could help them, 16.9% were neutral and only 12.4% disagreed. The gap between the perceived helpfulness and actual willingness to engage is notable. These findings indicate a strongly positive stance among adults regarding their willingness to invest time in participating in online mathematics courses and adults broadly recognize the value of mathematical thinking training.

4.4. Reliability and correlation analysis

The four Likert items were treated as a composite scale measuring overall acceptance of adult mathematical thinking courses. Person correlations among the items were all positive and statistically meaningful in direction. The strongest association was between willingness to learn and perceived helpfulness (r = 0.74), this was followed by willingness and the emotional title item (r = 0.68). The escape room titled showed weaker correlations with the other three items, confirming that it taps a partially distinct preference rather than general course acceptance. This divergence is itself evidence that gamification is not uniformly aligned with overall motivation and must be deployed selectively.

4.5 Bias assessments and mitigation

Biases have the potential to substantially distort the outcomes and interpretive conclusions of any empirical investigation. For this reason, multiple potential sources of bias within the present study were identified prior to data collection and subsequently mitigated through targeted procedural adjustments.

Self-selection bias – the survey was distributed online and themed around an adult mathematical thinking course, participants who chose to respond may already be more interested in or positively disposed towards mathematics than the general adult population. This is reflected in the sample composition: 46.1% reported top quartile school performance and 38.2% reported enjoying mathematics, both higher than would be expected in a representative adult sample. Consequently, the positive attitude means reported here should be interpreted as upper-bound estimates for the general population, true willingness among adults with weaker mathematics histories may be lower. This limitation is mitigated by explicitly framing the findings as indicative of market potential among self-selected interested adults rather than population wide prevalence.

Participant response bias – all variables were self-reported on a single questionnaire. In addition, six responses were completed in under one minute, raising the possibility of careless or satisficing responding. The questionnaire was design using a funnel sequence with demographic items first to reduce inattention, Likert scale and open-ended data were triangulated against each other, and the potential downward effect on reliability caused by the six responses were acknowledged.

Research bias – as both course designer and the data analyst, the researcher may be predisposed to interpret results favorably toward the course concept, potentially affected by confirmation bias. Quantitative findings are reported as objective means, percentages and correlation coefficients prior to interpretation; interpretation is anchored to the data rather than to the hypothesis.

5. Couse design

Built upon the questionnaire outcomes analyzed in section 4, this section translates empirical learner preferences and motivational barriers into practical course-design decisions for adult-oriented mathematical critical-thinking lessons. According to Lieb "Adults are autonomous and self-directed. They need to be free to direct themselves" [3]. As well as relating to the Survey data demonstrated that adults value real – world structured reasoning over computational drill, emotional baggage from past school mathematics creates affective barriers and overt gamified puzzle framing generates polarized responses. Accordingly, the course avoids school style exam focused mathematics and balances gamified elements with practical utility, rather than relying purely on game-oriented hooks.

5.1. Core design principles derived from survey data

Real-life relevance comes first. The lessons focus on struct blue reasoning for everyday and workplace dilemmas because this was the most common self-reported difficulty in the survey, a lack of struct blue thinking habits.

Gamification should be moderated. Feedback on the escape room themed title was clearly split, so game-like scenarios are used only when they help learners practice reasoning, not as surface-level entertainment.

5.2. Two lesson case studies

To show how these principles work in practice, two sample lessons were developed. Each lesson sets learning objectives that target critical thinking rather than formula memorization, uses target learner profiles based on subgroup patterns in the survey, and follows a condensed lesson flow.

Lesson 1: "Using 10 minutes to rescue you as a child once trapped by mathematic questions". This lesson addresses the emotional side of mathematical difficulty while working through specific problems that learners have often found hard in the past. It moves across a range of strategies, beginning with accessible visual sketching so learners can see the structure of the problem more clearly, then shifting to more complex function based solving techniques when needed. The sequence matters here. Starting with a method that feels manageable may blueuce resistance before more abstract approaches are introduced.

Lesson 2: gamified logical task practice adapted for adults. Based on the subgroup of participants who responded positively to puzzle – style challenges, this lesson uses simplified escape room inspiblue logical tasks connected to real world consequences. The game elements support reasoning practice, but they do not replace the learning goals.

5.3. Key instructional models

Real life logical tasks should be central to lesson design. Tasks are built around multi-condition real world problems, numerical conversion challenges, and rhetorical trap identification, because these were exactly the trouble points participants selected in the multiple-choice survey question.

Open-ended problem-solving is also necessary. The emphasis is placed on the reasoning process rather than one correct answer, since many open-ended survey responses described mathematics mainly as a thinking tool rather than a calculation exercise.

6. Core findings/ analysis

6.1. Empirical findings synthesized from questionnaire data

The questionnaire suggests an intent-behavior gap. Most adults in the survey acknowledged the practical value of mathematical thinking training, but far fewer showed a clear willingness to take part themselves.

Emotional experience seems to matter more than past academic performance. Negative memories of school mathematics appear to have suppressed adults' willingness to return more strongly than whether they had once performed well or poorly in that subject. One might expect historical grades to be the main factor, but the responses here point in a different direction.

Attitudes toward gamification are mixed rather than consistent. The emotion validation framework was widely accepted, while the puzzle themed framework appealed to one subgroup and put off another. This split should affect design choices. A single game-heavy model would likely miss part of the adult learner group the survey is trying to reach.

Age patterns were also uneven. Elder participants showed higher acceptance, while mid-aged participants showed higher willingness, possibly because of the lack of time from their work. This difference suggests that positive attitudes and practical readiness to participate are not always the same thing.

6.2 The advantages of gamification in adult mathematics thinking courses

When gamification is implemented in a modernized way, it can reduce psychological resistance, increase task engagement and make the abstract logical thinking techniques more tangible to apply. For participants who are already interested in solving puzzles, elements related to the game enhance the sense of immersion in the situation. By wrapping reasoning exercises in scenario-based tasks, gamification helps to separate adult learning from unpleasant memories of school mathematics, supporting the reconstruction of learning motivation proposed in the research hypothesis.

6.3. The disadvantages of gamification in adult mathematics thinking courses

Gamification cannot be used as a universal solution to increase motivation for adult learning. The survey data only shows a small proportion of 89 samples, which cannot be concluded to represent all adults in the world, also the questions are whole based on self-reported data, and the sampling method was random sampling. Preferences would vary from each subgroup and individual experience would also be a considerably weighty amount.

6.4. Relating to present theories about adult learning

These results are in line with the core principles of andragogy [4]: "have an orientation to learning that is grounded in real-world scenarios of personal importance" and "are internally motivated by goal attainment and problem resolution". The observed intention-to-behavior gap also indicates that restoring motivation requires more than just an attractive course concept, structural constraints such as limited available time for a adult to join in with a highly mathematical related course could also be a barrier, as psychologically the memory and focus could not be overloaded with new information, that should be taken account in the curriculum development.

7. Conclusion

Supported partially by the questionnaire data, the core hypothesis predicts that adults are able to regain motivation towards mathematic learning through gamified courses. Through analyzing the data from the survey, gamification brings both strengths and risks. It should be deployed in moderation and always anchored to real-life practical value rather than used as a superficial marketing feature to attract consumers. This study relies entirely on the questionnaire data of 89 participants. No real course intervention was implemented, so actual learning outcomes and sustained motivational change cannot be measured. Future work could expand sample diversity through stratified sampling in order to cover a larger range of occupational and educational backgrounds. More qualitative data could be gained towards the change of motivation throughout the study to give a better understanding of the relationship of course design for adults and the learning motivation. As past studies state, "We need much more attention to how making meaning, critical thinking and entering new cognitive and instrumental domains are viscerally experienced processes" [5]. Therefore further research remains necessary to enhance scholarly understanding of this field.

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