



Learning Strategies for Proof-Based Courses: Real Analysis at Tribhuvan University

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Abstract

Students majoring in mathematics at the bachelor's level at Tribhuvan University, Nepal, must take a proof-based course: Real Analysis. Under the convenience sampling, the study was conducted among 60 students of different campuses of Tribhuvan University to identify the most used learning Strategies of the O'Malley et al. (1985) framework. Participants were categorized as cognitive, metacognitive, and socio-affective strategies users with the help of semi-structured interviews. The relationship between strategies used and academic achievement (pass/fail in Real Analysis: Maths 425, Maths 302, and Maths 423 of the final examination 2024) was analyzed using statistical tools: percentage and Fisher's Exact Test. The result showed that most of the students (57%) who followed the cognitive strategies had the lowest pass rate (29.41%), whereas the students (33%) who used the metacognitive strategies had a higher pass rate (70%), and the association between strategy type and achievement was statistically significant. The finding shows that although cognitive strategies are commonly used but, they are not effective for examination success. The study suggests following the instructions guided by metacognitive strategies to get better results in the examination in the evidence-based nature courses of mathematics at the undergraduate level.

Keywords: Cognitive strategies, metacognitive strategies, proof-based courses, socio-affective strategies

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Introduction

Students majoring in mathematics at the bachelor's level from science, humanities as well as education streams at Tribhuvan University, Nepal, need to study some proof-based courses. Among them, Real Analysis is one of the most common and compulsory subjects in which students have to rigorously study the properties of real number system, $\mathbb{R}$ (completeness, order, Archimedean property), point set topology, sequences and series (convergence, Cauchy sequences, $\limsup/\liminf$), limits and continuity (ϵ - δ definition, intermediate value theorem), differentiation (mean value theorem, Taylor's theorem, inverse/implicit function theorems in one dimension), Riemann integration (Riemann sums, fundamental theorem of calculus), sequences and series of functions (point-wise/uniform convergence, different tests). These concepts built the axiomatic structure of the real number system. Real analysis emphasizes proofs, theoretical underpinnings, and precise logical justification of the results. So, it is called a proof-

based course.

From school to university level, mathematics has been recognized as a difficult subject. Thinking the same, proof-based mathematics courses are often seen as rote-learning courses. This discipline has become difficult due to its inherent character or improper facilitation, which has now become a burning issue. Mathematics learning is considered abstract thinking. An active role for the learner is demanding; the learning context and role of the facilitator are significant. Analyzing how a learner generally practices learning, what contexts and environments are most demanding in his or her learning style, and how the demands have been met is crucial in diagnosing and remedying mathematics learning.

How student sets their learning goal and develops a procedural plan for learning is defined as a learning strategy (hereafter LS). According to Oxford (1990), the concept of learning strategies refers to the specific actions, through thoughts, or behaviors that learners intentionally



employ to facilitate the acquisition, integration, and retrieval of knowledge. Weinstein and Mayer (as cited in Wittrock, 1986) defined learning strategies as behaviors and thoughts that a learner engages in during learning and that are intended to influence the learner's encoding process. As mentioned above, LS are actions learners take to assist in learning more effectively.

Over the past decades, several taxonomies have been proposed. Among them, the taxonomies proposed by O'Malley (1985), Rubin (1987), Oxford (1990), Sten (1992), etc., are quite widely familiar. Though these frameworks seem to differ in terminology, they can be categorized among cognitive (direct manipulation of materials), metacognitive (planning, self-monitoring, and evaluation), and socio-effective (social interaction and emotional regulation) strategies. This classification is exactly similar to the O'Malley framework.

O'Malley et al. (1985) classification of Learning Strategies (LS)

O'Malley et al. (1985) divided the LS into three main categories: Cognitive, Metacognitive, and socio-affective strategies.

i) Cognitive Strategies:

Cognitive Strategies provoke mental processes or procedures that help to acquire, manage, understand, and retrieve knowledge. Recitation, rote learning, rehearsal, elaboration, organization (structuring information), comprehension monitoring, inference, etc., are learning strategies. Cognitive strategies directly manipulate the material to be learned.

ii) Metacognitive Strategies:

Metacognitive Strategies provoke the thinking about (or knowledge of) the learning process, planning for learning, monitoring learning while it is taking place, and self-evaluation of learning after the task has been completed. Advance organizers, directed attention, selective attention, self-management, functional planning, self-monitoring, and self-evaluation are the major metacognitive strategies.

iii) Socio-affective Strategies:

Socio-affective strategies are the tools learners use to regulate their emotions (effectively) and leverage social interaction to facilitate comprehension, retention, and production. Working with peers, teachers, or native speakers to solve problems, share information, practice skills, or get feedback are the main activities under these strategies.

This study aims to explore and investigate the significant association between strategy use and the respective achievement of the students with real data in real ground and opens a wide horizon for the researchers. Not only the superficial analysis, it demands the in-depth and the systematic insights on the specific subjects and even the specific units as well. As real analysis is one of the core and fundamental mathematical discipline, it is better to

have the separate investigations. Majority of the Bachelor level students who doing major in Mathematics in any disciplines are facing challenges with Analysis and feels difficult. Based on these fundamental learning strategies and the nature, system, challenges, and practices of our existing teaching learning activities, we are encouraged to these research questions.

Research Questions

The research questions are as follows.

- i) What are the most frequently used learning strategies (LS) among Nepalese bachelor-level students studying Real Analysis at Tribhuvan University?
- ii) Is there a significant relationship between students' achievement levels (pass/fail) and their use of learning strategies (LS)?

Methods

In this study, a pragmatist paradigm was adopted, enabling the integration of both qualitative and quantitative data. The research design was exploratory, using a mixed-method (abductive) approach and semi-structured interviews as the primary data collection tool.

Qualitative data were gathered from semi-structured interviews conducted with 60 bachelor-level students. Their responses were systematically categorized into cognitive, metacognitive, and socio-affective learning strategies following O'Malley et al. (1985) framework. These categorical data were then transformed into quantitative form by calculating the proportion of students in each category. To investigate the relationship between the type of learning strategy employed and academic achievement (pass/fail status), the study applied Fisher's Exact Test, a statistical method suitable for small sample sizes and categorical data. This process enabled the identification of significant associations between learning strategy use and examination success, thereby providing both descriptive and inferential insights into the effectiveness of different strategies.

Participants and Sampling

A convenient sample of 60 bachelor-level students was selected to represent a diverse range of academic backgrounds within Tribhuvan University. The participants included 17 third-year students from science and humanities faculties, and 43 second-year students of the education faculty. All students had appeared for the final university examination of Real Analysis (Math 425, MAT 302, and Math Ed.) during the academic year 2024. To ensure the sample reflected both urban and rural academic settings, students were drawn from four major campuses located at four different locations of our country: Prithvi Narayan Multiple Campus (Pokhara), Gorkha Campus (Gorkha), Aadikavi Bhanubhakta Campus (Tanahun), and Dhaulagiri Multiple Campus (Baglung) of Tribhuvan University, Nepal. Such a sampling strategy allowed for the capture of a broad cross-section of experiences, learning environments,

and resource availability. This support increases the generalizability and relevance of the findings for Nepalese higher education.

Procedure

Data collection took place between February to March 2024. The researcher conducted individual semi-structured interviews lasting 10 to 15 minutes for each participant. Interviews were guided by open-ended questions derived from literature and the help of an expert educationist. (e.g., how did you prepare this subject for the examination? How did you plan your studies? Did you discuss problems with classmates, seniors, or teachers?, etc.). All interviews were audio-recorded with participants' consent and transcribed into English for analysis. Academic achievement data (pass/fail in the subject) were collected from campus records after obtaining institutional permission. A pass was awarded in accordance with university regulations.

Data Analysis

Using the taxonomy given by O'Malley et al. (1985), two independent coders categorized each participant's dominant strategy based on the interview transcripts. Inter-rated agreement was 90%, and disagreements were resolved through intensive discussion between the two coders and the researcher. After categorizing the strategies, the frequencies and percentages of each strategy type were calculated and summarized in a frequency distribution table. This provided a clear overview of the prevalence of each learning strategy among the participants.

To further examine the relationship between strategy types and the students' academic outcomes (pass or fail), a Fisher's Exact Test of independence was performed, followed by the calculation of adjusted standardized residuals to identify which strategy types differed significantly from expected values. Pass rates were reported with 95% confidence intervals (Wilson Score Method) because of small sample

sizes considered. Statistical significance was set at $\alpha = 0.05$.

Results

Dominant Learning Strategies

Table 1 provides the distribution of predominant LS among the 60 students. 57 percent of the students employed cognitive strategies, while 33 percent used metacognitive strategies, and 10 percent utilized socio-affective typical descriptions for each category included.

Cognitive strategy: "I read the note-copy/textbook again and again and attempt to memorize the steps of the proof."

Metacognitive Strategy: "Before starting a chapter, I set a goal to understand the definition and basic concepts and solve at least 5/6 fundamental problems. Then, I intensively practice the remaining portion of the chapter."

Socio-affective Strategy: "When I encounter difficulties, I ask my friend to explain it to me. Sometimes we study together and interact with what we understand."

Table 1: Preference of Learning Strategy (N = 60)

Strategy	N	Percentage (%)
Cognitive	34	57
Metacognitive	20	33
Socio-affective	6	10
Total	60	100

Relationship Between Strategies and Achievement

Due to the small size of the Socio-affective strategy, Fisher's Exact Test was used to calculate statistical significance. To calculate the 95% confidence intervals (CI), the Wilson Score method was employed as it provides more reliability for small sample sizes and proportions near the boundaries of 0% and 100% (Brown, L. D et al., 2001).

Table 2: Academic Achievement by Learning Strategies

Strategy	Pass (n)	Fail (n)	Total (n)	Pass Rate (%)	95% Exact (Fisher) CI
Cognitive	10	24	34	29.41	[15.10% - 47.48%]
Metacognitive	14	6	20	70.00	[45.72% - 88.11%]
Socio-affective	2	4	6	33.33	[4.33% - 77.72%]
Total	26	34	60	43.33	[30.59% - 56.76%]

Graphically, this can be presented as in Figure 1.

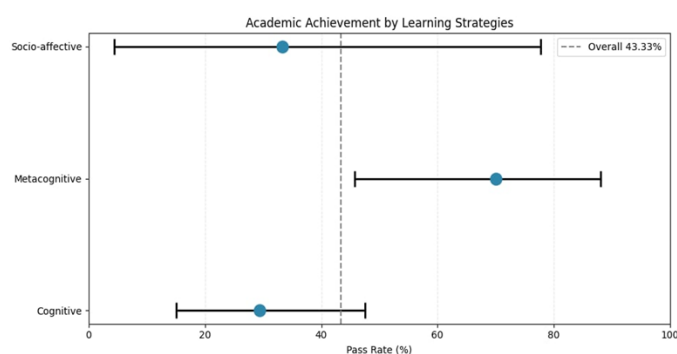


Figure 1: Academic Achievement by Learning Strategies

Based on Fisher's Exact Test with respect to Exact Confidence Intervals (CI), the result of Table 2 shows a statistically significant association between the learning strategy employed and the success rate of the participants ($p = 0.0148$). The metacognitive strategy seemed to be the most effective strategy because the pass rate is 70% with an exact 95% confidence interval of [45.72% - 88.11%]. This indicates a high level of worth, as even the lower bound of this interval remains above the overall average pass rate of 43.33%. On the other hand, though most of the students followed the cognitive strategy, the result is a significantly lower pass rate of 29.41% at 95% CI: [15.10% - 47.48%]. The Socio-affective strategy showed a pass rate of 33.33%, but due to the very small size, its exact confidence interval is extremely wide [3.33% - 77.72%], suggesting that these results should be interpreted with caution.

Overall, the table shows that metacognitive strategies appear to be superior, with a distinct and statistically measurable advantage in performance compared to purely cognitive or socio-affective strategies.

Discussion

This study aimed to survey the learning strategies used by Nepalese Bachelor-level students in Real Analysis and to examine the relationship between strategy use and academic achievement. The results show that cognitive strategies are overwhelmingly preferred (57%), yet they are associated with very low examination success (29.41% pass rate). In contrast, metacognitive strategies, through using only a minority (33%), are highly effective (70% pass rate). These findings align with previous research in other contexts (Ali & Raza, 2020; O'Malley et al., 1985) and extend them to the specific domain of Real Analysis in Nepal.

Why do students persist in using ineffective cognitive strategies? One probable explanation is that prior schooling- from primary to higher secondary levels- emphasizes memorization, repetition, and rote learning (Khanal, 2013). Students may have internalized these habits because they were rewarded for them in less demanding courses. However, Real Analysis requires abstract reasoning, theorem proving, and the ability to connect

multiple concepts; tasks that are poorly served by simple repetition. Without explicit instruction in metacognitive skills such as planning, self-monitoring, and evaluation, students default to familiar but inadequate approaches.

The very pass rate among cognitive strategy users is alarming. It suggests that most students who rely on rehearsal and verbatim memorization are destined to fail. This is not merely a matter of individual deficiency; it reflects a systematic issue in mathematics pedagogy. As Paneru (2013) noted, Nepalese mathematics instruction rarely includes strategy training. Teachers often assume that students will automatically develop effective study methods, but this assumption is false.

Limitations of the Study

The study had several limitations.

- Course Selection:** Among the many proof-based courses at the bachelor-level, only real analysis was studied. The findings may not apply to other mathematics subjects with different cognitive demands.
- Research paradigm, approach, and design:** The study employed a pragmatist paradigm, a mixed method (Abductive) approach, and an exploratory design with open-ended interviews.
- Sampling Method:** A convenient sampling method was used. The study population consisted of third-year B. Sc. and B. A. students, as well as second-year B.Ed. Students who had completed the final examination (2024) of the university and received their results. Participants were from Prithvi Narayan Campus (Pokhara, Kaski), Gorkha Campus (Gorkha), Dhaulagiri Multiple Campus (Dhaulagiri), and Aadikavi Bhanubhakta Campus (Tanahun).
- Categorization of Strategies:** Students' responses were categorized only according to O'Malley et al. (1985) framework: cognitive, metacognitive, and socio-affective.
- Selection of statistical tools:** The analysis was limited to basic statistical tools: percentage and Fisher's exact test.
- Other limitations:** The findings were based on self-reported interviews concerning how students studied for the real analysis course for the examination outcomes, which were only categorized as pass or fail without accounting for students' prior mathematics achievements.

Implication of the Study

The findings of this study have clear practical applications for mathematics educators, curriculum designers, and students in choosing the appropriate LS based on the nature of the subjects.

Conclusion

The findings of this study reveal that Nepalese bachelor-level students studying Real Analysis predominantly use cognitive learning strategies such as repetition, memorization, and translation. But these strategies are largely ineffective for passing the course. In contrast, students who employ the metacognitive strategies like planning their study sessions, self-monitoring their understanding, and regularly evaluating their progress are highly effective and achieve at much higher rates.

This significant association between strategy use and achievement (pass/fail) suggests adopting the suitable LS in learning/teaching activities in mathematics education. Encouraging students to adopt the metacognitive strategies can foster deeper understanding and improve their overall academic performance. Given these insights, future research should expand on the current findings by employing larger, randomly selected samples to increase the generalizability of results. In addition, using continuous measures of academic achievement rather than simple pass/fail results would provide a more relevant and implemented understanding of how different strategies affect learning. An intervention study is also expected to test whether teaching metacognitive strategies directly improves pass rate and the learning outcomes in mathematics courses.

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