Do explicit learning outcomes help or hinder: Evidence from a small-scale experimental study in calculus.

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Sharing learning outcomes prior to instruction is commonly justified through constructive alignment and theories of self-regulated learning. Constructive alignment proposes that clearly articulated outcomes align teaching and assessment, while research on self-regulation suggests that explicit goals support planning and monitoring. However, experimental evidence of their impact on undergraduate mathematics appears limited. This study reports a small-scale randomised experiment examining whether learning-outcome prompts influence achievement in a calculus topic (sequences). Twenty-two participants were randomly assigned to a treatment group (n =12), who received notes with learning outcome prompts and were instructed to use them to guide their reading and understanding, or to a control group (n = 10), who received identical notes without outcomes and were instructed to read for understanding. Participants completed a 12-item quiz and a brief background survey. An independent-samples t-test showed that the treatment group (M = 9.33, SD = 3.42) scored lower than the control group (M = 11.60, SD = 4.55), though the difference was not statistically significant, $t(20) = 1.34$, p = .197. The effect size was moderate (d = 0.57). Given the small sample, the study was likely underpowered. Follow-up interviews with six students suggested that learning outcomes functioned as navigational tools. The findings complicate assumptions about learning outcome-sharing and raise questions about how students interpret and enact stated goals in university mathematics.

Keywords: learning outcome, learning objectives, calculus.

Introduction

The practice of sharing learning outcomes with students before instruction has become commonplace in higher education. In many institutional contexts, course outlines and lecture slides foreground what students are expected to know or do by the end of a course, a topic, or a lecture. Instructors are often encouraged, and sometimes required, to make these expectations explicit. Within such environments, learning outcomes are often considered pedagogically beneficial because they clarify expectations, focus attention, and help align teaching with assessment.

This assumption is often grounded in the idea of constructive alignment (Biggs, 1996; Biggs & Tang, 2011). Constructive alignment proposes that effective teaching depends on the deliberate alignment of intended learning outcomes, teaching and learning activities, and assessment tasks. In this view, making learning outcomes visible to students is not an administrative exercise but part of the pedagogical architecture of a course. If students understand what they are expected to learn, they may be better positioned to engage with relevant tasks and recognise what matters in the material.

A second justification comes from theories of self-regulated learning. From this perspective, learners benefit from explicit goals because goals support planning, monitoring, and evaluation of one's own learning (Pintrich, 2004; Winne & Hadwin, 1998; Zimmerman, 2002). Students who are given clear targets may organise their reading more effectively, direct attention to important concepts, and monitor whether they have achieved what was intended. Explicit learning outcomes might therefore function as tools for orientation and metacognitive support.

Although these arguments are compelling, their application in undergraduate mathematics deserves closer scrutiny. Mathematics learning often involves navigating between conceptual understanding, symbolic manipulation, definition use, and proof-like reasoning. While learning outcomes are meant to provide clarity for students, they may not always foster deeper understanding. There is also a risk that students may interpret outcomes narrowly, treating them as a checklist of examinable items rather than as guides to meaningful engagement. In this sense, explicit learning outcomes may support focus while simultaneously constraining curiosity or relational understanding (Skemp, 1976).

The present study emerges from this tension. It asks a simple but important question: when students are given notes on a calculus topic, does including explicit learning outcome prompts improve achievement? The topic chosen was sequences, a foundational topic in Calculus II that often requires students to connect definition, representation, symbolic notation, and conceptual interpretation. A small-scale randomised experiment was conducted to compare performance between students who read notes with learning outcome prompts and those who read otherwise identical notes without such prompts. Follow-up interviews were also used to explore students' perceptions of the prompts.

The study is modest in scale and exploratory in purpose. It does not claim to settle the broader debate about learning outcomes. Rather, it offers a small piece of empirical evidence within undergraduate mathematics, where experimental work on this issue appears limited. In doing so, it contributes to wider discussions about curricular transparency, student agency, and the relationship between instructional structure and mathematical understanding.

Methodology

Research Design

A small-scale randomised experimental design was employed. Participants were assigned to one of two groups: a treatment group that received notes with explicit learning-outcome prompts, and a control group that received identical notes without learning-outcome prompts. The study focused on a single calculus topic, sequences, in order to maintain a manageable and controlled intervention. The experiment was designed to test whether explicit learning-outcome prompts, when presented before reading and referenced in the instructions, would influence short-term achievement on a post-reading quiz. The design does not isolate all possible mechanisms or covariates, but it provides a direct comparison between a learning outcome-prompt condition and a no learning outcome-prompt condition.

Participants

Twenty-two participants took part in the study. They were randomly assigned to a control group (n = 10) and a treatment group (n = 12). All participants had a relevant mathematical background sufficient to engage with introductory material on sequences. Because the study was exploratory and conducted on a small scale, the sample is not treated as representative of all undergraduate calculus learners. Rather, it provides an initial test case for examining how such prompts may function in a university mathematics setting

Materials and Procedure

The two groups of participants received calculus notes on sequences. The notes covered the core ideas needed for the reading task and subsequent quiz. These were: (i) definition and notation for sequences; (ii) numerical and graphical representations; (iii) convergent and divergent sequences; and (iv) canonical examples (e.g., geometric sequences).

The treatment version included a section with learning-outcome prompts at the beginning of the notes. These prompts stated the intended learning goals, and participants were explicitly instructed to use them to guide their reading and for understanding the material. The control group received the same notes without the learning outcomes and were instructed simply to read in order to understand the content.

After completing the reading task, all participants completed a 12-item quiz on sequences. The quiz was designed to assess understanding of the material covered in the notes. Participants also completed a brief demographic and academic background survey.

To complement the quantitative data, follow-up interviews were conducted with six students who had experienced classes in which learning outcomes were routinely shared at the beginning of lectures. These interviews were used not to validate the experimental result directly, but to explore how students described the role of learning outcomes when engaging with mathematical text and instruction.

Analysis

An independent-samples t-test was used to compare quiz scores between the treatment and control groups. Means and standard deviations were calculated for each group, and Cohen's d was used as an effect size measure. A 95% confidence interval for the effect size was also estimated. Because the sample size was small, the analysis was interpreted cautiously, with attention given to both statistical significance and effect size.

A brief post hoc power analysis was also conducted to assess the likely sensitivity of the study and to estimate sample size requirements for future work. This is important because a nonsignificant result in a small-sample experiment may reflect limited power rather than evidence of no effect.

Main Findings

Table 1 presents the descriptive statistics for quiz performance by group. The treatment group, which received notes with learning-outcome prompts, obtained a lower mean score than the control group on the post-reading quiz.

Table 1: Descriptive statistics for quiz scores by group

Group	n	Mean	SD
Control (without learning outcomes)	10	11.60	4.55
Treatment (with learning outcomes)	12	9.33	3.42

Although the difference in means is not large in absolute terms, it runs counter to the assumption that learning outcome prompts would necessarily enhance the performance on the reading task.

Inferential Statistics

Table 2 presents the inferential statistics supporting the differences in quiz scores of the two groups. An independent-samples t-test indicated that the difference between groups was not statistically significant, $t(20) = 1.34$, $p = .197$. The observed effect size was moderate, $d = 0.57$, with a wide 95% confidence interval, reflecting the uncertainty associated with the small sample.

Table 2: Independent-samples t-test and effect size summary

t	df	p	Cohen's d	95% CI for d	Approx. power
1.34	20	.197	0.57	[−1.281, 5.819]	.27

The confidence interval crosses zero, so the data are compatible with a range of possible effects, including no effect. Nonetheless, the observed difference is not trivial and warrants attention, especially because the direction of the effect runs contrary to the usual pedagogical expectation.

Because the study was exploratory and based on a small sample, it is important to interpret the non-significant result in relation to statistical power. With group sizes of 10 and 12, the study had limited ability to detect small or moderate effects reliably. Using the observed effect size from the present study ($|d| = 0.57$), the achieved power for a two-tailed independent-samples comparison at $\alpha = .05$ is approximately .27. In practical terms, this means that even if a true effect of this magnitude existed, the probability of detecting it with the current sample would have been low.

To estimate a more appropriate sample size for future work, illustrative calculations were conducted for a two-group independent-samples design with equal group sizes, $\alpha = .05$, and a desired power of .80. Assuming a moderate effect size ($d = 0.57$), approximately 50 participants per group (100 total) would be required. If a more conservative assumption of $d = 0.50$ is used, the estimate increases to approximately 64 participants per group (128 total). For a smaller effect of $d = 0.40$, approximately 100 participants per group (200 total) would be needed. Table 3 summarises these estimated sample sizes, related effect sizes, and power.

These estimates reinforce the point that the present study should be read as a pilot investigation rather than as a definitive test of the effect of learning outcome prompts. The absence of statistical significance should not be taken as straightforward evidence that the intervention had no effect. Rather, the study was substantially underpowered, and the observed moderate effect size suggests that a larger trial would be justified. The present experiment is valuable because it identifies a plausible pattern, highlights the need for careful interpretation, and informs the design of a more adequately powered follow-up study.

Table 3: Illustrative sample size requirements for future studies.

Assumed effect size (*d*)	Desired power	Required *n* per group
0.57	.80	50
0.50	.80	64
0.40	.80	100

Discussion

The central contribution of this study is not that it proves learning outcomes are harmful, but that it complicates the assumption that sharing them is automatically beneficial. In the present experiment, students who received explicit learning outcome prompts did not outperform students who received the same notes without them. Indeed, the mean score was lower in the treatment group, and the effect size was moderate in magnitude, even though the result was not statistically significant.

A follow-up interview with six students who had experienced lectures where learning outcomes prompts are explicitly shared points to several possible interpretations of the findings of this experimental study. One is that the outcome prompts changed how students approached the reading task. Students may have focused on the listed aims and therefore engaged with the notes in a more selective or procedural way. If the quiz required connections or flexible understanding beyond what students perceived as directly tied to the outcomes, such selectivity may have been disadvantageous. This possibility aligns with concerns from mathematics education about overly instrumental engagement (Skemp, 1976).

A second interpretation is that the effect of learning outcomes depends heavily on how they are introduced and used. Simply placing outcomes at the start of notes may not be sufficient. Outcomes might be more beneficial when instructors unpack them in class, model their use, or revisit them during problem-solving and reflection. In other words, outcomes may be pedagogically effective not merely because they are present, but because of the discourse and activity that surround them.

A third interpretation concerns learner variability. For some students, explicit outcomes may reduce uncertainty and improve focus. For others, especially those who already have strong study routines, the prompts may be redundant or distracting. A larger study would allow exploration of whether prior achievement, confidence, or study habits mediate the effects of outcome-sharing.

The study also raises an important theoretical point. Constructive alignment is primarily a framework for instructional design, but the present findings suggest that design intentions do not map straightforwardly onto student experience. Alignment is not simply a property of curriculum documents; it is enacted through interpretation. Students do not passively receive intended outcomes. They read, infer, and repurpose them according to their own goals and habits. This interpretive dimension is crucial if constructive alignment is to be understood pedagogically rather than administratively.

Conclusion

This paper reports a small-scale experimental study examining whether explicit learning-outcome prompts influence achievement in a calculus topic. The results showed that the treatment group, which received outcome prompts, scored lower on average than the control group, although the difference was not statistically significant. The effect size was moderate, and the study was underpowered, so the findings should be interpreted cautiously. Nonetheless, the pattern is meaningful because it challenges a common pedagogical assumption.

Future research will build on this pilot study with larger samples, stronger power, and richer measures of engagement. It would be valuable to examine how the wording of learning outcomes, topic type, prior achievement, and instructional context shape the effects of sharing learning outcomes. Such work would contribute not only to debates about teaching in undergraduate mathematics but also to broader questions about transparency, self-regulation, and the relationship between pedagogical structure and genuine understanding.

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