Comparing Epistemic Emotions and User Experience Across Two AI Instructional Designs in Biology Learning

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This pilot study investigates how two distinct AI instructional designs shape undergraduate students' epistemic emotions and user experience in biology education. Students interacted with either an AI-Tutor that provided structured conceptual guidance or an AI-Navigator that incorporated an uncertainty-centered instructional approach designed to strategically raise, maintain, and reduce conceptual, procedural, and epistemic uncertainty. After completing a biology lab quiz, students completed the Epistemically-Related Emotions Scales (EES) and several user-experience items. AI-Tutor users reported significantly higher enjoyment, perceived helpfulness, AI preference, and future use intention; while AI-Navigator users showed more varied epistemic-emotion profiles, including slightly elevated confusion. Drawing on Control–Value Theory and the ERAS (Emotion Regulation in Achievement Situations) model, these findings highlight a design tension, which is that systems that enhance perceived control tend to produce more positive epistemic emotions and user experiences, compared to the systems that introduce epistemic friction in the short term.

Introduction

AI-based instructional tools are becoming increasingly common in biology and science education, where they support students as they interpret evidence, solve problems, and construct scientific explanations (Aripin et al., 2024). Recent work shows that generative AI systems do more than streamline tasks. They also shape learners' cognition, epistemic engagement, and emotional experiences as they make sense of complex scientific ideas (Yan et al., 2025). Epistemic emotions play a central role in this process because they signal impasses, motivate deeper inquiry, guide metacognitive regulation, and influence students' willingness to persist with challenging problems (Muis, Chevrier, & Singh, 2018). However, despite the growing use of AI in science classrooms, much remains unknown about how specific AI design features shape the emotional dynamics that arise during scientific reasoning, particularly emotions linked to uncertainty such as curiosity, confusion, surprise, and frustration.

Biology learning frequently involves scientific uncertainty, whether students are analyzing data, evaluating competing interpretations, or reasoning through complex processes (Chen, Park, & Rapkiewcz, 2024). These moments often evoke epistemic emotions, such as confusion, surprise, or curiosity, that influence how learners process conflicting information, regulate their thinking, and engage with the task (Pekrun et al., 2017). The Control–Value Theory of emotions explains that these emotions arise from learners' appraisals of control ("Can I handle this uncertainty?") and value ("Does resolving this matter?") (Pekrun, 2024). High perceived control typically elicits enjoyment and curiosity, whereas reduced control, which is common in uncertainty-rich situations, tends to evoke confusion or frustration (Pekrun, 2024).

The ERAS extends this perspective by describing how learners regulate emotions during academic tasks. ERAS integrates the principles of Control–Value Theory with Gross's process model of emotion regulation, explaining how emotions such as confusion emerge from novelty, conflict, or epistemic impasses and how learners reappraise or regulate these emotions (Harley et al., 2019). Research on confusion regulation shows that confusion can support deeper learning when learners successfully regulate it, but it can also impede progress if it overwhelms perceived control (Muis et al., 2025).

This study compares two AI instructional designs that differ in how they structure uncertainty. The AI-Tutor provides structured, clarity-oriented conceptual guidance intended to sustain students' perceived control. The AI-Navigator builds on the AI-Tutor but embeds the uncertainty-centered instructional approach (Chen et al., 2024), which identifies conceptual, procedural, and epistemic uncertainty and strategically raises, maintains, or reduces that uncertainty to support productive struggle. These designs therefore create different epistemic-emotional experiences. The AI-Tutor may promote smoother, more comfortable interactions, while the AI-Navigator may evoke more effortful but potentially generative emotional states. Using the full 21-item EES (Pekrun et al., 2017) and targeted user-experience items, this study examines how these instructional differences shape students' epistemic emotions and user experiences during biology problem-solving.

Methods

Participants and Context

Participants were 34 undergraduate students enrolled in a biology laboratory course at a large public university in the southwestern United States. The course had two independently registered lab sections, which created naturally occurring groups for the AI-Tutor and AI-Navigator conditions. Both sections completed the same biology quiz and were instructed to use only their assigned AI tool, without assistance from peers, the internet, or other external resources. Immediately afterward, all students completed a post-quiz survey on epistemic emotions and user experience. Seventeen responses were collected from each section.

Designs of AI-Tutor and AI-Navigator

The AI-Tutor was built using a structured prompt that incorporated students' background knowledge, key biological concepts, and common misconceptions. It evaluated student responses without providing answers. When students expressed uncertainty or misunderstanding, the AI-Tutor offered a brief conceptual explanation and asked one or two follow-up questions to confirm understanding. This resulted in a structured, clarity-oriented form of guidance.

The AI-Navigator preserved the AI-Tutor's foundation but added an uncertainty-centered instructional approach. The system identified conceptual uncertainty (gaps in understanding), procedural uncertainty (uncertainty about methods or steps) and epistemic uncertainty (questions about evidence or justification) (Chen et al., 2024). When such uncertainty emerged, the AI-Navigator intentionally increased uncertainty by prompting students to reconsider assumptions, sustained it by withholding confirmation and encouraging deeper reflection, or reduced it when necessary. As with the AI-Tutor, it never provided answers. The design approached uncertainty as a productive space for scientific inquiry.

Measures and Procedure

Students in both groups completed a brief post-quiz survey that included (a) four user-experience items assessing ease of use, perceived helpfulness, preference for AI versus a peer, and intention to use the tool in future biology quizzes; and (b) the full EES (7 subscales: surprise, curiosity, enjoyment, confusion, anxiety, frustration, and boredom) (Pekrun et al., 2017). The internal consistency reliability estimates were acceptable for all subconstructs (α = .65–.91). All items used Likert-type response formats.

Quantitative analyses were conducted in R, including descriptive statistics and inter-correlations among all user-experience and epistemic-emotion variables (Table 3). Group differences between the AI-Tutor and AI-Navigator groups were examined using Welch's t-tests with Cohen's d effect sizes (Tables 1–2). These analyses allowed us to characterize initial emotional and experiential differences across the two AI-supported learning conditions.

Results

Several significant differences in user experiences were found across the two AI designs. As shown in Table 1, students using the AI-Tutor showed a statistically significantly stronger preference for AI over a peer than those using the AI-Navigator, $t(27.89) = -2.32$, $p = .03$, $d = 0.88$. They also demonstrated significantly higher intention to use the tool again, $t(25.13) = -2.41$ $p = .02$, $d = 0.85$, and rated the tool as more helpful, $t(30.92) = -2.35$, $p = .03$, $d = 0.83$. Differences in ease of use favored the AI-Tutor but were not statistically significant ($p = .17$).

Table 1.

Differences in user experience responses between AI-Tutor and AI-Navigator groups.

	Tutor (n=17)		Navigator (n=17)		t	df	p	Cohen's d
	M	SD	M	SD				
AI Preference (vs. Peer)	0.67	0.488	0.27	0.46	-2.32	27.89	0.03	0.88
Future Use Intention	1.82	0.393	1.35	0.70	-2.41	25.13	0.02	0.85
Easiness	3.94	1.03	3.41	1.18	-1.40	31.45	0.17	0.49
Helpfulness	4.12	1.11	3.29	0.92	-2.35	30.92	0.03	0.83

Note. AI Preference (vs. Peer) was coded as Peer = 0 and AI Tutor/AI Navigator = 1. Future Use Intention (FUI) was coded as No = 0, Maybe = 1, and Yes = 2. Easiness and Helpfulness were measured on 5-point Likert scales ranging from 1 (strongly disagree) to 5 (strongly agree).

For epistemic emotions, Table 2 shows that only enjoyment was statistically significantly higher among AI-Tutor users, $t(31.98) = -2.64$, $p = .01$, $d = 0.93$. Other differences showed moderate effect sizes: AI-Tutor users reported more surprise ($d = 0.70$), while AI-Navigator users reported slightly more confusion and boredom without statistical significance.

Table 2.

Differences in epistemic emotions between AI-Tutor and AI-Navigator groups.

Epistemic Emotions	Tutor	Navigator	t	df	p	Cohen's d

	(n=17)		(n=17)					
	M	SD	M	SD				
Surprise	3.25	0.94	2.61	0.96	-1.99	31.99	0.06	0.70
Curiosity	3.69	0.95	3.57	0.68	-0.42	28.81	0.68	0.15
Enjoyment	3.20	1.14	2.18	1.11	-2.64	31.98	0.01	0.93
Confusion	2.69	1.02	2.94	1.00	0.74	31.97	0.47	-0.26
Anxiety	2.59	1.16	2.88	1.17	0.74	31.99	0.47	-0.26
Frustration	2.27	1.10	2.53	1.18	0.65	31.83	0.52	-0.23
Boredom	2.02	0.90	1.98	0.64	-0.15	28.73	0.89	-0.05

Correlation analyses across all participants (Table 3) revealed several statistically significant relationships between epistemic emotions and user experience variables. Positive epistemic emotions, particularly surprise, curiosity, and enjoyment, were strongly and statistically significantly correlated with one another. In contrast, significant positive correlations emerged among negative epistemic emotions such as frustration, anxiety, and boredom. Importantly, future use intention (FUI) and perceived helpfulness showed statistically significant positive associations with enjoyment and surprise, and statistically significant negative associations with frustration. Perceived easiness demonstrated a similar pattern of significant links to both positive and negative emotions. These significant relationships indicate that students' evaluations of the AI tools were closely tied to their emotional experiences: stronger positive emotions predicted higher AI preference and FUI, while stronger negative emotions predicted diminished user experience.

Table 3.

Pearson's correlation matrix for user-experience and epistemic-emotion variables.

Variables	1	2	3	4	5	6	7	8	9	10	11
1. Surprise											
2. Curiosity	0.58*										
3. Enjoyment	0.79*	0.66*									
4. Confusion	0.02	0.16	-0.09								
5. Anxiety	-0.2	-0.03	-0.26	0.69*							
6. Frustration	-0.49*	-0.25	-0.51*	0.69*	0.73*						
7. Boredom	-0.21	-0.29	-0.35*	0.56*	0.56*	0.57*					
8. AI Preference	0.47*	0.1	0.36	-0.26	-0.2	-0.43*	-0.06				

9. FUI	0.52*	0.25	0.49*	-0.23	-0.25	-0.56*	-0.06	0.66*		
10. Easiness	0.35*	0.14	0.28	-0.44*	-0.48*	-0.56*	-0.4*	0.57*	0.46*	
11. Helpfulness	0.58*	0.35*	0.53*	-0.23	-0.33	-0.5*	-0.29	0.58*	0.54*	0.71*

Note. An asterisk (*) indicates a statistically significant correlation ($p < .05$). Higher significance levels ($p < .01$, $p < .001$) are included within this category but are not separately marked.

Discussions

The findings of this pilot study reveal that different AI instructional designs can shape students' experiences in meaningful ways during biology problem-solving. The AI-Tutor produced more positive user experience responses, including higher enjoyment, helpfulness, preference for AI, and future use intention. These findings align with Control–Value Theory, which asserts that enjoyment arises when learners perceive high control. The AI-Tutor's structured and supportive response style likely bolstered perceived control, resulting in more positive emotional reactions.

The AI-Navigator's uncertainty-centered design produced more varied epistemic-emotion profiles, including slightly higher confusion and lower enjoyment. The ERAS model explains that such emotions arise when learners confront novelty, conflict, or ambiguity and emphasizes that the regulation of these emotions is critical for productive learning. Although the AI-Navigator temporarily reduced perceived control, the uncertainty it introduced may support deeper reasoning by prompting learners to evaluate evidence, consider alternatives, or articulate gaps in their understanding.

Correlational findings further highlight the strong relationship between emotional responses and user experience evaluations. Enjoyment and surprise were strongly associated with preference for AI, perceived helpfulness, and future use intention, whereas frustration was negatively associated with these same outcomes. These relationships suggest that students' willingness to adopt AI tools is shaped not only by performance-related factors but also by the emotional climate of their interaction. This dynamic may help explain why the AI-Navigator, although designed to support productive struggle, was evaluated less favorably in the short term.

Together, these findings illustrate a design tension. Systems that reduce epistemic friction create smoother emotional experiences, while those that introduce uncertainty evoke more varied emotional responses. Emotional comfort and epistemic rigor therefore require careful balancing. Future analyses of students' chat logs and conceptual understanding will help determine whether the Navigator's uncertainty-raising moves supported deeper learning, despite lower immediate satisfaction.

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