From Missteps to Mastery:
AI as a Catalyst for Error-Based Learning

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The Learning from Errors Approach

Errors Are Part of Learning

- Errors naturally occur during learning and practice.
- Incorrect responses may indicate that task goals were not achieved, but they can also provide valuable learning opportunities.
- Errors can be as instructive as correct solutions when integrated into a structured learning process, that includes **feedback, reflection, and revision** .

In the last three decades, studies in the areas of mathematics (Borasi, 1996) , physics (Yerushalmi and Polingher, 2005; Pinkeron, 2005), computer science (Ginat and Shmallo, 2013; Shmallo & Ginat, 2025), and information system education (Shmallo & Shrot, 2020) have shown encouraging results supporting the learning from errors approach.

AI as a Powerful Error-Based Learning Partner

⏱️ **Immediate Feedback**

During debugging and problem solving

🧠 **Personalized Explanations**

Adaptive guidance tailored to student needs

🔍 **Explore Misconceptions**

Encourages independent reflection and revision

📊 **Consistent Learning Experience**

Supports students at different learning levels

🎯 **Deeper Understanding of Errors**

Focuses on ***why*** errors happen, not only how to fix them

-> GenAI can transform errors from "**errors to fix**" into opportunities for deeper understanding and reflection.

Methodology

Case Study in Web Programming Course

Courses Research Questions	Instructional Support	Tools	Participants
To what extent does the type of instructional support affect students' perceived learning experience, satisfaction, motivation, self-directed learning, and self-efficacy?	❑ AI Guided ❑ Teaching Assistant	Questionnaire measuring research-derived constructs, using validated instrument sections on a 5-point Likert scale.	Fifty-nine students volunteered to participate in the experiment in exchange for a 5-point bonus added to their final grade:

Research Design – Weeks 1-11 - Preparation

Weeks 1-9 – Error Examples

Practicing error-based learning in select lectures and tutorials.

Weeks 10-11 – Study Material

Learning and practicing JavaScript.

Research Design – Week 12 - Experiment

JavaScript Error Detection Exercise

Participants were asked to review a JavaScript code snippet containing several errors, identify the errors, and correct them.

- The AI-Guided group used AI to assist them with the review task.
- The Teaching-Assistant group performed the review task alone, after which the instructor solved it.

JavaScript Quiz:

For both groups, the assessment was conducted without AI assistance.

Questionnaire completion.

Research Design –JavaScript code snippet Example

```
function roll(){
    let collection=document.getElementsByClassName("ran");
    for (let i=0;i<inter;i++){
        let selection= 1+Math.floor(Math.random()*2);
        collection.innerHTML=selection;
        arr[i]=selection;
    }
    calc();
}
```

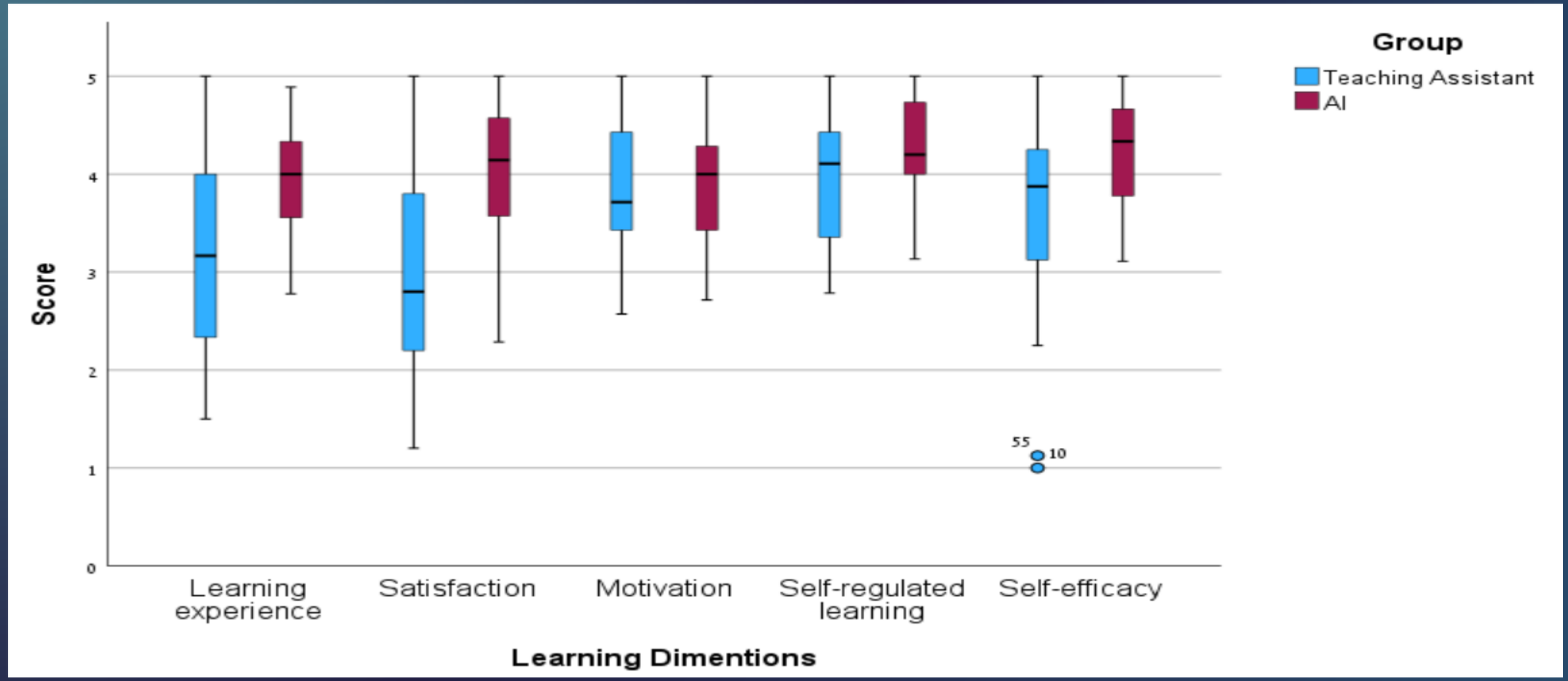
```
collection[i].innerHTML=selection;
```

Participants Demographics

Characteristic	Findings	
Gender	Woman	64%
	Men	34%
	Other	2%
Age	22-24	30%
	25-27	62%
	28-32	8%

Results

Distribution of Constructs Scores By Group



Comparison of Construct Scores by Group

Learning Dimension	Descriptive Statistics: Mean (SD)		Mann-Whitney and Effect Size (r)	Levene's Test
	Teaching Assistant Group	**AI Group**		
Learning experience	3.24 (0.97)	3.87 (0.57)	Z=-2.92 p=.004 r=0.38	F(1,57)=7.214 p=.009
Satisfaction	2.99 (1.16)	4.03 (0.68)	Z=-3.54 p<.001 r=0.46	F(1,57)=8.034 p=.006
Motivation	3.80 (0.67)	3.90 (0.60)	Z=-0.72 p=.567	F(1,57)=0.443 p=.509
Self-regulated learning	3.97 (0.57)	4.26 (0.52)	Z=-1.74 p=.041 r=0.23	F(1,57)=0.301 p=.585
Self-efficacy	3.66 (1.03)	4.21 (0.55)	Z=-2.21 p=.027 r=0.29	F(1,57)=5.968 p=.018

Note: All tests were two-tailed, except for the Mann–Whitney test for self-regulated learning.

Results Summary

- Students in the AI group reported a significantly more positive learning experience with a medium effect size, and higher levels of satisfaction, with medium-to-large effect size.
- Students in the AI group reported a significantly higher levels of self-efficacy with a small to medium effect size.
- Students in the AI group also reported significantly higher levels of self-regulated learning, although the effect size was small.
- The AI group demonstrated significantly lower score variability in learning experience, satisfaction, and self-efficacy.

Next Research Phase

- Conduct qualitative analysis of students' questionnaire responses
- Explore why students perceived AI guidance differently
- Compare students' reflections and learning processes
- Replicate the current research methodology across two different colleges and courses:
  - to evaluate how disciplinary context impacts AI engagement
  - to cross-examine variations in student reflections across both environments.

Future Research Questions

- How can AI better support reflective learning from errors?
- What balance between AI guidance and human instruction is most effective?
- What specific AI prompting strategies or guidance models best trigger deep metacognitive reflection when students encounter errors?
- How can institutions integrate AI responsibly into education?

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