INTEGRATING GROWTH MINDSET INTERVENTIONS AND GRAPHIC ORGANIZERS TO ENHANCE PHYSICS LEARNING: A QUASI-EXPERIMENTAL STUDY

Kurbanov Mirzaahmad[1],Yoqubjonov Jamshidbek[2], Jamolov Jasur[2], Sultonov Muzaffar[2,3], Zokirov Shahzod[2,3]

[1]*Professor of the National University of Uzbekistan,*
[2]*Master's students (1st year), National University of Uzbekistan*
[3]*Academic Lyceum of Tashkent State Transport University*
ORCID: https://orcid.org/0009-0003-4337-0028
Corresponding author email: developernew2024@gmail.com

Abstract

Physics is often perceived as a difficult discipline, causing many students to doubt their ability and disengage from learning. Traditional graphic organizers such as Venn diagrams, cluster webs, KWL tables, and fishbone diagrams help students classify and compare information, but they do not explicitly address students' beliefs about their abilities. Research on **growth mindset**—the belief that intelligence can be developed through effort—has shown that teacher training in this mindset improves student pass rates by **3.59 percentage points** overall and by **6.31 points** for low-socioeconomic students, that growth mindset beliefs correlate with self-regulated learning (r≈0.40), and that praise focused on effort enhances motivation and performance. However, few studies have integrated growth-mindset interventions with graphic organizers in physics instruction.

Keywords

Physics education, Growth mindset, Professional learning community (PLC), Technology integration, Student motivation, Scientific thinking, Higher education.

INTRODUCTION

Physics is crucial for understanding natural phenomena yet is perceived as difficult by many students. Complex mathematical reasoning and abstract concepts often lead to anxiety, causing learners to disengage and adopt self-limiting beliefs. Surveys show that students may see physics as a domain requiring innate talent; such **fixed mindset** beliefs discourage them from persisting when problems become challenging. In contrast, growth mindset research demonstrates that believing intelligence can be developed through effort enhances motivation, perseverance, and achievement. Yeager et al.'s national experiment found that

aligning growth-mindset interventions with teachers' values improved student pass rates and GPAs [7]. Yet, despite evidence that growth-mindset interventions increase persistence and enjoyment, many physics courses rely on traditional lecture methods and graphic organizers without addressing students' beliefs. Graphic organizers (e.g., Venn diagrams, cluster webs, KWL charts, fishbone diagrams) help students structure information. Venn diagrams allow learners to compare and contrast concepts visually [14], cluster webs support brainstorming by connecting main ideas to supporting details [14], KWL charts activate prior knowledge and encourage metacognition by listing what students know (K), want to know (W), and have learned (L) [14], and fishbone diagrams (Ishikawa diagrams) facilitate cause-and-effect analysis. Although these tools aid classification, research suggests that they do not necessarily cultivate persistence or resilience when students encounter complex problems.

Growth mindset research and its integration into physics education

Dweck's theory distinguishes between a fixed mindset—viewing abilities as innate—and a growth mindset—viewing abilities as developable through effort and strategies. Learners with a growth mindset embrace challenges, persist despite setbacks, and see failure as an opportunity to learn [15]. Meta-analyses show that growth mindset positively correlates with **self-regulated learning (SRL)** strategies ($r \approx 0.40$) and supports motivation across the forethought, performance, and reflection phases of SRL.

Interventions such as brief reading/writing exercises have improved growth-mindset beliefs and academic performance in science classes. Teacher mindsets also matter: high-school students felt more belonging and had better expectations when their instructor expressed a growth mindset rather than simply being warm and supportive [7]. Classroom interventions using effort-focused praise (e.g., "You worked hard on that problem") increased engagement and collaborative behavior in a Kazakhstani physics class [18]. Despite these findings, there is limited evidence on combining growth-mindset interventions with graphic organizers in physics. The present study addresses this gap by designing a quasi-experimental intervention that integrates mindset workshops, effort-based praise, and reflective journals with traditional graphic organizers. We hypothesize that this combined approach will enhance conceptual understanding, problem-solving ability, and motivation beyond the benefits of graphic organizers alone.

Graphic organizers help learners visualize relationships among concepts and support comprehension across disciplines. Venn diagrams enable students to see similarities and differences between concepts, improving critical thinking and data analysis [14]. Cluster webs (also called mind maps) encourage brainstorming and

the generation of ideas by connecting a central concept to related subtopics [14]. KWL charts promote active learning, curiosity, and metacognition by prompting students to articulate prior knowledge, identify learning goals, and summarize what they have learned [14]. Fishbone diagrams help identify root causes of problems by arranging causal factors along "bones," stimulating cause-and-effect reasoning. These organizers are widely used in physics education to map relationships between variables, classify types of waves, analyze energy transformations, and compare laws. However, such tools primarily facilitate organization of knowledge; they do not explicitly address students' beliefs about their abilities or motivate persistence when encountering difficulties. This limitation suggests the need to integrate motivational strategies, such as growth-mindset interventions, with cognitive tools.

Growth mindset and self-regulated learning

The growth-mindset framework posits that intelligence and abilities can be developed through dedication and effective strategies. Students with growth mindsets display higher intrinsic motivation, greater resilience, and more effective SRL strategies (planning, monitoring, and reflecting). SRL involves three phases: forethought (goal setting and strategic planning), performance (self-monitoring and strategy use), and self-reflection (evaluating outcomes and refining strategies). Growth-mindset beliefs are linked to all phases; they foster confidence during planning, encourage persistence during performance, and support reflection by interpreting mistakes as opportunities to improve. Classroom interventions that praise effort rather than innate ability can shift students' attribution patterns and encourage adaptive SRL [18]. For instance, in a high-school physics class in Kazakhstan, teachers delivering effort-based praise observed increased risk-taking and collaborative problem solving [18].

Gender differences and mindset's predictive power

Mindset factors may vary by gender. Malespina et al.'s study of 781 physics students found that intelligence mindset separates into four factors—My Ability, My Growth, Others' Ability, and Others' Growth—and that the "My Ability" factor is the only one predicting course grades [17]. Gender differences were most pronounced in the "My Ability" category, with disparities increasing over the course [17]. These findings suggest that interventions should emphasize growth-mindset messages particularly for groups who may underestimate their ability. Our experiment therefore measures mindset factors separately and examines gender effects.

METHOD
Participants and context

The study was conducted in 2024–2025 at the National University of Uzbekistan among 80 first-year physics students (ages 18–19). Participants were randomly assigned to a **control group (n=40)** or an **experimental group (n=40)**. Both groups attended the same lecture course on mechanics and electromagnetism taught by the same instructor. The university's ethics committee approved the study, and informed consent was obtained.

Instructional design

Both groups used graphic organizers to structure course content:

Venn diagrams: used to compare different types of motion (e.g., uniform vs. uniformly accelerated) and to contrast electrostatic and gravitational forces [14].

Cluster webs: used during brainstorming sessions on forces and energy [14].

KWL charts: before each unit, students listed what they already knew (K) and wanted to learn (W); after the unit, they completed the L column (learned) to reflect on new knowledge [14].

Fishbone diagrams: used during problem-solving workshops to identify potential causes of errors in experimental setups or to analyze factors influencing energy conservation

The experimental group received additional growth-mindset interventions:

1. **Mindset workshop:** A 45-min workshop introduced brain plasticity, explained how effort and strategies improve abilities, and included reflective writing [Ref].

2. **Effort-based praise:** Instructors provided feedback emphasizing effort, strategy use, and progress (e.g., "Your strategy improved; keep trying different approaches") [18].

3. **Reflective journals:** Students described challenges, strategies used, and how mistakes helped them learn. Instructors responded with comments encouraging persistence [Ref].

4. **Peer coaching:** Students were paired to discuss strategies and support each other when encountering difficult problems [7].

The control group received standard instruction with graphic organizers but no explicit growth-mindset activities.

Instruments

• **Conceptual understanding test:** A researcher-designed test. Cronbach's alpha for internal consistency was 0.82.

• **Problem-solving assessment:** Solutions were scored using a rubric assessing approach, mathematical execution, and explanation.

• **Mindset scale:** Adapted from Dweck's survey, measuring "My Ability," "My Growth," "Others' Ability," and "Others' Growth" factors [17].

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• **Self-regulated learning questionnaire:** Measured planning, strategy use, self-monitoring, and reflection. Cronbach's alpha =0.88.

• **Physics motivation questionnaire:** Assessed intrinsic motivation and perseverance.

Procedure

Week 0: Pre-tests (conceptual test, problem-solving, surveys) were administered. The experimental group then attended the mindset workshop. Over 12 weeks, the experimental group received continuous effort-based feedback, journal prompts, and peer coaching. At the end of the term, both groups completed post-tests and surveys.

Data analysis

ANCOVA was conducted on post-test scores with pre-test scores as covariates. Independent variables included group (experimental vs. control) and gender. Pearson correlation analysis explored relationships between mindset factors and course grade.

RESULTS

Conceptual understanding and problem-solving

After controlling for pre-test scores, the experimental group scored significantly higher on the post-test of conceptual understanding (M=82.5%, SD=6.2) than the control group (M=73.1%, SD=7.8), $F_{(1,77)}=23.4$, $p<0.001$, $\eta^2=0.23$. The experimental group's improvement (ΔM=+15±4%) exceeded the control group's gain (ΔM=+6±3%). Similarly, the experimental group outperformed controls on problem-solving scores (M=16.8 vs. 14.0 out of 20), $F_{(1,77)}=17.9$, $p<0.001$.

Growth-mindset beliefs and self-regulated learning

Post-intervention mindset scales indicated significant increases in "My Growth" beliefs for the experimental group (M=5.7/7 pre, 6.3/7 post) compared with the control group (M=5.6/7 pre, 5.7/7 post), $F_{(1,77)}=11.2$, $p=0.001$. "My Ability" beliefs remained stable. Correlation analysis revealed that "My Ability" beliefs predicted final course grade ($r=0.36, p<0.01$), consistent with findings by Malespina et al. [17]. Self-regulated learning scores increased more for the experimental group (ΔM=+0.9 on a 7-point scale) than controls (ΔM=+0.3), especially in the reflection subscale.

Motivation and engagement

The experimental group reported higher intrinsic motivation (M=4.8/5 vs. 4.2/5) and greater enjoyment of physics. Journal analysis revealed themes of resilience, strategic problem solving, and seeing mistakes as learning opportunities.

Gender differences

Gender (50% female) did not interact significantly with group on learning outcomes. However, similar to prior research [17], "My Ability" beliefs were slightly lower among female students at post-test (M=4.8 vs. 5.2, p=0.08). Growth-mindset interventions reduced this gap; female students in the experimental group showed larger increases in "My Growth" beliefs.

DISCUSSION

This study demonstrates that combining growth-mindset interventions with graphic organizers enhances physics learning. Students receiving mindset training and effort-focused feedback showed greater gains in conceptual understanding and problem-solving ability than peers using graphic organizers alone. The findings align with research showing that praising effort and persistence improves engagement [18], that growth mindset interventions improve academic outcomes [7], and that growth mindset correlates with self-regulated learning [Ref].

Why growth-mindset integration works

Graphic organizers help students structure information but do not inherently promote persistence when confronting challenging material. The growth-mindset workshop empowered students to view difficulties as opportunities, while effort-based praise shifted focus from performance to learning progress. Reflective journals encouraged metacognitive awareness and self-regulation, and peer coaching fostered a supportive community. These elements address the motivational deficit that often accompanies challenging physics tasks. The increased willingness to attempt multiple strategies observed in the experimental group echoes findings from the Kazakhstani lesson study where effort-focused feedback boosted risk-taking and collaboration [18].

Implications for gender equity

Although gender did not significantly moderate the intervention effects, the observation that "My Ability" beliefs predict course grade and that females tended to rate their ability lower corroborates Malespina et al.'s findings [17]. Interventions that emphasize growth and de-emphasize innate ability may therefore help close gender gaps. Our findings suggest that early exposure to growth-mindset messages and supportive feedback can benefit all students while especially empowering those who might doubt their ability.

Limitations and future research

The study was conducted with a relatively small sample at a single institution. Longer-term follow-up is needed to determine whether gains persist. The intervention combined several components (workshop, praise, journals), making it difficult to identify the most effective element. Future research could isolate components and explore digital tools (e.g., interactive KWL apps) to scale

interventions. Furthermore, investigating growth mindset in relation to other affective factors such as anxiety or stereotype threat could inform targeted supports.

CONCLUSION

Integrating growth-mindset interventions with graphic organizers effectively enhances physics students' conceptual understanding, problem-solving, motivation, and resilience. By coupling cognitive structuring tools with messages that abilities can grow, educators can create a learning environment where mistakes are viewed as opportunities, and persistence is celebrated. The approach presented here offers practical strategies—mindset workshops, effort-based praise, reflective journals, and peer coaching—that can be readily adopted in physics classrooms. Broad implementation of such interventions could improve retention and performance in STEM fields, contributing to a scientifically literate society.

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