SHORT COMMUNICATION

Volume 18 Suppl.1 2026

DOI: 10.21315/eimj2026.18.S1.2

ARTICLE INFO

Submitted: 14-11-2024
Accepted: 18-04-2026
Online: 28-08-2026

Correlations Between Master Adaptive Learners' Characteristics and Anatomy Performance in an Active and Game-based Anatomy Learning

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To cite this article: Nurhadi AA, Budu, Zainuddin AA, Afandi IN, Rasyid H, Yusuf I, Idris I, Arifin IA, Syarif LI, Soraya GV. Correlations between Master Adaptive Learners' characteristics and anatomy performance in an active and game-based anatomy learning. Education in Medicine Journal. 2026;18(Suppl 1):15–26. https://doi.org/10.21315/eimj2026.18.S1.2

To link to this article: https://doi.org/10.21315/eimj2026.18.S1.2

ABSTRACT

Master Adaptive Learners (MALs) can adjust their learning strategies to overcome challenges, a key trait for success in complex subjects like anatomy. This study explored the correlation between MAL characteristics—curiosity, motivation, growth mindset, and resilience—and anatomy performance in an active, game-based learning environment. A cross-sectional study was conducted among 246 first-year medical students at Hasanuddin University in 2022. The anatomy course used blended, active learning, and game-based learning methods. MAL traits were measured using validated Indonesian-language instruments: the Curiosity and Exploration Inventory-II, Academic Motivation Scale short form, Growth Mindset Scale, and Connor-Davidson Resilience Scale. Anatomy performance was assessed through a comprehensive final exam. Non-parametric Spearman's rank correlation was

applied due to non-normal data distribution. Students achieved a high average score (mean = 76.7, standard deviation (SD) = 16.2). Most MAL traits showed no significant correlation with performance: curiosity, motivation, and resilience ($p > 0.05$). However, growth mindset demonstrated a weak but significant positive correlation ($r = 0.26$, $p < 0.001$). In conclusion, while active learning may support student success regardless of MAL traits, the growth mindset was modestly linked to better performance. Curriculum strategies that cultivate a growth mindset may enhance learning outcomes in anatomy education.

Keywords: *Academic writing, Action research, Artificial intelligence in education, Health professions education, Self-efficacy*

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INTRODUCTION

Anatomy is a foundational subject in medical education that poses significant learning challenges due to its complexity, extensive detail, and the need to understand intricate spatial relationships in the human body. Traditional anatomy instruction relying on didactic lectures and cadaveric dissection often struggles to fully engage modern students or accommodate diverse learning needs (1). In response, medical educators have increasingly implemented active learning and game-based strategies in anatomy teaching to improve student engagement, motivation, and knowledge retention (2, 3).

Active learning emphasises student-centred activities and has been shown to enhance understanding and retention, especially for complex subjects like anatomy (4–6). Game-based learning, as an extension of active learning, introduces elements of competition, interactivity, and immediate feedback. Combining game-based elements with conventional teaching approaches can create a more enjoyable and immersive learning atmosphere, which recent studies suggest can significantly boost student motivation and academic performance in anatomy courses (3, 7, 8). Indeed, systematic evaluations of innovative anatomy teaching methods have reported improved learning outcomes when games and active exercises are incorporated (8, 9). Beyond instructional methods, the role of individual learner characteristics in such innovative learning environments is gaining attention. The Master Adaptive Learner (MAL) framework defines key traits—such as resilience, adaptability, self-regulation, curiosity, and a growth mindset—as critical qualities for lifelong learning and adaptability in medical professionals (10, 11). Research indicates that students who exhibit higher adaptive learning traits often perform better and experience less stress in challenging educational contexts (10, 11). Preliminary evidence further suggests that traits like self-regulation and resilience play pivotal roles in how students navigate complex, interactive learning environments (10, 11). A growth mindset, defined as the belief that one's abilities can develop through effort and learning, has been highlighted as a trait that fosters perseverance and a positive response to feedback (11). These attributes potentially help learners take initiative, cope with setbacks, and continuously improve—abilities that could be especially beneficial in mastering anatomy, where students must independently manage a large volume of information and overcome difficulties through practice. However, the relationship between such adaptive characteristics and objective academic performance, particularly in an active, game-based anatomy setting, remains underexplored and somewhat inconclusive. It is not yet clear to what extent possessing MAL

traits gives students an edge in a learning environment that is already highly engaging and supportive. Given this background, we aimed to examine the correlations between MAL characteristics and students' anatomy performance within a blended, game-based anatomy curriculum at the Faculty of Medicine, Hasanuddin University. By identifying how MAL traits (curiosity, motivation, growth mindset, resilience) relate to anatomy achievement in a highly interactive course, this research seeks to inform curriculum design and teaching strategies that support adaptive learning. We anticipated that students who score higher on MAL characteristics—particularly those with a strong growth mindset might achieve better anatomy exam results, due to their greater ability to adapt study strategies and persist through learning challenges.

METHODOLOGY

Study Design and Participants

This study was a cross-sectional analysis of first-year medical students enrolled in the anatomy course at Hasanuddin University's Faculty of Medicine. A total of 246 students (the entire first-year cohort of the 2022 academic year) participated. All students were in their first semester of medical school and took the anatomy course as part of the core curriculum. The study included all students by default (no sampling was performed); only those who did not complete the required assessments or questionnaires were excluded (if any). Formal informed consent was obtained, and the study was conducted with the approval of the relevant institutional authorities.

Active, Game-based Anatomy Course

Anatomy was taught using a fully blended active learning approach. The course spanned one semester and was structured into multiple modules organised by major anatomical systems (e.g., musculoskeletal system, cardiovascular system). Before each in-person session, students engaged with online learning resources (e-modules) and completed formative quizzes via the learning management system to prepare for class. During the face-to-face sessions, students worked in small groups of six on a learning module (which was developed using Quizizz) related to that anatomy topic. Each group collaboratively applied anatomical concepts they had studied online and then presented their findings or answers to the class. Instructors provided feedback and guided discussion after each presentation, ensuring any misunderstandings were addressed. At the end of each session, a game-based learning activity was conducted to reinforce the day's material. These activities varied and included educational games such as Jeopardy, Bingo, Pyramid, and Find the Thief. In each game, students competed with other groups to solve anatomy-related questions and achieve the highest score. Throughout the course, this combination of structured preparatory work, collaborative problem solving, and gamified activities was intended to maintain high engagement and help students consolidate their learning.

Instrument for MAL Characteristics

The key MAL characteristics examined were curiosity, motivation, growth mindset, and resilience. We used previously validated questionnaires in the Indonesian language to measure each trait (12–15). Curiosity was measured by the Curiosity and Exploration

Inventory-II (CEI-II), which assesses individuals' tendency to seek out new experiences and knowledge. Academic motivation was assessed with the short form of the Academic Motivation Scale (AMS), which provides subscores for intrinsic motivation (internal drive to learn), extrinsic motivation (learning due to external rewards or pressures), and amotivation (lack of motivation). Growth mindset was measured using the Growth Mindset Scale (adapted and validated for Indonesian students) (14), which evaluates the extent to which students believe abilities and intelligence can be developed. Resilience was measured by the Connor-Davidson Resilience Scale (CD-RISC) Indonesian version (15), which gauges the ability to withstand and bounce back from challenges. Each instrument was administered near the end of the course, close to the time of the final anatomy exam. All questionnaires have demonstrated good psychometric properties in prior studies of Indonesian student populations (12–15). In our study, we calculated internal consistency for each scale: all showed acceptable reliability (Cronbach's alpha values were ≥ 0.75 for each MAL characteristic scale), confirming that the measures were reliable for our participant group.

Assessment of Anatomy Performance

Students' performance in anatomy was evaluated via the course's end-of-semester examination. This summative assessment consisted of multiple-choice questions (MCQs) in a single best-answer format, covering all anatomy topics. For each topic, a total of 100 MCQs were administered, which tested both factual knowledge and applied understanding of anatomical concepts. The exam content was reviewed by anatomy faculty members to ensure alignment with the learning objectives and to maintain content validity. Each student's exam was scored as a percentage (number of correct answers out of 100), which served as the outcome measure for anatomy performance in this study. We did not conduct a separate pre-test; instead, we used the average of the topic final exam performance as a cumulative indicator of each student's mastery of anatomy after the active learning interventions. It should be noted that factors such as students' prior knowledge of anatomy, general study habits, or time spent studying were not directly measured in this study.

We compiled the data for all 246 students, including their anatomy exam score (percentage) and their scores on each MAL trait questionnaire (curiosity, three subscales of motivation, growth mindset, and resilience). First, descriptive statistics were calculated to summarise the cohort's performance and trait levels (mean and standard deviation for each measure). Next, the distribution of each variable was examined using the Kolmogorov–Smirnov test for normality. The normality tests indicated that the distribution of several variables deviated from normal (in particular, the motivation subscale scores were slightly skewed). Given these results, we opted for non-parametric correlation analysis. Spearman's rank correlation coefficient (Spearman's rho) was used to evaluate the association between each MAL characteristic and the anatomy exam score. We computed Spearman's rho for curiosity vs performance, intrinsic motivation vs performance, extrinsic motivation vs performance, amotivation vs performance, growth mindset vs performance, and resilience vs performance. In addition, 95% confidence intervals were calculated for the correlation coefficients to assess the precision of the estimates. We interpreted the strength of correlations based on conventional guidelines (for absolute rho: 0.10–0.29 = weak, 0.30–0.49 = moderate, ≥ 0.50 = strong correlation). A p-value < 0.05 was considered statistically significant for all tests. All statistical analyses were performed using IBM SPSS Statistics version 16.0. No other comparisons or multivariate analyses were conducted, as the primary focus was on simple bivariate correlations.

RESULTS

Descriptive Results

A total of 246 first-year medical students completed the study. The mean anatomy exam score among the students was 76.41 (SD = 16.18) out of 100, indicating a generally strong performance in the course. The majority of students (approximately 85%) scored above 60, and 30% of the class scored 85 or higher, reflecting excellent mastery for those students. This high average and wide range suggest that, overall, the cohort engaged well with the material in the active, game-based learning environment. For the MAL characteristics, the cohort's average scores indicated relatively high curiosity and motivation levels, a generally positive growth mindset, and moderate resilience (detailed descriptive statistics for each MAL scale are provided in Table 1 while students' anatomy performance and MAL characteristics are provided in Table 2.

Table 1: Questionnaire to measure MAL characteristics

Characteristics	Measurement tools
Curiosity	Curiosity and Exploration Inventory II
Motivation	Short version Academic Motivation Scale
Growth mindset	Growth Mindset Scale
Resilience	Connor-Davidson Resilience Scale

Table 2: Students' anatomy performance and MAL characteristics

Characteristics	Mean (SD)
Students' anatomy performance	
Total performance	76.41 (16.18)
Musculoskeletal	72.10 (18.84)
Neurology	77.04 (19.07)
Endocrine	78.16 (18.04)
Special senses	78.08 (14.67)
Cardiorespiratory	75.68 (17.07)
Urogenital	73.24 (15.11)
Gastroenterohepatology	82.01 (19.06)
MAL characteristics	
Curiosity	3.66 (0.45)
Growth mind set	4.59 (0.55)
Motivation	
Intrinsic motivation	5.19 (0.61)
Extrinsic motivation	5.31 (0.64)
Amotivation	1.41 (0.68)
Resilience	5.03 (0.42)

Correlation Between MAL Traits and Anatomy Performance

Table 3 presents the correlation analysis results between students' anatomy performance and each MAL characteristic. In general, we found no significant correlation between most MAL traits and anatomy exam scores. Specifically, curiosity was not significantly associated with performance (Spearman's r = 0.12, 95% CI [–0.01, 0.24], $p = 0.062$). Similarly, none of the motivation sub-components showed a meaningful relationship with exam results: intrinsic motivation (r = 0.023, $p = 0.714$), extrinsic motivation (r = 0.017, $p = 0.789$), and amotivation (r = 0.054, $p = 0.397$) all had correlation coefficients near zero and were statistically non-significant. Students' resilience scores also did not correlate with their anatomy scores (r = 0.06, $p = 0.355$), indicating that higher self-reported academic resilience did not translate into higher exam performance in this setting. These findings suggest that, in the context of our structured and interactive anatomy course, a student's level of curiosity, motivation, or resilience did not have a detectable impact on their test outcomes.

The only MAL characteristic that showed a significant correlation with anatomy performance was growth mindset. There was a weak positive correlation between students' growth mindset scores and their exam scores (Spearman's r = 0.26, 95% CI [0.14, 0.37], $p < 0.001$). Although the correlation coefficient indicates a small effect size, it was statistically significant, implying that students who more strongly believed in the improvability of their abilities tended to achieve slightly higher anatomy scores. In practical terms, this means that a student with a high growth mindset might outperform a low–growth mindset peer by a small margin on the exam, on average. We interpret this correlation with caution due to its weak magnitude; however, it does suggest some degree of alignment between having a growth mindset and succeeding in an active learning context.

To summarise the key quantitative results: The active, game-based anatomy course yielded high overall performance across the class, and most MAL characteristics (curiosity, motivation, resilience) were not predictive of which students did better or worse. Only the growth mindset trait had a noteworthy (albeit weak) association with anatomy performance.

Table 3: Correlation analysis of students' anatomy performance and MAL characteristics

Variable analysis	r	*p*
Curiosity-performance	0.12	0.062
Growth mind set-performance*	0.26	< 0.001
Motivation-performance		
Intrinsic motivation	0.023	0.714
Extrinsic motivation	0.017	0.789
Amotivation	0.054	0.397
Resilience-performance	0.592	0.355

Note: *significant weak correlation

DISCUSSION

In this study, we investigated whether first-year medical students' MAL characteristics were associated with their academic success in an active, game-based anatomy course. We found that, despite the students' excellent overall performance in anatomy, there was

no significant correlation between most MAL traits and exam scores. The only exception was growth mindset, which showed a weak positive correlation with performance. These findings have several important implications for medical education and warrant discussion in light of existing literature. First, the high average exam score (approximately 76%) indicates that students thrived in the blended, game-enhanced learning environment. Our students' strong performance is consistent with prior research showing that active learning and gamified strategies can lead to improved learning outcomes in anatomy education (9). The engaging course design—combining online preparation, collaborative problem solving, and interactive games—appears to have benefited the cohort as a whole. Notably, this success did not appear to depend heavily on individual differences in MAL characteristics such as curiosity, self-regulation, or resilience. In other words, even students who might not score highly on those adaptive traits still performed well in anatomy, presumably because the course's structure kept them on track. One possible explanation for the lack of performance differences related to MAL traits is the structured and supportive nature of the curriculum. Our blended learning environment provided students with clear guidance (through preparatory modules and instructor feedback) and multiple reinforcement opportunities (through group work and games). This may have levelled the playing field by ensuring that even students with lower inherent adaptability or self-directed learning skills could keep up with the material.

Prior studies support the idea that a well-designed learning environment can mitigate the influence of individual trait differences on academic outcomes. For example, research by Bierer and Dannefer (16) noted that a strong educational environment and coaching can shape student study strategies, thereby reducing performance disparities that might arise from varying self-regulatory skills. Similarly, Zalts et al. (17) observed that medical students' motivation and stress levels were closely tied to aspects of the learning climate, rather than being solely personal attributes. In line with these findings, our results suggest that the active, game-based course structure was a dominant factor in student success, potentially overshadowing what each student brought in terms of MAL characteristics. Studies in educational psychology have long indicated that when learners are given extensive scaffolding, feedback, and engagement, even those with initially lower adaptive skills can achieve strong outcomes (16–18). Our study provides empirical evidence of this in a medical education context: even though we measured traits like resilience and curiosity, these did not translate into differential performance, likely because the course design helped all students to stay engaged and learn effectively.

The one MAL trait that did show a measurable impact was growth mindset. The weak yet significant correlation between growth mindset and anatomy scores aligns with the notion that students who believe in their capacity to improve tend to embrace challenges and persist in the face of difficulty. In the context of our game-based anatomy course, these growth-minded students might have been more willing to tackle difficult anatomy problems, learn from mistakes during quizzes or games, and seek feedback to improve. This interpretation is supported by educational theory and prior research: a growth mindset has been associated with greater perseverance and a positive response to corrective feedback, which are behaviours conducive to learning in active environments (19, 20). Mrazek et al. (19) for instance, found that students with a growth mindset of self-regulation put in more effort and showed more perseverance when learning new material. In our study, although the effect was small, students with higher growth mindset scores possibly engaged more deeply with the iterative learning processes (pre-class quizzes, in-class challenges, post-class reviews), leading to slightly better retention and exam performance.

It is worth noting that the correlation we observed ($r \approx 0.26$) indicates only a modest association. This is consistent with larger-scale evidence on growth mindset interventions in education. A recent systematic review and meta-analysis by Macnamara and Burgoyne (21) reported that growth mindset interventions have, on average, a very small effect on academic achievement (pooled effect size $d \sim 0.05$). Our finding of a weak positive correlation in a natural classroom setting aligns with that meta-analytic result, suggesting that while promoting a growth mindset can be beneficial, it alone is not a powerful determinant of short-term academic performance. However, even a small effect can be meaningful in an educational context, especially when considering the low cost and broader benefits of mindset-oriented approaches. Encouraging a growth mindset may not dramatically boost exam scores for every student, but it can foster attitudes of resilience and continuous improvement that are valuable throughout medical training. Other studies in medical education have highlighted that instilling growth mindset principles (such as viewing failures as learning opportunities) can improve students' resilience and willingness to engage in challenging learning tasks (20, 22, 23). Thus, a growth mindset stands out as an adaptive trait that, despite its modest direct effect on grades, holds considerable importance for a student's approach to learning.

Another aspect to consider is that each MAL characteristic in our study might exert effects that are not captured by exam performance alone. For example, a student high in curiosity or intrinsic motivation might delve deeper into the subject matter or enjoy the learning process more, even if their exam score ends up similar to others. The absence of correlation with grades does not necessarily mean these traits are unimportant; rather, in a course thoroughly designed to engage everyone, even the less curious or less motivated students were pulled along by the interactive pedagogy. Our findings contribute to the literature by suggesting that when an active-learning curriculum is very effective, it can somewhat equalise academic outcomes among students with different personal characteristics. This idea resonates with the MAL framework itself: the framework posits that certain skills and mindsets help learners teach themselves, but here we provided an environment so enriched that students may not have needed to rely as much on their own adaptive skills to succeed.

To put our results in context with existing theories, Cutrer et al. (10)'s conceptual model of the MAL emphasises that learners cycle through phases of planning, learning, assessing, and adjusting. In a highly structured course, the 'planning' and 'assessing' phases are heavily guided by instructors (through provided resources and feedback), which might reduce the demand on students' self-regulation or resilience. Our observation that self-regulatory traits did not correlate with outcomes can be seen as evidence supporting the model's implication that context and guidance matter. It also underscores the importance of gradually developing MAL skills. It could be that in later, less structured courses (for example, clinical rotations or self-directed research projects), those traits would play a larger role in performance.

Practical Implications

Given the findings, what should educators and curriculum designers take away? Firstly, the overall success of the active, game-based anatomy course confirms that investing in interactive and student-centred teaching strategies can greatly benefit student learning. We recommend that medical curricula continue to incorporate active learning and gamification techniques for challenging subjects like anatomy, as these methods appear to support all students in achieving competency. Secondly, while traits like curiosity and resilience did not show immediate payoff in exam scores under these conditions, it is still desirable to cultivate these characteristics for students' long-term growth and adaptability. Educators might consider gradually reducing scaffolding in advanced courses to encourage students to

exercise their adaptive learning skills more independently. Importantly, our study highlights growth mindset as a trait worth nurturing explicitly. Simple interventions can be integrated into the curriculum to promote a growth mindset: for example, brief workshops on learning from mistakes, reflective exercises after exams where students identify how effort led to improvement, or feedback that praises effective strategies rather than innate ability. Such steps could reinforce students' belief that they can improve with effort, which in turn may lead to greater engagement and persistence. Over time, fostering a growth mindset culture in the classroom could not only give a slight performance boost (as observed) but also enhance students' resilience and willingness to tackle difficult material beyond this one course. In the context of anatomy teaching, instructors can emphasise progress (You've improved a lot in identifying structures, which shows your practice is paying off) and frame challenges as opportunities to learn, aligning with growth mindset principles.

Study Limitations

We acknowledge that our study has certain limitations. We did not control for all variables that might influence anatomy performance. For instance, students' prior knowledge of anatomy (from high school or other courses), general academic ability, and study habits were not measured. It is possible that these factors could mask or confound the relationships between MAL traits and performance. For example, a student with excellent prior preparation might do well in anatomy regardless of their MAL characteristics. Additionally, our study did not include a comparison group (e.g., students in a traditional lecture-based anatomy course), so we cannot definitively say how the active, game-based environment interacted with MAL traits versus another environment. Another consideration is the measurement of MAL traits: all data on traits were self-reported, which could introduce bias or inaccuracy. However, since the questionnaires were validated and administered under standard conditions, we expect the data to be reasonably reliable. We also note that our findings represent a single cohort at one institution; generalisability may be limited. Different student populations or educational contexts (e.g., a less supportive learning environment) might yield different correlations between MAL characteristics and performance.

Despite these limitations, our study provides useful insights. The lack of correlation between many MAL traits and short-term performance does not undermine the importance of developing those traits. Instead, it suggests that our course's design was highly effective in supporting students across the board. For educators, an important takeaway is that curriculum design can significantly influence whether student personal characteristics manifest as performance differences. By creating a learning environment rich in resources, feedback, and engagement, we may help all students succeed, which is particularly valuable in a subject as demanding as anatomy. At the same time, encouraging adaptive learner qualities, especially a growth mindset, can add value by slightly enhancing performance and preparing students for future learning challenges.

CONCLUSION

In conclusion, our study found that in a blended anatomy course with extensive active and game-based learning components, most MAL characteristics (curiosity, motivation, and resilience) were not directly linked to students' exam performance, whereas growth mindset showed a weak but positive correlation with performance. These results suggest that a well-structured, supportive learning environment can enable students to excel in

anatomy largely independent of their baseline adaptive traits. The one trait that did confer a modest advantage was a growth mindset, reinforcing the idea that believing in one's ability to improve can be beneficial even in highly guided learning settings. For medical educators, these findings highlight the efficacy of active and gamified teaching strategies in promoting broad student success. We recommend continuing to implement such interactive learning approaches in the curriculum and, additionally, incorporating simple interventions to foster growth mindsets among students. By doing so, educators can create an environment that not only imparts knowledge effectively but also cultivates adaptive learners prepared to meet the challenges of advanced medical training.

Looking ahead, future studies could explore whether the impact of MAL characteristics on performance becomes more pronounced in less structured or more advanced learning contexts. For example, in clinical clerkships or self-directed learning scenarios, traits like self-regulation and resilience might play a larger role in determining success. Longitudinal research following students through different phases of medical education would be valuable to see how the role of MAL traits evolves as the curriculum shifts towards greater learner independence. Additionally, intervention studies could be conducted to test methods of strengthening MAL characteristics (such as targeted mentorship to improve self-regulated learning or resilience training workshops) and examine their effects on academic outcomes. By further investigating these areas, we can better understand how to develop both effective curricula and adaptable, lifelong learners in medicine.

ACKNOWLEDGEMENTS

The authors would like to thank the Faculty of Medicine, Universitas Hasanuddin, for supporting this study, and all the first-year medical students who participated. We are grateful for the students' enthusiastic engagement in the active learning activities, which made this study possible. We also acknowledge our colleagues in the Department of Anatomy for their help in implementing the game-based learning sessions and in validating the assessment materials.

ETHICAL APPROVAL

The study was approved by the Health Research Ethics Committee of FK UNHAS with protocol number UH24030192, ensuring adherence to ethical standards throughout the study.

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