Agile Teknik Agility Model (AAM): A Peer-Based Behavioral Assessment Framework for Vocational Software Development Education

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***Abstract*—In educational settings, Agile software development requires both technical skills and important behavioral traits, such as collaboration and resilience, which are essential for effective teamwork. This study presents the Agile Teknik Agility Model (AAM), a peer-based assessment framework designed to measure twelve core agility traits aligned with Agile principles in Vocational Software Development Education (VSDE). The model was integrated into a project-based learning curriculum and evaluated over two semesters with two student cohorts (n = 109) over a two-semester period. The results revealed consistent improvements in key traits, including growth mindset, self-organization, and openness. These findings demonstrate AAM's potential to capture and enhance behavioral growth in Agile learning environments. By combining peer-assessed Likert-scale instruments with iterative Agile practices, AAM provides a scalable and practical approach to character-focused evaluation in VSDE. The study highlights the importance of structured behavioral assessment as an innovative pedagogical tool in integrating ICT-based learning analytics into vocational software development curricula. Furthermore, additional validation and longitudinal studies are recommended to confirm the model's robustness and broader applicability.**

***Keywords*—agile education, Vocational Software Development Education (VSDE), peer assessment, learning analytics, behavioral traits, innovative pedagogies**

I. Introduction

Agile methodologies have become increasingly prominent in educational settings, particularly in software development programs that emphasize teamwork, adaptability, and iterative progress [1, 2]. While technical skills are typically assessed through project deliverables and academic grades [3], essential behavioral traits—such as resilience, openness, and commitment—often remain unmeasured [4]. This lack of behavioral assessment creates a gap in preparing students for collaborative, ICT-driven learning environments [5]. Recent research on Industry-Integrated Project-Based Learning (I-PBL) further highlights that future readiness requires not only technical expertise but also social adaptability, teamwork, and resilience as essential competencies [6]. This gap is especially critical in vocational education, where graduates must excel in dynamic, team-oriented industries that require both technical and behavioral skills [7].

In Indonesia, vocational institutions are mandated to produce graduates with strong technical proficiency and soft skills that meet evolving industry demands [8]. However, hiring decisions rely heavily on academic transcripts and certifications, which may fail to capture behavioral dimensions for Agile team performance [9]. Given the Agile Manifesto's emphasis on *"individuals and interactions over processes and tools"* [10], this study frames behavioral agility as a vital component of digital and project-based learning contexts [11].

Peer-assessed behavioral instruments have been increasingly used in education to capture nuanced interpersonal traits such as teamwork, leadership, and adaptability [12, 13]. These tools enable learners to evaluate each other based on observable behaviors during collaborative activities [14], offering a scalable approach for assessing traits aligned with Agile values [15].

In both national and international contexts, structured frameworks have been developed to align behavioral dimensions with organizational goals. In Indonesia, for example, the AKHLAK value system adopted by state-owned enterprises (BUMN) codifies six values: *Amanah* (Trustworthy), *Kompeten* (Competent), *Harmonis* (Harmonious), *Loyal* (Loyal), *Adaptif* (Adaptive), and *Kolaboratif* (Collaborative) [16, 17]. Internationally, tools such as the Agility Health Radar assess team maturity across behavioral dimensions like clarity, leadership, and culture [18], while instruments such as the Agile Work Practices Instrument (AWPI) [19] and multidimensional workforce agility models [20] demonstrate how behavioral agility influences planning, innovation, and adaptability.

Despite the existence of these national and international frameworks, two important gaps remain in vocational software development education. First, most prior applications of Agile in education emphasize processes and deliverables rather than systematically measuring students' behavioral growth. Second, existing validated instruments—such as AWPI and workforce agility models—were developed for professional or organizational contexts and are not tailored to the developmental needs or assessment constraints of vocational learners.

To address this gap, the present study introduces the Agile Teknik Agility Model (AAM) [21], a structured peer-assessment framework developed through collaboration between the SimHive Group and the Agile Product Development Laboratory at Politeknik Elektronika Negeri Surabaya. AAM operationalizes twelve fundamental traits—such as resilience, growth mindset, courage, and self-organization—into behaviorally anchored Likert-scale

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descriptors, enabling peer-based assessments of behavioral agility in Agile teams.

This study aims to evaluate the application of AAM in vocational software development education by embedding structured behavioral assessments into an Agile-based project-based learning environment. By doing so, it provides empirical evidence and practical recommendations for equipping graduates to perform effectively in collaborative, rapidly changing industry contexts.

This study offers four key contributions:

1) Proposes the Agile Teknik Agility Model (AAM) to assess behavioral traits that support team agility, addressing a gap in the Agile education literature.
2) Develops a structured metric system with twelve core traits, implemented through peer-based Likert-scale assessments for scalable classroom use.
3) Validates the framework with two cohorts of vocational students over two semesters, demonstrating measurable improvements in agility-related behaviors.
4) Illustrates how vocational education can integrate character development metrics into curricula to meet the soft skill demands of dynamic industries.

The remainder of this paper is organized as follows: Section II reviews literature on Agile education and human capital measurement. Section III outlines the course design and curricular context in which AAM was implemented. Section IV details the research methodology, including framework development, data collection, and analysis procedures. Section V presents empirical results, while Section VI discusses findings, practical implications, and limitations. Section VII concludes the study and proposes directions for future research.

II. Literature Review

Understanding how agility can be effectively cultivated and measured in educational contexts requires engaging with two core strands of literature: (1) the role of Agile methodologies in student learning environments, particularly vocational software development education (VSDE), and (2) the conceptualization of agility as a behavioral component of human capital. This section reviews both domains and identifies the gaps addressed by the Agile Teknik Agility Model (AAM).

A. Agile in Vocational Software Development Education

Higher education has long adopted Agile methodologies to promote collaboration, adaptability, and iterative problem-solving, especially in software engineering programs [22]. Avila *et al*. [23] demonstrated the effectiveness of Scrum in enhancing student ownership and teamwork, while Ragas *et al*. [24] showed that Agile learning environments promote stronger communication and flexibility.

However, much of the literature emphasizes process adherence and product outcomes—such as deliverables and grades—while paying limited attention to **behavioral traits** (e.g., resilience, openness, self-organization) that are vital for Agile team dynamics [25–27]. Although the Agile Manifesto prioritizes *"Individuals and Interactions over Processes and Tools"* [10], most educational implementations lack structured instruments to evaluate whether students internalize these principles [28]. This highlights a gap in systematically assessing whether vocational learners internalize agility-supporting traits.

B. Human Capital and Agility Measurement

Human capital theory considers individuals as evolving assets whose skills and attributes contribute to sustained organizational outcomes [29]. In Agile contexts, commitment, reflection, adaptability, and collaboration are central to team productivity and sustainability [27, 30].

Corporate frameworks exemplify the alignment between behavior and performance. In Indonesia, the AKHLAK values system—mandated for State-Owned Enterprises (BUMN)—codifies six values: *Amanah* (Trustworthy), *Kompeten* (Competent), *Harmonis* (Harmonious), *Loyal* (Loyal), *Adaptif* (Adaptive), and *Kolaboratif* (Collaborative) [16, 17]. This model integrates character-based performance metrics into long-term talent development, promoting ethical behavior and organizational excellence.

In academic research, comparable instruments remain limited. The Personality Systems Framework for Assessment (PSF-A) organizes personality and contextual factors to support character development [31]. Similarly, Junker *et al*. [19] validated the Agile Work Practices Instrument (AWPI), distinguishing between Agile taskwork and teamwork, demonstrating how behavioral agility can be reliably measured and improved.

Yet, most measurement models are workplace-oriented [32]. Frameworks such as the Team Agility Framework [33] assess team-level maturity but are not suited to isolating individual behavioral development, particularly in educational settings. This limitation highlights the need for instruments adapted to student-level contexts.

C. Toward Educational Agility Assessment

As industries increasingly prioritize soft skills and behavioral alignment [34], education must evolve to shape students not only as skilled workers but as agility-oriented human capital [35]. This shift requires structured tools to assess attributes like courage, resilience, and openness—traits that reflect a student's potential to contribute to agile teams [36].

Building on these insights, the Agile Teknik Agility Model (AAM) was developed as a context-specific, empirically grounded framework for vocational software development education. AAM operationalizes twelve behavioral traits into peer-assessed Likert-scale descriptors, providing a systematic means of evaluating individual-level agility within collaborative learning environments.

To clarify how AAM builds upon and differentiates itself from prior research, Table 1 summarizes representative studies and frameworks, highlighting their contexts, focus areas, and limitations in educational settings, together with AAM's specific contributions as a repeatable assessment framework with scalable metrics and initial empirical validation for vocational classrooms.

III. Course Design

To implement the Agile Teknik Agility Model (AAM) in an academic setting, this section explains how the framework was embedded into a Project-Based Learning (PBL) curriculum for vocational software development students. structure with Agile practice implementation, creating an environment that both cultivates and evaluates the behavioral traits emphasized by the AAM. The following subsections describe: (1) the curriculum structure across two semesters, and (2) the systematic application of Agile principles within the courses.

Table 1. Comparison of existing studies and the AAM contribution

Study/Framework	Context	Focus Area	Limitations in the Educational Context	AAM Contribution
Avila *et al*. [23]	Higher Education	Scrum for teamwork, ownership	No behavioral measurement	Adds structured behavioral metrics
Ragas *et al*. [24]	Higher Education	Agile for communication, flexibility	No tracking of personal agility	Provides agility trait tracking
AWPI [19]	Workplace	Agile taskwork/teamwork	Not designed for students	Adapted for vocational learners
Teamwork Effectiveness Model [30]	Workplace/Higher Education	Team-level effectiveness & maturity	No individual-level behavioral focus	Measures individual traits
Workforce Agility Model [37]	Workplace	Multi-dimensional agility	Professional context only	Classroom-ready peer assessment

A. *Curriculum Structure*

The Agile Teknik Agility Model (AAM) was implemented in a two-semester PBL curriculum at the D4 Informatics Engineering Program, Politeknik Elektronika Negeri Surabaya. The curriculum was designed to simulate real-world Agile software development while fostering agility-related character traits through authentic team collaboration and reflective practice.

The program adopted an integrative teaching approach centered on PBL, where the same student groups collaborated across interrelated courses to develop a single product. This package system ensured that each group participated in all classes during both semesters, strengthening team cohesion and learning continuity.

Students were divided into eight cross-functional teams, each tasked with developing a functional mobile application. A specific constraint required that early adopters come from the student community. This design simplified the user review process and guaranteed continuous feedback from actual users—classmates and juniors—throughout development.

The process spanned five sprints of four weeks each, distributed across two semesters. These sprints aligned with course content and Agile rituals, enabling iterative product development. At the end of each sprint, teams delivered a Minimum Viable Product (MVP), which was tested and reviewed by over 200 underclassmen. The Net Promoter Score (NPS) provides a quantitative measure of user satisfaction, complemented by qualitative feedback from users that informs product improvements. During Sprint Review sessions, industry experts participate to refine the product backlog and define objectives for the next sprint. This process reinforces feedback-driven, incremental development consistent with established industry practices.

The integrative PBL model was implemented as follows:

1) Semester 4: Courses included Agile Methodologies, UX Design, and Mobile Programming.
2) Semester 5: Courses included Software Development Workshop, Clean Code and Refactoring, and Software Quality Assurance.

B. *Agile Implementation across Courses*

Scrum served as the primary coordination framework across courses, complemented by Lean Startup (MVPs, NPS, Lean Canvas, Build-Measure-Learn (BML) cycles) and XP practices (clean code, pair programming, collective code ownership) where appropriate to each course's learning outcomes. A synchronized sprint calendar which included five sprints throughout the academic year, helped coordinate deliverables and foster peer interactions.

Other Scrum ceremonies—such as Sprint Planning, Daily Scrum, and Sprint Retrospective—were conducted independently by student teams outside class hours. This approach allowed for flexibility and ownership while ensuring overall coordination across the curriculum.

Each course maintained its learning objectives (for example, Agile principles in Agile Methodologies and testing in Software Quality Assurance), but the product development activities were shared across courses. This collaboration facilitated real-time teamwork and the joint development of both technical skills and essential behavioral traits.

Tables 2 and 3 illustrate the structure of course activities throughout each sprint. By aligning course content with Agile practices, the curriculum created an authentic environment for applying and assessing the AAM framework. This design established a foundation for systematically observing and measuring agility-related traits in conditions that closely resembled real-world software development.

Table 2. Integrative teaching in the fourth semester

Week	Stage	Activities in Every Course		
		Agile Methodology	UX Design	Mobile Programming
1–4	Basic knowledge lectures	Agile Fundamental: Mindset, Values, Principles	Team Formation, Product Ideas Proposal, Pitch	Basic Mobile Programming, Boiler Plate
5–8	Inception stage	Lean Thinking, NPS, MVP	Lean Canvas, Competitive Analysis	Mobile UI/UX Integration
9–12	Sprint Development 1	Agile Practices, Processes, and Tools	Design Thinking, Double Diamond	Backend Integration, API Setup
13–16	Sprint Development 2	Guest Talks, Project Checkpoint	Laws of UX	Deployment, Debugging

Table 3. Integrative teaching in the fifth semester

Week	Stage	Activities in Every Course		
		Software Quality Assurance	Clean Code & Refactoring	Software Development Workshop
1–4	Basic knowledge lectures	QA, QC, Testing Foundations	SOLID Principles, Code Smells	Agile Roles & Project Setup
5–8	Sprint Development 3	Testing Types, Test Case Design	Refactoring Techniques	Human Patterns, Project Management Antipatterns
9–12	Sprint Development 4	Automated Testing, Bug Fixing	Final Refactor, Technical Review	Mentor Coaching, Feedback Implementation
13–16	Sprint Development 5	Test Reports, QA Documentation	Code Clean-Up & Optimization	Product Presentation & Public Showcase Preparation

IV. Research Methodology

This section outlines the methodological approach used in this study, covering the development of the Agile Teknik Agility Model (AAM), the research questions, data collection process, data analysis procedures, and the validated metrics. The methodology was designed to ensure coherence between the study's objectives, research design, and analysis.

A. Development of The AAM Framework

The Agile Teknik Agility Model (AAM) was developed through a structured collaboration between the SimHive Group—a holding company for Agile-based startups—and the Agile Product Development Laboratory at Politeknik Elektronika Negeri Surabaya (PENS). This partnership, known as Agile Teknik**,** aims to enhance the quality of IT education through Project-Based Learning (PBL) and bridge the gap between academia and industry, particularly in Agile software development. The model's development was primarily motivated by real-world challenges faced by the software industry, especially the difficulty in identifying and cultivating individuals whose behavioral traits align with Agile values.

A systematic approach guided the framework's design. First, using *first principles thinking*, all twelve Agile principles were analyzed in depth to extract their fundamental behavioral meanings, without oversimplification. For example, from Agile Principle 1—*"Our highest priority is to satisfy the customer through early and continuous delivery of valuable software"*—four behavioral elements were distilled: customer satisfaction, incremental delivery, iterative feedback, and value orientation. This process was repeated for all Agile principles to derive core human and behavioral dimensions.

These elements were grouped and classified with emphasis on the people-first philosophy in Agile Manifesto value 1: *"Individuals and interactions over processes and tools."* It ensured a focus on individual-level traits that directly influence Agile team performance. Drawing on Eric Ries's perspective that *"a startup is a human institution"* [38], the classification concentrated on traits that can be attributed to individuals rather than tools or processes. The overall structure of the Agile Teknik Agility Model, including its three maturity layers (People, Process, and Product & Finance) and its twelve behavioral attributes, is illustrated in Fig. 1.

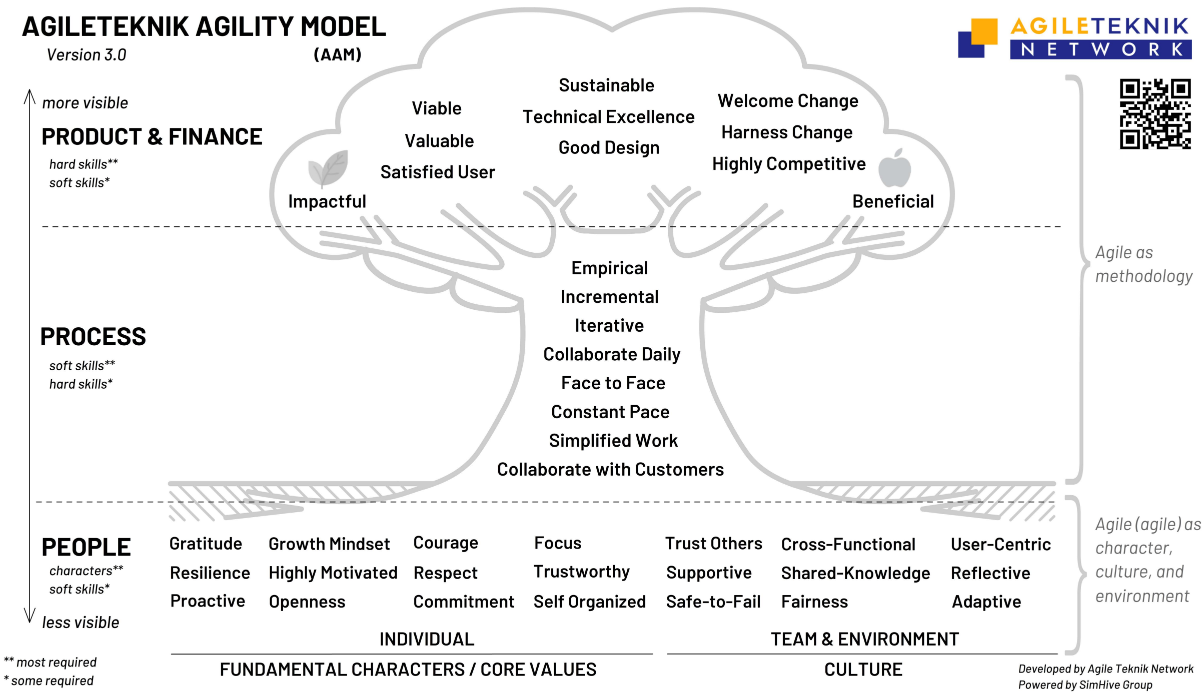

Fig. 1. Agile Teknik Agility Model (AAM) tree structure [21].

Each trait in the AAM was operationalized into a five-point Likert scale. This scale was developed through iterative refinement and is anchored in empirical insights from practitioners at SimHive Group. These experts draw on decades of hands-on experience in three interrelated domains:

1) Professional fieldwork: This includes direct involvement in Agile teams, where they have served as developers,

product managers, product owners, and Scrum Masters in both Indonesian and international settings, working with both high-performing and dysfunctional teams.
2) Human capital development projects: This involves designing gamified talent assessments and competency frameworks specifically for Indonesian State-Owned Enterprises (BUMN).
3) Educational innovation: This encompasses the development of Agile curricula, implementation of character coaching programs, and ongoing academic–industry collaborations.

By integrating professional, corporate, and educational perspectives, the resulting behavioral descriptors are both contextually relevant and pedagogically meaningful. The observed improvements in specific traits are consistent with prior research, reinforcing both the theoretical foundations and practical significance of the AAM.

The process culminated in the identification of twelve core attributes representing essential agility-related traits: *Gratitude, Resilience, Proactive, Growth Mindset, Highly Motivated, Openness, Courage, Respect, Commitment, Focus, Trustworthy,* and *Self-Organized*. The formal definitions of these twelve traits are summarized in Table 4, providing conceptual clarity before their behavioural operationalization.

Each attribute was operationalized into a behaviorally anchored 5-point Likert scale. A score of 1 indicates the minimal or absent presence of the trait, while a score of 5 reflects consistent behavioral demonstration in Agile environments. To illustrate the depth of this operationalization, Table 5 presents four representative traits: Gratitude, Growth Mindset, Trustworthy, and Courage. For each trait, behavioral anchors are provided for scores 1 and 5. The intermediate levels (scores 2–4) were also developed but are omitted here for brevity. The complete Likert-scale rubrics for all twelve traits are provided in the Appendix.

Table 4. Definitions of the twelve AAM behavioral traits

Trait	Definition
Gratitude	Acknowledging and appreciating the positive aspects of life and others.
Resilience	The ability to recover from setbacks and maintain effort under adversity.
Proactive	Taking initiative and anticipating needs or challenges in a team setting.
Growth Mindset	Believing that abilities can be developed through effort and learning.
Highly Motivated	Sustained drive and enthusiasm in pursuing personal or team goals.
Openness	The willingness to be honest and transparent, including acknowledging one's weaknesses and limitations
Courage	The willingness to speak honestly and act openly for mutual improvement, including facing discomfort, admitting faults, and addressing difficult issues constructively.
Respect	Valuing others' contributions, diversity, and perspectives.
Commitment	Dedication to team objectives and consistency in fulfilling responsibilities.
Focus	Concentration and attention to task without being easily distracted.
Trustworthy	The quality of being reliable and consistent in fulfilling responsibilities, maintaining integrity, and upholding ethical commitments.
Self-Organized	The ability to manage tasks and make decisions independently, showing initiative and creativity without direct supervision.

Table 5. Sample AAM trait descriptor for Likert ratings

Trait	Score 1—Lowest Expression	Score 5—Highest Expression
Gratitude	Ignoring positive aspects of life and never appreciating others' efforts	Consistently spread positivity, kindness, and appreciation for others.
Growth Mindset	Avoids learning; resists new knowledge, challenges, and constructive feedback.	Consistently self-motivated to seek learning, embraces challenges and feedback, sees failure as growth, and actively shares insights to enhance team development.
Trustworthy	Neglects responsibilities and fails to fulfill entrusted tasks.	Reliably complete all tasks with integrity and uphold all commitments.
Courage	Always silent and passive, avoiding necessary actions for the common good.	Consistently takes courageous actions using proper methods.

The Likert descriptors were initially developed by SimHive experts and later refined for developmental appropriateness in student contexts, with support from generative AI tools (e.g., ChatGPT). Clarity and relatability were ensured without compromising rigor.

B. Research Questions

The following research questions guide this study:
1) **RQ1:** How can fundamental individual character traits that support agility be systematically defined, structured, and measured among vocational software development students working in Agile teams?
2) **RQ2:** Does the structured application of Agile principles over two semesters significantly improve students' fundamental character traits relevant to team agility?
3) **RQ3:** Which fundamental character traits show the most notable growth after Agile-based learning and cultural coaching interventions?

These questions were formulated to examine and validate the Agile Teknik Agility Model (AAM) as a framework for measuring and nurturing personal agility—viewed as a dimension of human capital—within a vocational education setting based on Agile principles.

C. Data Collections

To address these research questions, a data collection process was implemented as follows. The study was conducted at the D4 Informatics Engineering Program of PENS, involving two cohorts:
1) PBL 2023 cohort: 50 students with no prior exposure to AAM before starting Agile software development.
2) PBL 2024 cohort: 59 students who had been introduced to AAM attributes during the Non-Technical Skills course in Semester 3, before entering the software development phase.

Data collection was conducted at two points: Sprint 1 (baseline) and Sprint 5 (post-intervention). At each point, students completed peer assessments of their teammates using the 5-point Likert scale behavioral rubrics for twelve agility traits (see Table 4). Assessments were anonymous to encourage honest feedback.

Before each assessment, facilitators provided standardized guidance on rubric interpretation to ensure consistent application across evaluators. All participants provided informed consent and were assured that their responses would be used solely for research purposes in an aggregated form.

D. Data Analysis

The collected data were analyzed in several steps. For each cohort, we averaged peer-assessed scores across traits and compared these averages between Sprint 1 and Sprint 5. We calculated delta scores (Δ) by subtracting baseline values from post-intervention scores, thereby allowing us to identify trait-level growth. These Δ scores helped rank the traits, addressing Research Question 3 (RQ3) to determine which attributes showed the most significant improvement. We used bar charts and summary tables to visualize patterns across the cohorts.

Descriptive statistics were computed to examine the distribution of scores, and inferential tests were performed to evaluate the significance of any observed changes. Paired t-tests were applied when the assumptions of normality were satisfied; otherwise, we considered non-parametric alternatives. Effect sizes were calculated using Cohen's d to assess the magnitude of the changes.

Additionally, we conducted reliability analyses to assess the instrument's consistency. We assessed internal consistency using Cronbach's alpha, and inter-rater reliability using the Intraclass Correlation Coefficient (ICC) based on peer ratings. These procedures aimed to ensure that peer assessments were applied consistently and that the framework functioned reliably across all cohorts.

E. Instrument Reliability and Validity

To address methodological concerns about the reliability and validity of the AAM instrument, three statistical procedures were conducted. First, internal consistency reliability was assessed using Cronbach's alpha across the twelve AAM traits. Second, inter-rater reliability was evaluated using the Intraclass Correlation Coefficient (ICC), since peer assessments were used to score each student. Third, to determine whether AAM scores improved significantly over time, paired t-tests were conducted to compare the scores from Sprint 1 and Sprint 5 within each cohort. Effect sizes were calculated using Cohen's *d* to indicate the magnitude of improvements. These analyses were performed separately for the 2023 and 2024 cohorts.

V. Results

The Agile Teknik Agility Model (AAM) was implemented and measured across two cohorts over a two-semester period. Data collection included peer-assessed Likert scores for twelve predefined traits at both the initial and final stages of the semester.

A. Trait Definitions and Measurement

A total of twelve agility-supporting traits were defined, structured, and operationalized through peer-assessed instruments. Each trait was measured using a 5-point Likert scale with explicit behavioral descriptors corresponding to each point. Table 4 provides a complete list of the traits, their definitions, and measurement descriptors.

B. Comparative Peer-Assessment Scores

Table 6 presents the average Likert-scale scores at Sprint 1 and Sprint 5 for each attribute, along with the Δ values indicating improvement over the project. Both cohorts demonstrated positive gains across all twelve attributes.

Table 6. Mean peer-assessment scores for Sprint 1, Sprint 5, and Δ values for PBL 2023 and PBL 2024

Trait	Average Score at PBL 2023			Average Score at PBL 2024		
	Sprint 1	Sprint 5	Δ Change	Sprint 1	Sprint 5	Δ Change
Gratitude	3.08	3.86	0.78	4.2	4.66	0.46
Resilience	3.1	3.92	0.82	4.15	4.51	0.36
Proactive	3.02	3.84	0.82	4.17	4.53	0.36
Growth Mindset	3.12	4.22	1.1	4.31	4.75	0.44
Highly Motivated	3.02	3.94	0.92	4.24	4.54	0.31
Openness	3.14	4.08	0.94	4.27	4.64	0.37
Courage	2.96	3.68	0.72	3.97	4.61	0.64
Respect	3.58	3.98	0.4	4.29	4.63	0.34
Commitment	3.12	4.04	0.92	4.17	4.56	0.39
Focus	3.16	3.86	0.7	4.08	4.53	0.44
Trustworthy	3.56	4.48	0.92	4.63	4.81	0.19
Self-organized	3.04	4.02	0.98	4.27	4.69	0.42

The PBL 2023 cohort—introduced to the AAM framework during project execution—started with lower baseline scores but recorded the largest improvements in *Growth Mindset* (+1.10), *Self-Organized* (+0.98), and *Openness* (+0.94). In contrast, the PBL 2024 cohort, which had prior exposure to AAM through a non-technical skills course, began with higher baseline scores and showed more moderate gains, with the highest improvements in *Courage* (+0.64), *Gratitude* (+0.46), and both *Growth Mindset* and *Focus* (+0.44).

The distribution of scores for Sprint 1 and Sprint 5 is illustrated in Fig. 2, highlighting a pronounced upward shift in the performance curve of PBL 2024.

C. Pre- and Post-Implementation Score Differences

The mean scores before and after the AAM-based intervention for each cohort are summarized in Table 7.

Table 7. Rank of trait-level score changes in each cohort

Attribute	2023 Δ	2024 Δ	2023 Rank	2024 Rank
Growth Mindset	1.10	0.44	1	3
Self-organized	0.98	0.42	2	5
Openness	0.94	0.37	3	7
Highly Motivated	0.92	0.31	4	11
Commitment	0.92	0.39	4	6
Trustworthy	0.92	0.19	4	12
Resilience	0.82	0.36	7	8
Proactive	0.82	0.36	7	8
Gratitude	0.78	0.46	9	2
Courage	0.72	0.64	10	1
Focus	0.70	0.44	11	3
Respect	0.40	0.34	12	10

Both cohorts show positive score changes across all attributes, with PBL 2024 demonstrating greater average improvement (Δ = 0.42) compared to PBL 2023 (Δ = 0.31).

The aggregated improvement patterns are visualized in

Fig. 3, where PBL 2024's improvement slope is steeper than PBL 2023's. This supports the observation that early-stage integration of the AAM evaluation and feedback mechanism yields better results.

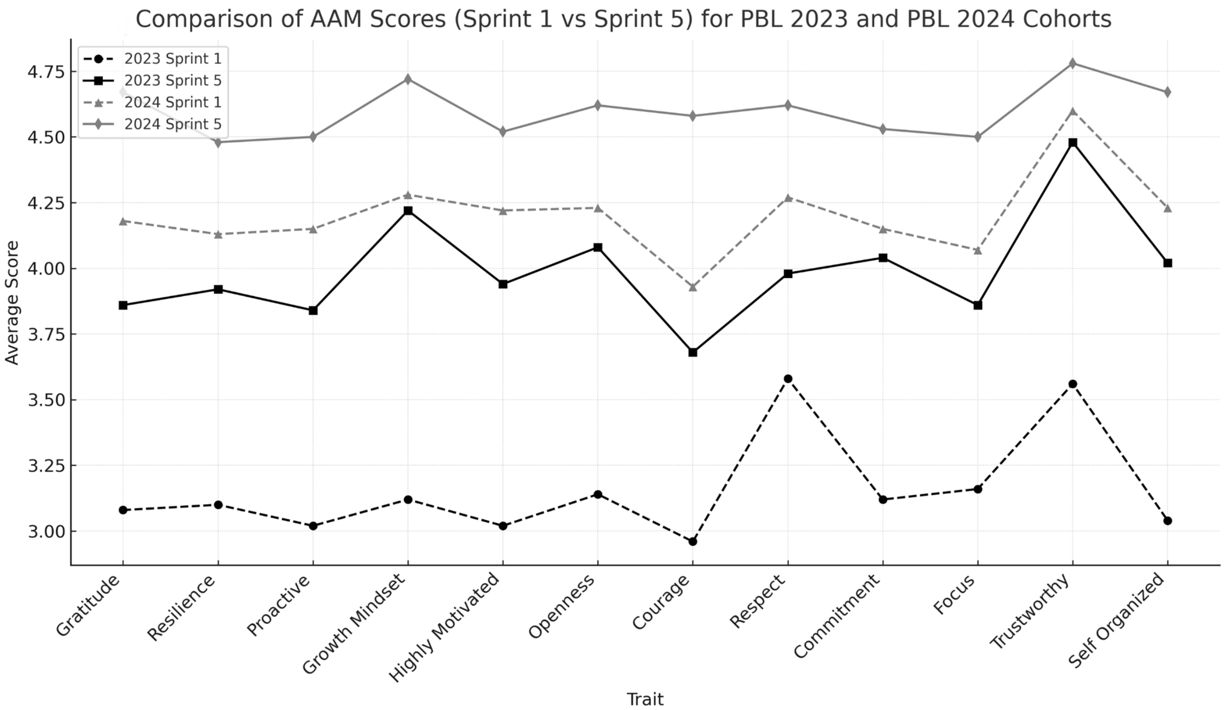

Fig. 2. AAM score comparison for Sprint 1 and Sprint 5 in both cohorts.

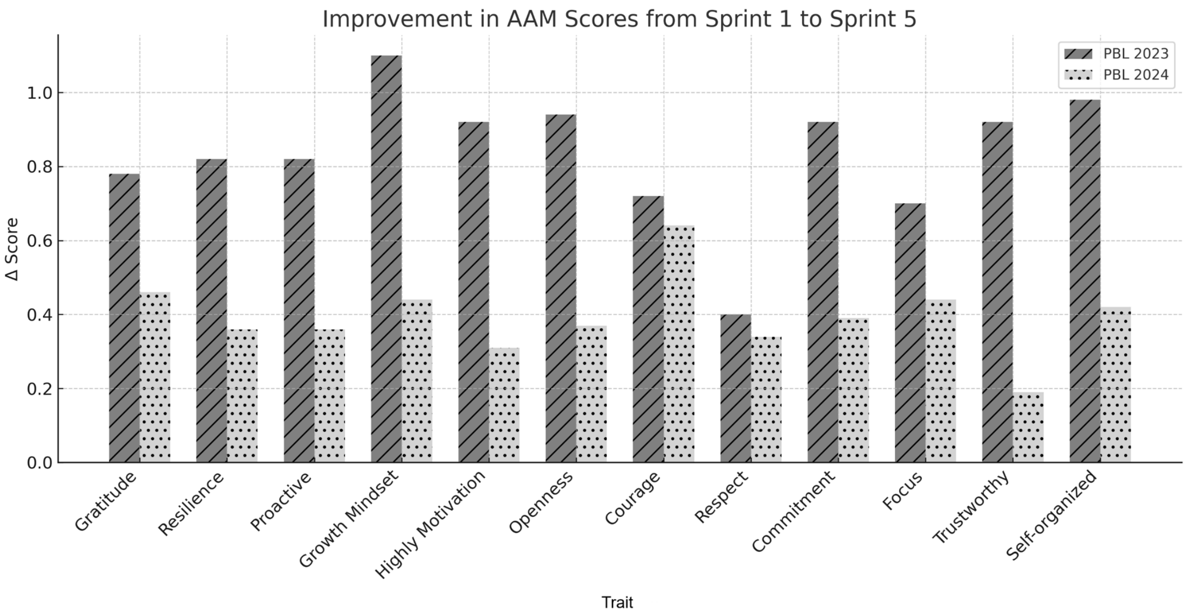

Fig. 3. Mean improvement in AAM scores across sprints.

D. *Instrument Reliability and Inferential Results*

The AAM instrument demonstrated high internal consistency, with Cronbach's alphas of 0.82 for Sprint 1 and 0.84 for Sprint 5. These values indicate reliable measurement across the 12 traits assessed. Table 8 summarizes the Cronbach's alpha values across cohorts and sprints, indicating that the AAM instrument maintained acceptable internal reliability in both implementations.

Inter-rater reliability, evaluated using the Intraclass Correlation Coefficient (ICC(2,k)), produced an average value of 0.80, suggesting strong consistency among peer assessments. The detailed ICC values across both cohorts and sprints are presented in Table 9, supporting the consistency of peer-assessed ratings throughout the program.

Table 8. Cronbach's alpha values by cohort and sprint

Cohort	Sprint	Cronbach's Alpha
2023	1	0.82
2023	5	0.84
2024	1	0.81
2024	5	0.83

Paired t-tests showed a significant improvement in mean AAM scores from Sprint 1 to Sprint 5 for both cohorts. For the 2023 cohort, the results were $t(49) = 6.22$, $p < 0.001$, $d = 0.76$; for the 2024 cohort, $t(58) = 5.48$, $p < 0.001$, $d = 0.67$, indicating moderate to large effect sizes. Table 10 provides a summary of the statistical test results, showing mean scores, significance levels, and effect sizes for each cohort.

Table 9. Inter-rater reliability (ICC 2,k) for AAM ratings

Cohort	Sprint	ICC (2,k)
2023	1	0.78
2023	5	0.81
2024	1	0.79
2024	5	0.82

Table 10. Paired t-test results for total AAM scores

Cohort	Mean (S1)	Mean (S5)	t(df)	p-value	Cohen's d
2023	3.42	4.18	6.22 (49)	< 0.001	0.76
2024	3.58	4.22	5.48 (58)	< 0.001	0.67

Moreover, trait-level analysis showed substantial improvements across almost all traits ($p < 0.05$), reinforcing the intervention's effectiveness in enhancing behavioral agility.

E. Ranking of Trait-Level Improvements

To further investigate behavioral improvements, each agility attribute was ranked based on the change in scores between Sprint 1 and Sprint 5. As illustrated in Fig. 4, the top three improvements for PBL 2023 were: Growth Mindset (+1.10), Self-Organization (+0.98), and Openness (+0.94). For PBL 2024, the leading improvements were Courage (+0.64), Gratitude (+0.46), and a tie between Focus and Growth Mindset (+0.44 each).

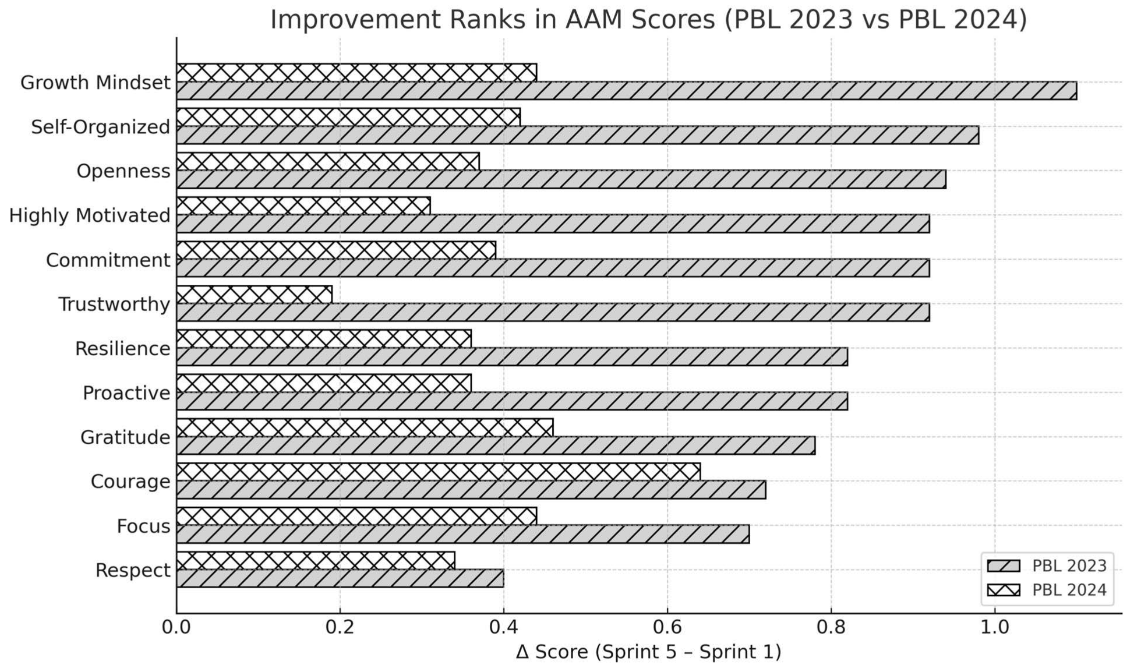

Fig. 4. Top trait-level improvements in each cohort.

To validate these patterns, statistical reliability and inferential tests were performed. The AAM instrument demonstrated strong internal consistency, with Cronbach's alphas of 0.82 for Sprint 1 and 0.84 for Sprint 5. It also showed high inter-rater reliability, with an average ICC(2,k) of approximately 0.80. Paired t-tests confirmed that average AAM scores increased significantly between the sprints for both cohorts ($p < 0.001$), with moderate to large effect sizes. These findings reinforce the observed behavioral changes and confirm the reliability of peer-assessed improvements.

A summary of descriptive statistics for all attributes is provided in Appendix A.

VI. Discussion

This section interprets the core findings related to the research questions, outlines practical implications for vocational Agile education, and discusses key limitations, providing suggestions for future research.

A. Interpretation of Findings

The results from both cohorts indicate that the Agile Teknik Agility Model (AAM) effectively measures and enhances behavioral agility traits in vocational software development education. Statistically significant improvements were observed across all twelve traits, demonstrating the model's ability to track behavioral changes over time.

When examining the trait-level rankings (see Section 5.4), distinct growth profiles emerge for each group, as illustrated in Table 11.

Table 11. Trait improvement ranking per cohort

Rank	PBL 2023 (introduced during project)	Δ Mean	PBL 2024 (Introduced pre-project)	Δ Mean
1	Growth Mindset	+1.10	Courage	+0.64
2	Self-Organized	+0.98	Gratitude	+0.46
3	Openness	+0.94	Focus / Growth Mindset (tie)	+0.44

In PBL 2023, the leading gains—*Growth Mindset, Self-Organized*, and *Openness*—reflect adaptability, self-directed learning, and receptiveness to new ideas. This suggests that introducing AAM in an active project context can sharpen traits that help students navigate uncertainty and take ownership of their contributions.

By contrast, PBL 2024's top gains—*Courage, Gratitude*, and *Focus/Growth Mindset*—point toward a values-oriented and sustained-attention profile. Early AAM exposure in a non-technical skills course appears to strengthen personal ethos, motivational resilience, and attentional stability more than rapid adaptability.

The cohort comparison suggests that while early exposure builds a strong baseline, immersive and high-stakes project contexts may foster sharper gains in adaptability-related traits. These findings reinforce that behavioral agility is dynamic and context-dependent, benefiting from both preparatory learning and situated, team-based challenges.

Recent work on industry-integrated project-based learning (I-PBL) also highlights how collaboration with industry stakeholders strengthens teamwork, adaptability, and communication [6]. In this regard, AAM complements I-PBL by providing a low-cost, classroom-embedded mechanism for capturing peer-based behavioral development without requiring external intervention.

Statistical validation reinforces these findings. A high Cronbach's alpha indicates the instrument's internal reliability, while a strong inter-rater reliability (ICC ≈ 0.80) confirms the consistency of the peer assessments. Additionally, the significant improvements in AAM scores from Sprint 1 to Sprint 5—along with moderate to large effect sizes—demonstrate not only pedagogical progress but also measurable behavioral growth. These results effectively address previous concerns about methodological rigor and provide empirical evidence of AAM's reliability and effectiveness as an assessment tool in vocational education.

Unlike previous agility models, such as the Agile Work Practices Instrument (AWPI) [19], which was initially designed for industry professionals, the AAM provides a peer-based behavioral assessment tool tailored explicitly for vocational education. This model is distinctive because it tracks students' agility traits over time, across Agile project sprints, enabling educators to monitor soft skill development in real time. Additionally, the AAM functions independently of external observers, utilizing structured peer feedback within team environments. By integrating this tool into the educational process, this study presents a novel framework that addresses a significant gap in the Agile education literature: validated behavioral agility tools for vocational learners have been largely absent.

The observed improvements in specific traits align with previous research, reinforcing the theoretical foundations of the AAM. For instance, the significant gains in "growth mindset" support Dweck's theory, which emphasizes the importance of adaptive learning orientations in the face of complex challenges [39]. Additionally, the notable enhancements in "self-organization" and "focus" reflect key behaviors that are developed through iterative project cycles in Agile environments, aligning with studies on self-directed learning in Scrum teams [40]. Furthermore, the advancements in "gratitude" and "courage" indicate a movement toward values-based collaboration, likely influenced by the psychological safety fostered by peer-driven feedback systems [41]. These results highlight not only cognitive but also affective dimensions of agility development, reinforcing AAM's relevance for holistic behavioral education.

B. Practical Implications

Empirical evidence supports integrating structured behavioral assessment tools like AAM in vocational curricula to better align with industry expectations. The key implications are:

1) Curriculum Design: Incorporating AAM ensures that behavioral traits are systematically addressed alongside technical competencies, resulting in more balanced graduate profiles.
2) Feedback-Driven Development: Peer assessments offer real-time, context-relevant feedback that can guide personal and team growth without overburdening instructors.
3) Scalability: AAM's standardized structure allows adaptation across varying class sizes and institutional contexts.

Additionally, connecting improvement rankings to curriculum decisions helps educators target interventions—such as emphasizing adaptability and openness for early-stage teams, or focusing on value-driven traits for maintaining performance in long-term projects.

Importantly, the integration of AAM also supports ICT-based learning analytics by generating behavioral data that can inform personalized pedagogical strategies.

C. Threats to Validity

Several factors may affect the validity of this study's findings:

1) Internal Validity: Without a control group, improvements cannot be attributed solely to AAM; however, consistent trends across cohorts strengthen interpretive confidence.
2) Measurement Validity: Comprehensive psychometric validation (e.g., reliability coefficients, factor analysis) was outside the present scope. Future studies should address this across institutions and terms.
3) External Validity: Findings derive from a single institution and discipline, limiting generalizability. Broader replication is necessary to confirm applicability in different vocational and cultural contexts.

Although the results of this study are promising, it is important to note that a complete psychometric validation—such as establishing construct validity and comparing our findings with existing validated instruments—was not included in this research. While the current analyzes offer initial evidence of reliability and responsiveness, future studies should incorporate confirmatory factor analysis and comparisons with other instruments to validate the AAM framework across various contexts more thoroughly.

D. Generalizability and Future Application

While the results are promising, the specific institutional and cultural context of a single Indonesian polytechnic limits the generalizability of these findings. To enhance applicability, broader validation across various institutions, disciplines, and learner populations is necessary.

Future research could investigate whether the timing of introductions—either before or during a project—consistently leads to the contrasting growth profiles observed in this study. Additionally, it would be valuable to determine if these patterns continue to influence workplace performance. Longitudinal and cross-context studies, which include secondary education and professional training, would further clarify the potential of AAM as a tool for long-term human capital development.

Moreover, integrating AAM-based assessments with digital dashboards or institutional analytics systems could broaden their function within a comprehensive educational technology ecosystem

VII. Conclusion

This study introduced and evaluated the Agile Teknik Agility Model (AAM), a peer-based behavioral assessment framework designed for vocational Agile education. By operationalizing 12 core agility traits into structured Likert-scale instruments, AAM enables scalable, classroom-based measurement of behavioral growth. Implemented over two semesters with two student cohorts, the model showed statistically significant improvements in all measured traits, highlighting its pedagogical utility and initial validity.

Despite these encouraging results, the study has several limitations. The sample was confined to a single vocational institution in Indonesia, which limits the generalizability of the findings. Additionally, the intervention lasted only five sprints across two semesters, which may not adequately capture long-term behavioral changes. While we established internal consistency and inter-rater reliability, comprehensive psychometric validation, including construct validity and comparison with existing validated instruments, was beyond the scope of this study.

Future research should focus on longitudinal studies to examine the sustained impact of AAM on student behavior and industry readiness. Expanding the model's application to multiple institutions and cultural contexts will help assess its generalizability. Furthermore, confirmatory factor analysis and cross-instrument validation are necessary to strengthen AAM's psychometric foundation.

Overall, the AAM offers a practical and innovative contribution to Agile education by integrating structured behavioral assessment within project-based learning. With further refinement and broader validation, it has significant potential to serve as a robust tool for developing adaptable, collaborative, and resilient graduates equipped to meet the demands of dynamic, team-oriented work environments..

Appendix

To enhance clarity and relevance, Appendix A provides a concise summary of the trait-level results. The complete data set is available upon request. Additionally, Appendix B includes the complete AAM rating rubric, which serves as the conceptual foundation for the proposed model and allows for replication in future educational applications.

A. Summary of Descriptive Statistics for Selected AAM Traits

Table A1. Selected AAM traits scores and changes by cohort

Trait	Cohort	Sprint 1 (M ± SD)	Sprint 5 (M ± SD)	Δ Mean
Growth Mindset	2023	3.31 ± 1.03	4.13 ± 0.86	+0.82
Self-Organized	2023	3.18 ± 1.15	3.99 ± 0.96	+0.81
Openness	2023	3.26 ± 1.05	4.06 ± 0.81	+0.80
Commitment	2023	3.31 ± 1.00	4.06 ± 0.86	+0.75
Courage	2024	3.98 ± 0.93	4.39 ± 0.76	+0.41
Gratitude	2024	4.12 ± 0.77	4.50 ± 0.68	+0.38
Focus	2024	4.05 ± 0.81	4.42 ± 0.70	+0.37
Respect	2024	4.17 ± 0.61	4.48 ± 0.60	+0.31

Note: This table presents selected traits to ensure clarity and brevity. Full descriptive results for all 12 traits are available upon request.

Table A1 summarizes key trait-level descriptive statistics from Sprint 1 to Sprint 5 for both cohorts. The table highlights the three traits that showed the most significant improvement in each cohort, along with an additional trait to demonstrate the overall consistency of results across the AAM framework. These improvements underscore the behavioral shifts noted in the Results section.

B. Full Likert Descriptors for all AAM Traits

The following Tables A2–A13 present the complete set of 5-point Likert-scale behavioral descriptors for 12 representative traits in the Agile Teknik Agility Model (AAM). These descriptors were developed to support consistent peer-based assessment of individual agility traits in Agile classroom settings.

1) Gratitude

Definition: Acknowledging and appreciating the positive aspects of life and others.

Table A2. Behavioral descriptors for the AAM trait—gratitude

Score	Behavioral Descriptor
1	Ignoring positive aspects of life and never appreciating others' efforts
2	Shows little gratitude toward life or the efforts of others.
3	Occasionally expresses gratitude, but inconsistently, especially during stress.
4	Feels grateful but lacks motivation to share positivity.
5	Consistently spread positivity, kindness, and appreciation for others.

2) Resilience

Definition: The ability to recover from setbacks and maintain effort under adversity.

Table A3. Behavioral descriptors for the AAM trait—resilience

Score	Behavioral Descriptor
1	Able to give up easily and despair when facing obstacles or failures.
2	Able to recover occasionally, but still easily discouraged at times.
3	Able to recover from obstacles or failures, but only after a long time.
4	Able to recover quickly and independently from obstacles or failures.
5	Able to recover quickly and even turn obstacles or failures into opportunities.

3) Proactive

Definition: Taking initiative and anticipating needs or challenges in a team setting.

Table A4. Behavioral descriptors for the AAM trait—proactive

Score	Behavioral Descriptor
1	Always blaming external factors when encountering unexpected situations.
2	Occasionally, blame external factors when encountering unexpected situations.
3	Accepting some external factors while rejecting others when encountering unexpected situations.
4	Focusing on internal factors and being able to ignore external ones when encountering unexpected situations.
5	Focusing on internal factors and finding opportunities within external factors when encountering unexpected situations.

4) Growth mindset

Definition: Believing that abilities can be developed through effort and learning.

Table A5. Behavioral descriptors for the AAM trait—growth mindset

Score	Behavioral Descriptor
1	Avoids learning; resists new knowledge, challenges, and constructive feedback.
2	Shows little curiosity; learns only when required, avoids challenges, and rarely engages in reflection.
3	Willing to learn when guided, but hesitant to ask questions or take initiative; views failure as discouraging rather than instructive.
4	Actively learns and reflects with enthusiasm but still depends on external prompts and is reluctant to go beyond expectations.
5	Consistently self-motivated to seek learning, embraces challenges and feedback, sees failure as growth, and actively shares insights to enhance team development.

5) Highly motivated

Definition: Sustained drive and enthusiasm in pursuing personal or team goals.

Table A6. Behavioral descriptors for the AAM trait—highly motivated

Score	Behavioral Descriptor
1	Perform tasks without enthusiasm.
2	Shows enthusiasm only for preferred tasks, less motivated for others.
3	Enjoys and is motivated for most tasks but remains selective with certain ones.
4	Enthusiastic about all tasks but rarely initiates discussions about them.
5	Consistently eager to learn more and takes the initiative to open discussions related to assigned tasks.

6) Openness

Definition: The willingness to be honest and transparent, including acknowledging one's weaknesses and limitations.

Table A7. Behavioral descriptors for the AAM trait—openness

Score	Behavioral Descriptor
1	Unwilling to admit personal shortcomings and completely closed to feedback or criticism.
2	Selectively open to feedback, filtering what to accept and what to ignore.
3	Willing to admit some weaknesses but still occasionally hurt by criticism.
4	Open to all feedback without taking it personally, though still selective in disclosure.
5	Proactively acknowledges mistakes and is fully open to all feedback and criticism.

7) Courage

Definition: The willingness to speak honestly and act openly for mutual improvement, including facing discomfort, admitting faults, and addressing difficult issues constructively.

Table A8. Behavioral descriptors for the AAM trait—courage

Score	Behavioral Descriptor
1	Always silent and passive, avoiding necessary actions for the common good.
2	Occasionally shows courage in certain situations yet remains dominated by fear.
3	Mostly able to act with courage, although some fears and avoidance persist.
4	Actively engages in courageous actions, though sometimes the approach is not ideal.
5	Consistently takes courageous actions using proper methods.

8) Respect

Definition: Valuing others' contributions, diversity, and perspectives.

Table A9. Behavioral descriptors for the AAM trait—respect

Score	Behavioral Descriptor
1	Always belittles others.
2	Respects only those they like but belittles those they dislike.
3	Respects capable people but belittles those seen as incapable.
4	Respects everyone without exception.
5	Respects everyone and actively appreciate their hard work.

9) Commitment

Definition: Dedication to team objectives and consistency in fulfilling responsibilities.

Table A10. Behavioral descriptors for the AAM trait—commitment

Score	Behavioral Descriptor
1	Avoids responsibilities related to assigned tasks or projects.
2	Completes assigned tasks but tends to downplay achievements.
3	Performs project tasks passively, only following instructions.
4	Shows initiative and enthusiasm for learning and working.
5	Demonstrates strong commitment by voluntarily providing extra time and effort to achieve excellence.

10) Focus

Definition: Concentration and attention to task without being easily distracted.

Table A11. Behavioral descriptors for the AAM trait—focus

Score	Behavioral Descriptor
1	Taking pride in being busy, yet many tasks remain unfinished.
2	Feeling proud of being busy while still completing tasks effectively.
3	Recognizing that being busy does not equal productivity but inconsistently refusing non-essential tasks.
4	Capable of acting as an essentialist but still developing skills in prioritization.
5	Functions as an essentialist and is highly skilled in prioritization.

11) Trustworthy

Definition: The quality of being reliable and consistent in fulfilling responsibilities, maintaining integrity, and upholding ethical commitments.

Table A12. Behavioral descriptors for the AAM trait—trustworthy

Score	Behavioral Descriptor
1	Neglects responsibilities and fails to fulfill entrusted tasks.
2	Selectively fulfills responsibilities, prioritizing only those that offer personal benefit.
3	Occasionally completes assigned tasks but often leaves others unfinished without clear justification.
4	Generally, fulfils responsibilities but may leave some tasks incomplete due to situational factors.
5	Reliably complete all tasks with integrity and uphold all commitments.

12) Self-Organized

Definition: The ability to manage tasks and make decisions independently, showing initiative and creativity without direct supervision.

Table A13. Behavioral descriptors for the AAM trait—self-organized

Score	Behavioral Descriptor
1	Always passive, waiting for directions from leaders or peers without showing initiative.
2	Proactive only in tasks that are preferred.
3	Proactive only in areas where one has expertise.
4	Proactive across various tasks but inconsistent in reporting progress.
5	Proactive across various tasks, demonstrating initiative in reporting progress and taking on additional responsibilities.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Umi S. drafted the initial manuscript and conducted all experiments with guidance from Maulidan B.A.R., a representative of the SimHive Group. U.L. Yuhana and Siti R. contributed insights into experimental design and reviewed the article. All authors approved the final version.

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