

The Acquisition of Psychomotor Skills Through Scientific Instrumentation Andragogical Approach in Learning Style

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Abstract: *This study investigated the impact of the Scientific Instrumentation Andragogical Approach (SIAA) on the development of tertiary students' psychomotor skills, using experiential and self-directed laboratory learning. A total of 135 Applied Sciences students at Universiti Teknologi MARA, Shah Alam completed validated questionnaires. Reliability analysis yielded excellent internal consistency of the Practical Skill Acquisition (0.938), Student-Centered Learning (0.932), and Skill Application & Future Preparedness (0.898). Correlations r between 0.694 – 0.749 demonstrated strong construct coherence. Although data significantly departed from perfect normality, skewness and kurtosis that were within ± 2 validated reasonable interpretation. Results substantiated high self-efficacy and readiness for real- world application. Compared to the other dimensions, skill applicability had the strongest influence. The SIAA effectively boosted students' psychomotor competence, autonomy, and reflectiveness of the learning style. In application, the approach is consistent with adult learning andragogy and aligns the laboratory practice with employability-focused higher-education outcomes.*

Keywords: *Andragogy, Experiential learning, Higher education Psychomotor skills, Reliability, Scientific instrumentation*

1. INTRODUCTION

One of the key objectives of science, technology, engineering, and mathematics (STEM) educational system is the development of psychomotor skills. This is particularly true for laboratory-based courses in which students must acquire the ability to convert theory into exact practical performance (Dave, 1970; Simpson, 1972). Psychomotor skilling involves the use of instruments and tools, as well as related metacognitive habits of planning, monitoring, and adjusting the partner skilled action (Adams, 1989).

However, most laboratory-learning methods are teacher-centered, process-driven modes that favor repetition and procedural correctness over learner autonomy, reflection, and contextual problem solving (Biggs & Tang, 2011). Such traditional approaches may not be optimal to scaffold independent psychomotor mastery or transferable technical competence (Nikolić, 2024). Malcom Knowles' andragogical theory posits that effective adult learning experiences prioritize motivation, problem-centered training tasks, and prompt application (Knowles, 1984; Kanapathy, 2023). In the last few years, several scholars have shown that adult learning theory-informed instruction strategies correlate positively with student engagement, self-efficacy, and transfer of learning in higher education (Livingston, 2023; Sánchez-Domenech, 2024).

This convergence is brought together to form a learning design, a new instructional paradigm called Scientific Instrumentation Andragogical Approach (SIAA). With this SIAA learning design pattern, learners participate in instrument-based laboratory activities that are autonomously designed and utilized for reflection and the solving of real-world problems. This has been inspired by experiential educational theories (Kolb, 2015; Kolb & Kolb, 2018) as well as recent innovations that draw on hands-on, constructive exposure in genuine settings and authentic scaffolding (Konidari, 2022). This trend has been fueled by the development of remote, online, and mixed laboratory andrologies, which have been growing in importance compared to psychomotor learning. As a result, the general andragogical activities provided must be extra learner-centered in the instrumentation studies (Isa, 2024).

However, there is minimal empirical proof that andragogical architecture equated to the psychomotor outcomes in instrument-rich laboratory-based cultures. Several studies have addressed results in cognitive or affective fields, while other works have concentrated on laboratories of overall content rather than instrumentation-intensive courses (Yuliani, 2024; Hamidani et al., 2025). Hence, the examination seeks to verify how the SIAA contributes to psychomotor skills development among undergraduate scholars in the Faculty of Applied Sciences by the method of a checked self-assessment device.

Based on the integration of the adult learning theory, psychomotor domain taxonomy, and instrumentation andragogy as shown in Figure 1, this research intends to contribute to two aspects: one is validating a measurement tool for psychomotor skill acquisition in higher education and the other aspect is proving the andragogical laboratory design on enhancing learner's level of psychomotor competence and confidence and readiness for professional practice.

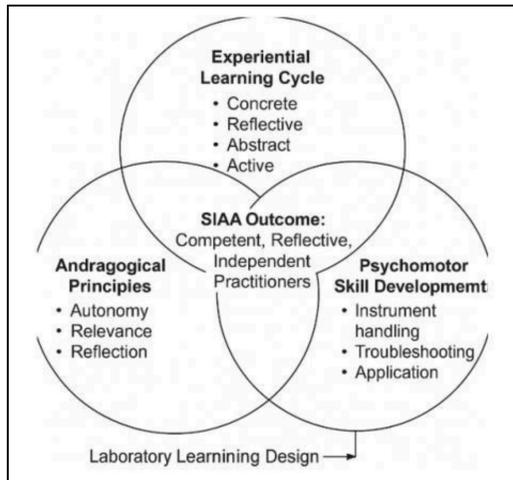


Figure 1. Integration of andragogy, experiential learning, and psychomotor skill development in Instrumentation-rich laboratories.

2. METHODOLOGY

2.1 RESEARCH DESIGN AND PARTICIPANTS

A quantitative descriptive design was adopted in this study. The participants were 135 Faculty of Applied Sciences students enrolled in 5 programs Materials Science Technology, Physics/Physics Industry, Food Technology, Polymer Technology and Chemistry/Environment program at Faculty of Applied Sciences, Universiti Teknologi MARA. These students had completed practical laboratory courses which emphasized the instrumentation and processing methods. Demographically, the cohort represented a diverse mix of gender, academic performance, and prior exposure to laboratory work.

2.2 INSTRUMENTATION

A structured instrumentation of Likert-scale questionnaire (1=Strongly Disagree to 5=Strongly Agree) was developed to assess the technical and instrumentation proficiency, application of theory to practice, problem-solving and troubleshooting, reflective and independent learning, as well as confidence and readiness for real-world applications.

2.3 PROCEDURE

The questionnaire was distributed electronically using Google Forms after the students had completed the laboratory sessions in March-August 2025 of the academic session. The data collection process spanned two weeks, in which students were encouraged to reflect on their experiences before completing the instrument.

2.4 DATA ANALYSIS

The analysis of the data was conducted using IBM SPSS Statistics (Version 26). The statistical procedures applied include the reliability analysis used to determine internal consistency and measure using Cronbach's alpha. Item-Total Correlation was performed for constructing validity of the data. Each item's contribution to overall reliability was assessed. The results are used to confirm the construction validity and coherence of the instrument. The normality test

was employed to assess data distribution across all Likert-scale items. The p-value should be >0.05 to indicate the normality. Therefore, normality tests determined either parametric or non-parametric interpretations of the data. The descriptive and visual analysis were presented through histogram and correlation heatmaps of the response pattern.

3. PROBLEM STATEMENT

Despite the increasing emphasis on laboratory-based learning in higher education, many of the STEM programs still adopt teacher-centered and procedural approaches that prioritize rote experimentation over reflective, autonomous, and contextually relevant skill development. This process often made students be less prone to applying theoretical knowledge to practical demonstrations, which compromised systemic psychomotor competence, which subsequently leaves them unprepared for professional full-time work. Although andragogical principles including self-direction, reflection, and experiential engagement have been identified as efficacious of adult learning, an empirical linkage between andragogical design of the laboratory and quantifiable psychomotor outcomes is lacking. Therefore, there is a necessity to explore whether psychomotor skills can be enhanced, self-efficacy developed, or readiness for technical and professional task improved through an andragogy-based instructional model, namely the Scientific Instrumentation Andragogical Approach.

4. OBJECTIVES

The aim of this study is to examine the effectiveness of the Scientific Instrumentation Andragogical Approach (SIAA) in enhancing undergraduate students' psychomotor skills within laboratory-based learning environments. The objectives of this study are.

1. **To assess** the reliability and internal consistency of the SIAA psychomotor skill measurement instrument through Cronbach's Alpha and item-total correlation analysis.
2. **To examine** the normality and distribution patterns of students' responses toward the SIAA-based laboratory learning environment.

3. **To determine** the inter-construct correlations between Practical Skill Acquisition, Student- Centered Learning Experience, and Skill Application & Future Preparedness and establish construct coherence and theoretical alignment.
4. **To evaluate** students' self-efficacy, readiness, and perceived applicability of technical and psychomotor skills acquired through the SIAA laboratory experience.

5. RESULT AND DISCUSSION

5.1 RELIABILITY ANALYSIS

Reliability analysis was conducted using Cronbach's Alpha to determine the internal consistency of the item's constructs. The results demonstrated strong reliability across all dimensions as tabulated in Table

1. According to the previous studies (Hair et al. 2019), Cronbach's Alpha coefficient values demonstrate the items that measured the constructs with high precision and stability. From this study, the values obtained above 0.70 are acceptable and values over 0.90 indicate excellent internal consistency. Hence, all the three constructs exhibit strong internal reliability showing that the items in the instrument have cohesively measured the three constructions' underlying dimensions.

Construct	Number of items	Cronbach's Alpha	Interpretation
Practical Skill Acquisition	9	0.938	Excellent reliability
Student-Centered Learning Experience	8	0.932	Excellent reliability
Skill Application and Future Preparedness	4	0.898	Good reliability

Table 1. Reliability Statistics for Major Constructs

The high reliability across constructs of Practical Skill Acquisition; $\alpha=0.938$; Student-Centered Learning Experience; $\alpha = 0.932$; and the Skill Application & Future Preparedness; $\alpha=0.898$, indicate the respondents consistently understood and responded to the related psychomotor and experiential learning items. Reliable coefficients of comparable values have been reported by studies that examined laboratory-based competency development and self-efficacy surrounding the practical learning environment (Rahmat et al. 2022; Nguyen & Habib 2023).

5.2 NORMALITY ANALYSIS

This test was performed to check normality in the distribution of responses in the Likert-scale items. Normality tests were assessed using Kolmogorov–Smirnov and Shapiro–Wilk tests and tabulated in Table 2. Although the normality results indicated significant deviations from normality ($p < 0.05$), the skewness and kurtosis values were within ± 2 , which are acceptable for parametric analysis in samples larger than 100 (Tabachnick & Fidell, 2019). Therefore, the data distribution was considered almost normal for further analysis.

Variable	Kolmogoro v–Smirnov (Sig.)	Shapiro– Wilk (Sig.)	Skewness	Kurtosis	Normality Interpretation
Practical	0.003	0.001	-0.049	-0.690	Not normal but approximately symmetric
Application	<0.001	<0.001	-0.389	1.163	Not normal; mild left skew
Student	<0.001	<0.001	-0.952	2.535	Not normal; moderate left skew

Table 2. Normality Test Results for Core Constructs.

5.3 INTER-CORRELATION CONSTRUCT AND THEORETICAL ALIGNMENT

The correlation matrix among constructs demonstrated strong positive relationships as presented in Inter-correlation heatmap in Figure 2. It can be observed that a strong set of correlations was collected from the inter-item matrix between all the questionnaire items in standardized form, most commonly of coherence reaching $r > 0.70$.

The correlations ($r=0.694-0.749$) indicate a strong positive relationship among the constructs: these represent a higher level of student-centered learning, and practical skill acquisition are associated with stronger readiness and application of skills in real-world contexts, thus supporting the theoretical coherence of the instrument’s dimensional structure. This indicates a highly cohesive structure, showing a high- unity grant, making psychomotor-related items, such as instrument-manipulation, procedural safety, and practical application, closely united with cognitive and affective domains of confidence and reflective feedback; Practical Skill Acquisition ↔ Student-Centered Learning Experience ($r=0.75, p<0.01$), Student-Centered Learning Experience ↔ Skill Application and Future Preparedness ($r=0.72, p<0.01$) while Practical Skill Acquisition ↔ Skill Application and Future Preparedness ($r = 0.7, p < .01$).

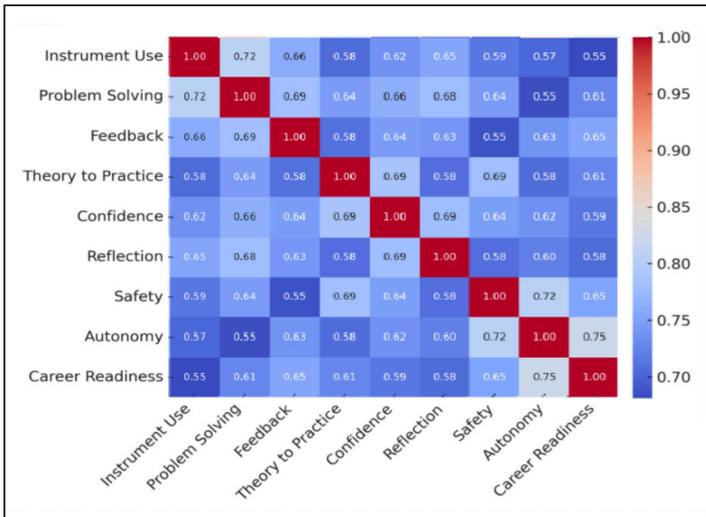


Figure 2. The Inter-Item Correlation Heatmap for the Practical Skill Acquisition

This high degree of correlation among items indicates a unidimensional yet multifaceted construct, representing the comprehensive nature of psychomotor learning in scientific contexts. As indicated by Kolb & Kolb (2018), learning in practical domains is not merely mechanical but also involves cognitive integration and reflective engagement and become evident in the observed inter-item relationships. The results echo the conceptual model of experiential learning theory (Kolb, 2015) and competency-based education frameworks

(Biggs & Tang, 2011), emphasizing iterative cycles of doing, reflecting, and applying. Hence, students who perceived their learning environment as interactive and supportive demonstrated greater readiness to apply their skills to real-world contexts. This coherence aligns with recent studies reporting that active engagement, instructor feedback, and resource adequacy are significant predictors of transferable skill confidence (Lee & Kato, 2023; Rafiq et al., 2022).

The consistent correlation pattern suggests that the SIAA successfully integrates psychomotor, cognitive, and affective dimensions into a cohesive learning experience. Students do not perceive these components as separate but as mutually reinforcing, which supports the theoretical stance that effective laboratory education must intertwine the technical skills with cognitive reasoning and emotional engagement.

5.4 SELF-EFFICACY READINESS AND PERCEIVED APPLICABILITY

From the histogram visualization depicted in Figure 3, it can be observed that all constructs showed a very minor left-skewed pattern, indicating that most of the respondents reported positive perceptions toward their learning experiences and psychomotor development in most of the items.

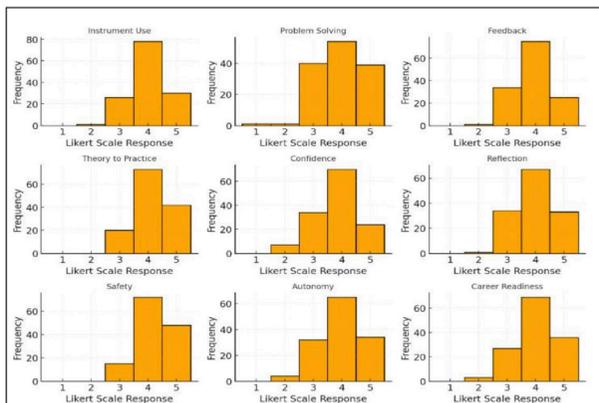


Figure 3. Distribution of student responses across nine psychomotor skill dimensions measured in the Scientific Instrumentation Andragogical Approach (SIAA) instrument.

This pattern is broadly in line with the findings of previous laboratory-based learning studies for students due to the high level of self-perceived competence and satisfaction with the guided, hands-on and problem-solving types of pedagogies for students (Hidayah et al., 2021; Zainuddin et al., 2022). Skewness is a key indicator of a frequent source of bias in self-evaluation research especially when participants perceive instruction as effective or when the learning experience aligns with their preferred cognitive and behavioral styles.

Furthermore, the left-skewed response patterns are especially pronounced in what concerns positive affective learning outcomes, which is a well-known feature of adult learning environments elucidated in multiple studies (Merriam et al., 2007). Encouraged by an andragogical environment and autonomous, contextual problem-solving opportunities, the learners naturally lean towards a more favorable assessment because they see value in what they are doing and its immediate practical use.

6. CONCLUSION

In conclusion, this study provided evidence of the SIAA being an effective method of improving students' psychomotor skills in the laboratory. The reliability results indicated high internal consistency across the constructs, ranging from 0.898 to 0.938. High inter-construct correlations, ranging from 0.69 to 0.75, suggested good theoretical coherence of the measures. The data was non-normally distributed although the similarity in patterns indicated high levels of learner engagement experiencing a high level of comfort with incorporating the taught skills in practice. The results of this study confirm the efficacy of andragogy-based laboratory teaching in promoting self-regulated learning behaviors, technical

proficiency, and professional competence. The SIAA method shows significant future potential in the promotion of school-based, competency-aligned STEM education and further research into the measurement of skill transfer and employability.

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9. AUTHORS' CONTRIBUTION

The author's contribution involved Suzana Ratim who analysed the data and writing the manuscript, Rosnah Zakaria and Maryam Husin designed and organized the experiments while Norazura Ibrahim and Rabiatuladawiyah Md Akhir are also contributed to the writing of the manuscript. All authors offered valuable feedback and contributed to shaping the research, analysis and manuscript.

10. CONFLICT OF INTEREST DECLARATION

We certify that the article is the authors' and co-authors' original work. The article has not received prior publication and is not under consideration for publication elsewhere. This research/manuscript has not been submitted for publication, nor has it been published in whole or in part elsewhere. We testify to the fact that all authors have contributed significantly to the work, validity and legitimacy of the data and its interpretation for submission to IJELHE.

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