



MEASURING SELF-DIRECTED LEARNING IN THE INTERACTIVE MULTIMEDIA: AN EXPLORATORY FACTOR ANALYSIS

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ABSTRACT

Self-directed learning (SDL) is a key 21st-century competency that enables students to identify learning needs, set goals, select strategies, and manage their learning process independently. However, existing SDL instruments are generally not specifically designed for physics learning supported by interactive multimedia. This study aimed to develop a valid and reliable SDL instrument tailored to STEM-R-based interactive multimedia learning environments. The study employed a research and development framework consisting of test planning, implementation, and validity and reliability evaluation. Participants were 133 physics education students from UIN Walisongo Semarang and several other universities in Indonesia. The instrument initially consisted of five dimensions: learning awareness, learning strategies, learning activities, evaluation, and interpersonal skills. Student responses were collected using a modified Likert scale. Content validity was assessed using Aiken's V coefficient, while construct validity was examined through Exploratory Factor Analysis (EFA). The results produced 13 valid items with a Cronbach's alpha coefficient of 0.851, indicating good internal consistency and reliability. EFA further refined the initial five-dimensional theoretical model into a four-factor structure, providing empirical evidence for the instrument's construct validity. Overall, the developed instrument demonstrated satisfactory validity and reliability and can be used by lecturers and researchers to assess students' self-directed learning in physics learning environments supported by interactive multimedia.

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1. INTRODUCTION

The industrial revolution 5.0 is proven by the technological transformation in all aspects of life, which requires humans to be able to utilize digital technology. The rapid pace of global technological change requires universities to equip students not only with knowledge but also with various 21st-century skills to enable them to adapt to changing times. One such skill is self-directed learning (Morris, 2019). Self-directed learning is the key for students to support the realization of a lifelong learner profile that is adaptive to developments in science and technology (Liang, 2025). Self-directed learning emphasizes students' autonomy in managing their learning, beginning with

the recognition of learning needs, followed by the determination of goals, selection of suitable strategies, and proactive regulation of the learning process a crucial 21st-century competency (Cohen, 2019)), can also be defined as an individual process to take the initiative with or without the help of others, formulate goals, identify users and evaluate learning outcomes (Knowles, 1975). Self-directed learning encourages increased independent learning (Collier, 2023). The main dimensions in self-directed learning include planning, monitoring, and self-evaluation, which is in line with self-regulation theory (Zimmerman, 2002), Self-directed learning is a very important skill in STEM fields (Felder & Brent, 2024), Meanwhile, other benefits of self-directed learning include increasing motivation and responsibility (Lai et al., 2022), improve understanding of concepts (Aulakh et al., 2025), increase engagement in learning (Sun et al., 2023) encourage appropriate time management and learning methods (Yousaf et al., 2023) and encourage problem-solving skills, critical and creative thinking skills (Liu, Wang, et al., 2023).

Self-directed learning can be enhanced with the help of interactive media, this is in accordance with research that media-based learning such as video games is very important to encourage and facilitate learning initiatives and provide direct feedback, encourage reflection and self-control which are indicators of self-directed learning (Toh & Kirschner, 2020), Media-based learning in the form of LMS can provide instant feedback and can track learning progress, evaluate information, encourage involvement and motivate students to learn independently (Li, 2023), Media online mampu memberi ruang bagi siswa untuk memilih sumber dan belajar mandiri (Gerard et al., 2022), Online media can provide space for students to choose sources and learn independently (Dowell & Small, 2011), Learning media helps students to be responsible for: choosing materials, determining learning strategies and conducting learning evaluations which are indicators of self-directed learning (Loyens et al., 2008).

The assessment of students' independent learning capabilities has been supported by various instruments, which encompass measures of self-directed learning, readiness for self-directed learning, and self-regulation (Guglielmino, 1977), self-directed learning Williamson (2007), and more recent instruments proposed by Ahmady et al. (2023) and Lim and Willey (2024). These instruments were primarily designed to assess self-directed learning in healthcare education and general educational settings. At the secondary education level, self-directed learning instruments have also been developed by Ayyildiz & Tarhan (2015) and Liu, Gui, et al. (2023), particularly for high school students in software design learning. Despite the availability of these instruments, to the best of our knowledge, no self-directed learning instrument has been specifically developed for STEM-R-based interactive multimedia in physics education. Therefore, the instrument developed in this research was designed to incorporate the distinctive characteristics of self-directed learning in physics instruction supported by interactive multimedia. Interactive multimedia-supported physics learning possesses distinctive pedagogical characteristics that differentiate it from conventional learning environments. Students are expected to autonomously navigate learning content, explore interactive simulations, perform virtual experiments, and construct conceptual understanding through active inquiry. These learning processes require greater self-directed learning than traditional textbook-based instruction. The need for self-directed learning is particularly evident in nuclear physics, where many concepts are abstract and cannot be directly observed. Interactive multimedia enables the visualization of these phenomena, thereby enhancing students' conceptual understanding. Consequently, students' self-directed

learning in this learning environment may not be adequately represented by existing self-directed learning instruments developed for more general educational contexts.

The foregoing discussion reveals a significant research gap, namely the lack of a context-specific self-directed learning instrument that has been systematically developed and psychometrically validated for interactive multimedia-supported physics learning. Existing self-directed learning instruments were developed for broader educational contexts and may not adequately capture the unique learning processes associated with STEM-R-based interactive multimedia. Accordingly, this research aims to develop and validate an self-directed learning instrument specifically designed for physics learning supported by STEM-R-based interactive multimedia. The instrument was developed by adapting the core dimensions of self-directed learning proposed by Williamson (2007) and contextualizing them to reflect the distinctive learning activities and interactions that characterize interactive multimedia environments.

2. METHOD

This study adopted a research and development approach to produce a self-directed learning questionnaire specifically designed for use in interactive multimedia-based learning of nuclear physics. Instrument development was carried out through three main stages: test planning, test trials, and determining the validity and reliability of the instrument (Winarto et al., 2022; Yanto et al., 2019). The flow of this research follows the flow chart as shown in Figure 1.

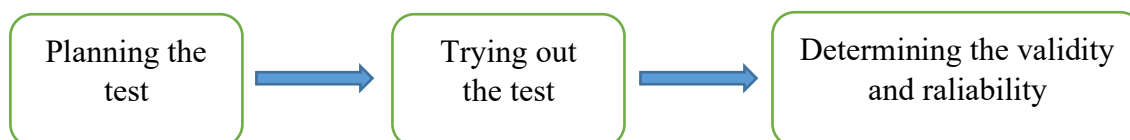


Figure 1. Instrument and development flowchart

2.1. Participant

The research involved 133 participants recruited from the undergraduate Physics and Physics Education programs at a public university in Semarang, Indonesia. The characteristics of the study participants are systematically summarized in Table 1.

Table 1. Participant Characteristics

Participant Characteristics	Category	N	Percentage (%)
Gender	Male	33	24.8
	Female	100	75.2
Study Program	Physics education	88	66.2
	Physics	45	33.8
Institution	UIN Walisongo Semarang	126	94.7
	Others universities	7	5.3

2.2. Procedure

The study followed a systematic sequence of activities for developing and evaluating the research instrument. The development process involved three main activities: designing the test, conducting an instrument try-out, and examining its validity and reliability (Ubaidillah et al., 2022). At the design stage, the researchers first established the intended purpose and test format, followed by the preparation of the instrument content, test blueprint, and individual items. The purpose of this test is to determine self-directed learning abilities while engaging with STEM-based multimedia. Responses to the instrument were recorded using a 5-point Likert scale. The self-directed learning instrument developed by Williamson consists of five aspects: awareness, learning strategies, learning activities, evaluation, and interpersonal skills Williamson (2007), can be seen in table 2. Each aspect was represented by two or three statements. This instrument has been validated by three experts. Then the instrument is corrected based on recommendations provided by the experts, then its content validity was evaluated using Aiken V. A total of 133 students enrolled in a physics course participated in the research. The students were taught physics using interactive multimedia and a STEM approach. A self-directed learning instrument, a questionnaire, was randomly distributed to the students, and the results were processed and analyzed using EFA.

2.3. Data analysis

The analysis proceeded through a series of statistical procedures applied successively to the data obtained from the study. Descriptive analysis was first performed to summarize participant characteristics and examine the distribution of questionnaire responses before conducting further analyses. Content validity was tested using Aiken V. The content validity value criteria showed that there were 8 items with a value of 0.81 - 1, indicating very valid, and 5 questions showed a value of 0.75, so that in the range of 0.61 - 0.80 in the valid category (Aiken, 1996).

The internal consistency of the instrument was assessed through Cronbach's alpha. As reported in Table 3, the resulting coefficient was greater than 0.85, indicating that the instrument achieved a high degree of reliability. The construct validity of the instrument was examined further through Exploratory Factor Analysis (EFA). Before extracting the underlying factors, the dataset was first evaluated to determine whether it met the requirements for factor analysis. This preliminary assessment included two statistical procedures. The first involved the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, which was applied to assess whether the correlations among the variables were sufficiently strong to support their classification into underlying factors. A KMO value exceeding 0.748 was regarded as adequate for proceeding with factor analysis (Kaiser, 1974). Second, Bartlett's sphericity test was employed to assess whether the correlation matrix significantly differed from an identity matrix. A significance value of $p < 0.05$ indicated that the correlations among the variables were sufficient to support the application of factor analysis. The factor structure was subsequently explored through principal component analysis (PCA), with varimax rotation applied to facilitate the interpretation of the extracted components. This analytical procedure was used to determine the latent dimensions responsible for explaining the variability among the measured variables. The number of factors retained was determined based on eigenvalues greater than 1, following the Kaiser criterion, together with substantive

interpretability supported by the scree plot. The results of the instrument development are presented in Table 2.

Table 2. Results of self-directed learning synthesis indicators

Aspect	Indicator
Awareness (A)	Awareness of the role of independent learning (A1)
	Understanding the benefits of independent learning (A2)
	Self-motivation for learning (A3)
Learning Strategies (B)	Study time planning (B1)
	Trying the most effective methods (B2)
	Ability to choose effective learning methods (B3)
Learning Activities (C)	Time management in learning (C1)
	Discipline in completing assignments (C2)
Evaluation (D)	Ability to evaluate one's own learning outcomes (D1)
	Identifying learning difficulties (D2)
	Ability to find learning solutions (D3)
Interpersonal Skills (E)	Ability to communicate with lecturers (E1)
	Discussions with lecturers to clarify material (E2)

The following is an example of a statement in a learning independence questionnaire based on Table 2:

A1: I realize the importance of independent learning to achieve learning objectives

C2: I always complete assignments and student worksheets from multimedia on time

The distribution of scores obtained from the self-directed learning instrument was examined descriptively by calculating the mean and standard deviation. A summary of these statistical results is provided in Table 3.

Table 3. Self-Directed Learning Instruments

	Indicator	Number	Mean	Standard deviasi
Awareness (A)	Awareness of the role of independent learning (A1)	1	4.24	0.86
	Understanding the benefits of independent learning (A2)	2	4.53	0.58
	Self-motivation for learning (A3)	3	4.51	0.63
Learning Strategies (B)	Study time planning (B1)	4	4.50	0.51
	Trying the most effective methods (B2)	5	4.14	0.64
	Ability to choose effective learning methods (B3)	6	4.17	0.64
Learning Activities (C)	Time management in learning (C1)	7	3.94	0.75

	Indicator	Number	Mean	Standard deviasi
	Discipline in completing assignments (C2)	8	3.93	0.76
Evaluation (D)	Ability to evaluate one's own learning outcomes (D1)	9	4.21	0.61
	Identifying learning difficulties (D2)	10	3.86	0.82
	Ability to find learning solutions (D3)	11	3.91	0.75
Interpersonal Skills (E)	Ability to communicate with lecturers (E1)	12	3.88	0.82
	Discussions with lecturers to clarify material (E2)	13	3.44	0.71

3. RESULTS AND DISCUSSION

3.1. Content Validity

The content validity of the instrument was established through an expert assessment involving three experts. The corresponding Aiken's V coefficients are presented in Table 4.

Table 4. Content Validity

Aspects	Aiken's V Score	Category
Awareness (A)	0.803	Very high
Learning strategies (B)	0.806	Very high
Learning activities (C)	0.83	Very high
Evaluation (D)	0.803	Very high
Interpersonal Skills (E)	0.79	High

The adequacy of the instrument's content was evaluated based on expert assessments from three specialists. The resulting Aiken's V coefficients fell between 0.79 and 0.83, indicating that the instrument achieved a high to very high level of content validity. These values reflect strong consistency and agreement among the experts in evaluating the instrument items (Aiken, 1985; Penfield & Giacobbi Peter R, 2004). The findings suggest that each item adequately represents the construct of self-directed learning in accordance with the intended measurement objectives. Although the interpersonal skills dimension also demonstrated a high level of content validity, it yielded the lowest Aiken's V coefficient among the five dimensions. This finding suggests that the interpersonal skills dimension is relatively more challenging to conceptualize and operationalize within the context of self-directed learning than the other dimensions.

The descriptive statistical analysis showed that the mean scores ranged from 3.44 to 4.53, indicating high to very high levels of self-directed learning. These findings suggest that the experts considered the instrument items to possess a high degree of clarity, relevance, and construct representativeness. The highest mean score was observed for the Awareness dimension, particularly Item A2 (Mean = 4.53), highlighting the central role of awareness in self-directed

learning. Awareness is widely recognized as a key factor in fostering self-directed learning and strengthening learners' understanding of the value and benefits of autonomous learning (Loyens et al., 2008). The standard deviation values ranged from 0.51 to 0.86. Mean scores approaching the maximum value of 5 indicate a strong positive evaluation of the instrument items, whereas the relatively small standard deviations suggest a high level of consistency among the experts' ratings.

3.2. Instrument reliability

An internal consistency analysis was conducted using Cronbach's alpha to determine the reliability of the questionnaire items as a set. The statistical results of this analysis are summarized in Table 5.

Table 5. Instrument Reliability

Cronbach's Alpha	N of Items
0.851	13

The reliability analysis indicated that the instrument had good internal consistency, with a Cronbach's alpha value of 0.851. This value indicates that all instrument items possess a high level of internal consistency (George & Mallery, 2024). Furthermore, because the Cronbach's alpha coefficient exceeded the recommended threshold of 0.70, the self-directed learning instrument can be considered reliable (Barbera et al., 2020; Tavakol & Dennick, 2011).

3.3. Exploratory factor analysis

Analysis (EFA) was employed in the development and evaluation of the self-directed learning instrument to identify and examine its underlying latent factor structure. The results obtained from the analysis are reported in Table 6.

Table 6. Results of the KMO and Bartlett tests

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.746
Bartlett's Test of Sphericity	Approx. Chi-Square	1118.831
	Df	78
	Sig.	.000

The KMO value shows 0.746, which means that the KMO value is > 0.6 , thus indicating that the data is adequate and can be continued with factor analysis (Kaiser, 1974), and the sphericity test with a Sig. value = 0.000 (< 0.05) indicates a significant relationship between instrument items and supports the feasibility of the data for further analysis using the EFA test factor analysis (Hair, 2011).

Principal Component Analysis (PCA) with varimax rotation extracted five underlying factors that collectively accounted for 76.6% of the total variance. The rotated factor structure is presented in Table 7.

Table 7. Extraction of communalities

	Initial	Extraction
A1	1	.785
A2	1	.869
A3	1	.737
B1	1	.812
B2	1	.744
B3	1	.929
C1	1	.726
C2	1	.539
D1	1	.883
D2	1	.742
D3	1	.735
E1	1	.773
E2	1	.694

Table 7 shows the item indicator values and their ability to explain the factors. The communality analysis results indicate that the extraction value is between 0.539 and 0.929, indicating that the item can explain the factors and that the instrument has a fairly good construct. A communality value of ≥ 0.50 indicates that the instrument item is worth retaining (Izquierdo et al., 2014). The average communality value of 0.77 provides information that this value has a strong contribution to each indicator, thus increasing the reliability and validity of the instrument (Knekta et al., 2019).

Table 8. Eigenvalues for the self-directed learning test

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	5.216	40.126	40.126
2	2.153	16.565	56.691
3	1.518	11.678	68.369
4	1.079	8.297	76.665

The extracted solution consisted of four components with eigenvalues ranging from 5.216 to 1.079. Component 1 exhibited the largest eigenvalue (5.216) and accounted for 40.126% of the total variance, indicating that it explained the greatest proportion of variability among the observed variables. The four-factor solution was further supported by the scree plot presented in Figure 2, which shows that only four factors had eigenvalues greater than 1. This finding provides empirical evidence that the self-directed learning construct is represented by a four-factor structure.

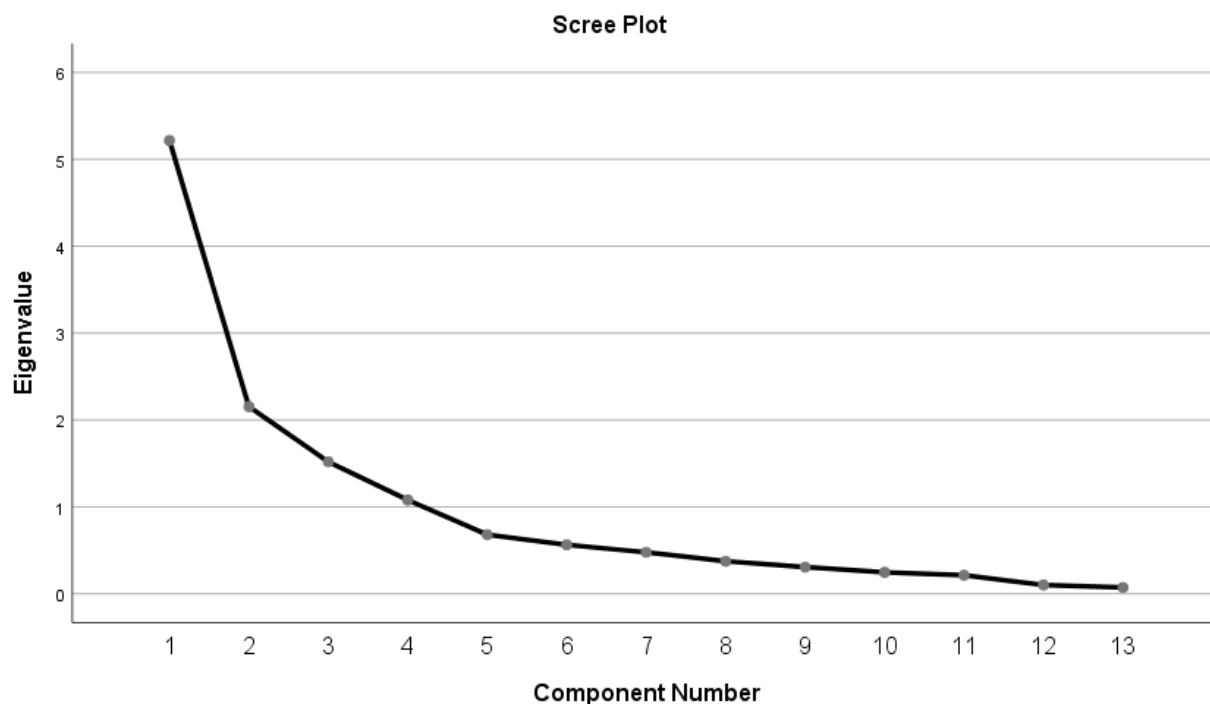


Figure 2. Scree Plot.

Table 9. Rotated matrix factors

	Component			
	1	2	3	4
E1	.844			
D3	.831			
D2	.828			
C1	.828			
E2	.780			
C2	.697			
B3		.948		
D1		.934		
B2		.820		
A2			.907	
A1	.371		.786	
B1				.884
A3				.794

Extraction Method: Principal Component Analysis.

The results of the EFA using varimax rotation of the instrument structure, which initially consisted of 5 aspects, were reduced to 4 empirical factors. The rotation process resulted in a clear centering of items in four component groups, with all indicators having loadings greater than >0.55 , indicating good construct validation results (Osborne & Costello, 2009). Based on the rotation results, four dominant factors were obtained that represent the key dimensions of students' self-directed learning abilities. Factor 1: The first factor consists of items E1 (.844), D3 (.831), D2

(.828), C1 (.828), E2 (.780), and C2 (.697). This factor combines the ability to communicate and discuss with lecturers (interpersonal skills) as well as reflective activities such as identifying difficulties and finding solutions in learning. It shows that students who actively interact with lecturers tend to be disciplined and able to reflect on the learning process independently (Fisher & King, 2010). This factor tends to represent Interpersonal and Reflective Learning Activities. The second factor is learning strategies and self-evaluation formed through B3 (.948), D1 (.934), and B2 (.820), related to the ability to design and implement learning strategies and evaluate the results. This factor shows the ability to choose effective learning methods and their evaluation supports independent learning (Panadero et al., 2017). Students who choose good strategies demonstrate a good level of reflection and self-evaluation. The third factor, awareness, consists of items A2 (.907) and A1 (.786), which reflect students' awareness of the benefits of independent learning. This awareness drives individuals to develop self-directed learning attitudes and behaviors (Saks & Leijen, 2014). Awareness is a key driver and motivation for the formation of learning autonomy (Zhoc et al., 2018). The fourth factor consists of B1 (.884) and A3 (.794), which lead to Active Self-Regulation. Both items emphasize the ability to regulate learning behavior and take initiative, related to planning study time and intrinsic motivation for independent learning and both are mutually reinforcing aspects. Time management and learning motivation are two main determinants of the success of independent learners, students with strong internal motivation tend to have better time control in organizing their learning activities (Sun et al., 2023) .

The scree plot plots eigenvalues against component number (1–13). The graph shows a sharp decline from the first to the second component, followed by a gradual decline after the fourth component. A change in the angle (elbow) is seen around the fourth component, indicating that the fourth component contributes less and less. This indicates that the scree plot results support four latently significant factors. A scree plot is one technique for determining the number of factors to be taken (Cattell, 1966). The scree plot confirms the four-factor empirical structure from the Rotated Component Matrix results. Furthermore, the scree plot results align with the Total Variance Explained analysis, which shows that four factors have eigenvalues above 1 and are able to explain 76.66% of the total variance. This indicates that the four factors have a substantial contribution to the construct of student self-directed learning, thus empirically and theoretically, the four-factor model is acceptable.

The results of the instrument analysis indicate that the self-directed learning instrument used in interactive multimedia learning possesses acceptable validity and reliability. The reliability test resulted in a Cronbach's alpha coefficient of 0.851, indicating strong internal consistency among the items. An instrument is generally considered reliable when its reliability coefficient exceeds 0.60 (Cho & Kim, 2015; Setyowati & Chung, 2021). The instrument was initially constructed using the five dimensions of self-directed learning identified by Williamson (2007), consisting of awareness, learning strategies, learning activities, evaluation, and interpersonal skills. However, the EFA results demonstrated that these five dimensions were represented by four factors in the empirical data. The four factors explained 76.6% of the total variance. This finding indicates that the empirical factor structure does not completely correspond to the initial five-dimensional structure. Nevertheless, the factor structure obtained through EFA supports the construct validity of the instrument for measuring students' self-directed learning attitudes in interactive multimedia learning in nuclear physics courses

EFA using initial extraction and Varimax rotation aims to identify latent structure and varimax rotation to facilitate interpretation (Osborne & Costello, 2009). The scree plot presented maps the eigenvalues, so that there are 4 factors that have values with eigenvalues > 1 (Fabrigar et al., 1999). After conducting a scree plot test, four factors were obtained, with the first factor containing indicators of interpersonal skills, evaluation, and learning activities. This indicates that students who actively interact with lecturers and other fellow students tend to be disciplined and able to reflect on their learning process independently (Fisher & King, 2010). This factor tends to present more about Interpersonal and Reflective Learning Activities (learning and evaluation activities) because it emphasizes the role of feedback in independent learning strategies (Fullana et al., 2016).

The second factor consists of learning strategies and self-evaluation formed through B3 (.948), D1 (.934), and B2 (.820) relating to the ability to design effective learning strategies and their evaluation to support independent learning (Wilcox, 1996). Students who choose good strategies demonstrate good levels of reflection and self-evaluation. Self-assessment in students can improve their use of learning strategies, thus facilitating independent learning (Lizzio & Wilson, 2006). Students who implement effective learning strategies tend to demonstrate higher levels of reflection and self-evaluation, which ultimately supports independent learning and learning achievement in science subjects.

The third factor is awareness, awareness is the main component driving self-directed learning behavior. (Saks & Leijen, 2014). Awareness is an intrinsic motivation that is a driving force in the formation of Learning Autonomy (Zhoc et al., 2018), and also an important dimension that is irreplaceable for completing self-directed learning (Saks & Leijen, 2014). Reflective awareness serves to recognize learning barriers, and enhance independent learning, and also increases the role and responsibility to achieve learning goals independently (Ross, 2014). The fourth factor consists of learning strategies, namely the ability to regulate learning behavior, and self-awareness, namely the intrinsic drive for independent learning. Both factors awareness and students' ability to regulate learning behavior—are important components of self-directed learning (Zimmerman, 2002). The two main items in this factor, namely study time planning (time management) and intrinsic motivation, are mutually reinforcing and thus become drivers of success for independent learners in higher education (Lourenço & Paiva, 2024). Students with strong internal motivation were significantly more likely to demonstrate more effective time control, using structured time management strategies, such as goal setting and planning (Wolters et al., 2025).

4. CONCLUSION

This research aimed to develop and validate a self-directed learning instrument for physics learning supported by STEM-based interactive multimedia. The research involved 133 undergraduate students enrolled in Physics Education programs at UIN Walisongo Semarang and several other universities in Indonesia. The required data were obtained through a questionnaire employing a modified Likert scale. Instrument quality was examined from the perspectives of content validity and construct validity. The instrument was evaluated through both content and construct validity analyses. Content validity was assessed using Aiken's V coefficient, whereas construct validity was examined through EFA. Reliability analysis yielded a Cronbach's alpha

coefficient of 0.851, reflecting strong internal consistency of the instrument and confirming its suitability for measuring students' self-directed learning in the context of interactive multimedia-supported physics learning. The rotated component matrix revealed that the 13 items were grouped into four empirical factors. Conceptually, the findings indicate that the structure of self-directed learning in interactive multimedia-based physics learning does not fully align with the original five-dimensional theoretical framework proposed by Williamson (2007). Instead, it is represented by a four-factor structure that more accurately reflects the characteristics of multimedia-supported physics learning. The four factors comprise : interpersonal and reflective learning activities, learning strategies and self-evaluation, self-awareness, and learning behavior management strategies. The integration of several theoretical dimensions into these empirical factors suggests that, within an interactive multimedia learning environment, learning activities, learning strategies, strategic planning, self-evaluation, and learning behavior management operate as interconnected components of a unified self-directed learning process.

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