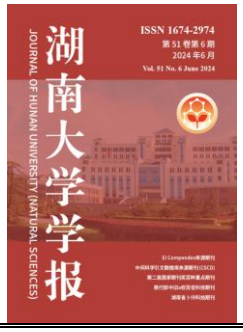

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Assessing Students' Learning Adaptability in the Aftermath of the COVID-19 Outbreak: A Model Validation Approach

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Abstract: This groundbreaking research ventures into uncharted territory, pioneering the development and validation of a trailblazing model that measures students' adaptive learning prowess in the tumultuous landscape of post-pandemic education. The COVID-19 pandemic has significantly impacted education, necessitating a shift to "new normal learning" methods. Therefore, this research aimed to develop and validate a model measuring students' adaptive learning in the new normal of learning management following the outbreak of the COVID-19 pandemic. The study involved 1,295 high school students. The research instrument was a 54-item adaptive learning questionnaire with reliability values ranging from 0.846 to 0.905. Data analysis included correlation analysis and second-order confirmatory factor analysis (2^{nd} order CFA). The developed model for measuring students' adaptive learning in the new normal of learning management following the outbreak of the COVID-19 pandemic comprised 4 components with 15 indicators: 1) health care in learning, consisting of two indicators: reducing disease risk and enhancing physical resilience; 2) self-sentiment in learning, consisting of four indicators: self-regulation of emotions, adaptability to learning situations, practicing mindfulness, and self-solving learning issues; 3) roles of learning, consisting of five indicators: learning technology, enthusiasm, self-development, utilizing media and applications, and time allocation between learning and other activities; 4) interaction in learning, consisting of four indicators: accepting differences among students, appropriate student behavior, teaching peers willingly, and utilizing full potential in learning. The model's validity was confirmed, with first-order loading values ranging from 0.649 to 0.898, second-order loading values ranging from 0.752 to 0.888, and a variance in student adaptive learning of 0.152. The conclusion unveils a revolutionary framework that not only illuminates the path to successful student adaptation but also ignites a paradigm shift in learning management, empowering educators to craft transformative strategies that propel students toward unparalleled success in the face of adversity.

Keywords: students' learning adaptability, model validation, new normal, aftermath of the COVID-19 pandemic.

评估新冠疫情后学生的学习适应性：一种模型验证方法

摘要：这项开创性的研究进入了未知领域，率先开发和验证了一个开创性的模型，用于衡量学生在后疫情时代教育动荡中的适应性学习能力。新冠肺炎疫情对教育产生了重大影响，迫使人们转向"新常态学习"方法。因此，本研究旨在开发和验证一个模型，用于衡量新冠肺炎疫情爆发后学习管理新常态下学生的适应性学习。研究对象为1295名高中生，研究工具为一份54项适应性学习问卷，信度值从0.846到0.905不等。数据分析包括相关性分析和二阶验证性因子分析（二阶特许金融分析师）。所开发的用于衡量新冠肺炎疫情爆发后学习管理

新常态下学生适应性学习的模型包括4个部分，共15个指标：1）学习中的医疗保健，包括两个指标：降低疾病风险和增强身体适应力；2）学习中的自我情绪，包括四个指标：自我调节情绪、适应学习环境、练习正念和自我解决学习问题；3）学习的角色，包括五个指标：学习技术、热情、自我发展、利用媒体和应用程序以及学习与其他活动之间的时间分配；4）学习中的互动，包括四个指标：接受学生之间的差异、适当的学生行为、愿意教导同伴和充分发挥学习潜力。该模型的有效性得到证实，一阶载荷值范围为0.649至0.898，二阶载荷值范围为0.752至0.888，学生适应性学习的方差为0.152。结论揭示了一个革命性的框架，不仅照亮了成功学生适应的道路，而且引发了学习管理的范式转变，使教育者能够制定变革性策略，推动学生在逆境中取得无与伦比的成功。

关键词：学生的学习适应性、模型验证、新常态、新冠肺炎疫情的后果。

1. Introduction

The outbreak of coronavirus disease 2019 (COVID-19) has significantly impacted the global education system. School closures as a measure to contain the spread of the virus [10] have necessitated a swift transition from traditional face-to-face instruction to online learning. This transition presents a formidable challenge to students' learning adaptability, which has become an increasingly crucial attribute for navigating and succeeding in learning amidst such crises. Scholars in behavioral and social sciences have shown keen interest in studying students' adaptability, focusing on human-centered learning experiences [25]. The concept of learning adaptability comprises various dimensions, including adjustment to environmental conditions, social interactions, roles, and individual characteristics [2, 27]. Students with higher adaptability tendencies are inclined to achieve continuous academic success and exhibit consistent learning development [24].

The characteristics of effective student adaptability encompass several key components. These attributes include eagerness for learning and seeking new knowledge, self-confidence, self-efficacy [21], efficient time management, clear goal-setting, motivation, teamwork skills, collaboration with others [6, 16], problem-solving abilities, coping with stress effectively [4, 18, 19], determination, and commitment to achieving set goals [9, 17]. These attributes enable students to adapt and confront various challenges in educational contexts smoothly, ultimately leading to academic success.

During the COVID-19 pandemic, students have faced challenges due to the transition to online learning. Consequently, more research studies have focused on exploring and understanding students' adaptive behaviors across different dimensions, such as the utilization of technology and online platforms for learning, online teaching methodologies, group work interactions, and time management strategies [1, 3, 28], as well as stress management skills impacting mental health [12, 13, 29]. Insights into these adaptive behaviors are crucial for developing models that accurately measure students' adaptive learning in the context of new learning paradigms in the post-pandemic era.

However, from the literature review and the synthesis of relevant research, it is evident that there is still a lack of clear perceptual information regarding the components and indicators suitable for measuring students' learning adaptability in the context of the new way of life following the COVID-19 pandemic. The adaptive behaviors derived from the synthesis exhibit a significant association between pre-pandemic and pandemic-induced behaviors, necessitating the development of measurement models capable of adequately assessing the level of students' learning adaptability aligned with the new learning paradigms.

Therefore, this research develops a measurement model to assess students' learning adaptability. The objective is to develop and validate the structural validity of indicators representing the components of learning adaptability. The research outcomes will produce a measurement model that comprehensively reflects students' adaptability characteristics, thus aiding in evaluating learners' potential and providing valuable feedback for educators and educational institutions. This will facilitate the cultivation of students' ability to adapt for future academic success. Additionally, understanding the components of adaptability will help prepare students to respond to situations, manage themselves effectively, and increase their awareness of mental health. Simultaneously, it will be advantageous in helping students grasp essential skills for self-development, such as self-directed learning, teamwork, and the use of information and communication technology. These insights will be instrumental in improving and implementing learning methodologies that are aligned with the rapid changes

of the future. The research outcomes will enhance educational quality and enable learners to confront new challenges in the constantly evolving global society.

2. Literature Review

2.1. Significance of Students' Learning Adaptability during the COVID-19 Pandemic

Students' learning adaptability in such circumstances is a vital characteristic that necessitates their ability to navigate swift changes in their learning environment. This includes adjusting lifestyles, behaviors, and learning strategies to comply with disease prevention measures, such as comprehensive online learning, embracing new technologies, establishing discipline, managing time, maintaining focus and motivation, and effectively managing stress arising from this health crisis [10]. Students must develop self-learning and problem-solving skills, enhance flexibility and resilience, maintain a positive outlook to overcome obstacles, and be prepared to confront new challenges in the future [10, 19, 23].

2.2. Components of Student Learning Adaptability

Learning adaptability refers to a student's capacity to adjust and grow to overcome learning challenges, which directly affects academic achievement and educational progression [24]. Currently, various theories and concepts have endeavored to elucidate the components and mechanisms of adaptability in the context of learning, enriching our comprehension of the nature and complexity of this phenomenon. One of the foundational theories elucidating adaptability is Rogers' concept [25], which posits that humans inherently strive for self-actualization and persist in a state of perpetual change. Adaptation encompasses two primary dimensions: self-adjustment and adjustment stemming from interpersonal experiences. Additionally, Andrews and Roy [27] postulated that adaptability encompasses three dimensions: physical, cognitive, and role adjustment. However, Roy [27] expanded upon this framework and delineated four dimensions of adaptation: physical, cognitive, role, and interpersonal adjustments, which entail communication skills, understanding, acceptance of individual differences, and fostering positive relationships with others.

From the synthesis of the aforementioned ideas and theories, it is possible to identify the four main components of students' learning adaptability. These components are as follows: 1) health care in learning, which pertains to managing physical health to support learning, such as ensuring sufficient rest, consuming nutritious food, and engaging in regular exercise [6, 19]; 2) self-sentiment in learning, which relates to psychological factors, such as self-perception, motivation, determination, and emotional management [4, 18, 21]; 3) roles of learning, which involve responsibility, self-discipline, time management skills, and systematic learning planning [9, 17, 28]; 4) interaction in learning, which concerns communication and collaboration with peers, teachers, and parents; fostering good relationships, and accepting differences among individuals in society [1, 3, 16]. These four components help us understand the diverse dimensions of learning adaptability, which is a complex and dynamic phenomenon.

This literature review demonstrates that students' learning adaptability is a process that involves a combination of internal factors within individuals, including physical, psychological, role-related, and environmental factors, such as interactions with others, to facilitate adjustment, change, and development toward suitable states [13, 29]. Students must possess the ability to manage various components, including healthcare, inspiration, planning, coordination, and building relationships with their surroundings [12, 21]. These skills are crucial for learning and navigating life amidst rapid changes.

2.3. Behavioral Indicators of Students' Learning Adaptability

Students' learning adaptability is a significant factor that directly influences educational success [4, 13, 18]. Through document synthesis and relevant research, it is essential to identify these components and indicators to understand the complex and well-defined phenomenon of learning adaptability.

The first component is health care in learning, which comprises two indicators: reducing the risk of illness during learning and enhancing physical fitness for learning readiness [4, 13]. Good physical health is considered a crucial foundation because it helps mitigate obstacles stemming from illness and bolster readiness for learning [18]. Students who prioritize their health will establish a solid foundation for adapting to learning seamlessly [26]. Therefore, robust physical health is a critical attribute that diminishes risks and amplifies competency in learning, enabling students to effectively participate in the learning process.

In addition to physical health, readiness for learning also depends on psychological and emotional factors, known as self-sentiment in learning, which comprises four indicators: 1) the ability to balance emotions and not easily be shaken by obstacles, 2) flexibility in adapting to new situations without being stuck in familiarity, 3) continuous focus on learning materials, and 4) the ability to analyze and solve problems independently [10, 19, 23]. These indicators reflect students' resilience, a crucial component that enables them to face challenges and learn effectively. These behaviors demonstrate positive mental health and self-management skills among students, which facilitate their readiness for learning and effective adaptation to new situations [10, 19, 23].

In addition to good physical and mental health, students' readiness for learning also depends on their understanding of the roles of learning and their preparedness to assume them fully, which is a significant component of readiness. This includes indicators like technology proficiency [3, 17], which are crucial in contemporary learning. Enthusiasm, determination, and dedication drive self-development. Acquiring appropriate skills for using various learning media is essential [21], alongside systematic time management [9]. These indicators reflect students' readiness and determination to effectively fulfill their roles and achieve successful learning outcomes [3, 16].

The final crucial component for students' readiness for learning is interaction in learning, which appropriately reflects communication skills and teamwork, which are essential for learning and adapting in educational environments [6]. Indicators of this component include accepting differences among individuals because of societal cultural diversity, employing appropriate communication expressions to prevent conflicts [28], teaching skills or transmitting knowledge for mutual understanding [18], and, importantly, fully utilizing one's potential in working with others to achieve goals [4]. Therefore, interpersonal skills are vital to social adaptation and learning readiness.

The identification of these 15 indicators marks a significant advancement in developing a model for assessing learning adaptability. These indicators were used as the framework for the model, encompassing all four primary components. The research suggests that this model is congruent with empirical evidence and serves as a basis for evaluating students' learning adaptability in the face of contemporary change. The systematic synthesis of these indicators across various research reviews enhances our understanding of this vital educational phenomenon from a holistic perspective. Consequently, it helps students to better adapt in the future.

3. Data and Methodology

3.1. Sample

This study employed a rigorous multi-stage random sampling technique to select a representative sample of secondary school students (Grades 7-12). The focus on secondary school students was due to their transition period between childhood and adolescence, during which adaptive learning skills are crucial for academic success and future prospects. This robust and unbiased sampling approach provided a solid foundation for our research. The sample comprised a total of 1,295 individuals, including 423 male and 872 female students. In determining the sample size for second-order confirmatory factor analysis, the researchers considered the ratio of the sample size to the indicators and parameters in the hypothetical model, adhering to the Rule of thumb principle. This principle recommends a minimum of 10 samples per parameter for estimation [7, 15]. With 49 parameters in this study, the minimum suitable sample size should be at least 490 individuals. However, to address issues arising from incomplete questionnaires and improve parameter estimation accuracy, the researchers collected data from a sample group of 1,295 individuals. The sample size was sufficient and appropriate for data analysis using the second-order CFA technique.

Furthermore, since the analysis of second-order CFA relies on testing the fit of the hypothetical model to empirical data using chi-square test statistics, which has limitations when the data deviates from the assumptions of multivariate normal distribution, the researchers opted to use the Satorra-Bentler scaled chi-square method to test the model fit. This method is known for its robustness against violations of the assumptions underlying the distribution of the data [7]. Prior to analysis, the researchers screened and validated the questionnaire to ensure the reliability of the measurement model. This step was taken to ensure that the results of the measurement model test were credible and could be appropriately generalized to the population.

3.2. Research Instruments

The research tools used in this study consisted of a questionnaire assessing students' learning adaptability in the context of the new normal arising from the COVID-19 pandemic. This questionnaire comprises 54 items and utilizes a Likert-type rating scale with 5 levels (1 - strongly disagree/not engaging in the described behavior at all, 5 - strongly agree/fully engaging in the described behavior). The measurement scope of students' learning adaptability (SAL) encompasses the following aspects:

Health care in learning (SHCL) encompasses preventing illness outbreaks, reducing disease occurrences during learning, and enhancing physical resilience. It consists of two indicators: reducing disease risk (SH1) and enhancing physical resilience (SH2). The t-test values range from 6.900 to 10.890. Discrimination values, assessed using item-total correlation, range from 0.372 to 0.625. The reliability analysis of the indicators, using Cronbach's alpha coefficient, ranges from 0.656 to 0.832. Sample items include "I wash my hands with soap or hand sanitizer after touching high-risk areas such as railings, tables, and chairs in school" and "I clean learning equipment every day when going to school."

Self-sentiment in learning (SSSL) refers to the ability to flexibly regulate one's emotions and needs in learning situations, accept oneself realistically, be adept at using technology, and fulfill assigned tasks. It comprises four indicators: self-regulation of emotions (SL1), adaptability to learning situations (SL2), practicing mindfulness (SL3), and self-solving learning

issues (SL4). The t-test values range from 4.380 to 10.541. Discrimination values, assessed using item-total correlation, range from 0.354 to 0.695. The reliability analysis of the indicators, using Cronbach's alpha coefficient, ranges from 0.592 to 0.843. Sample items include "When I feel stressed by online learning, I engage in relaxing activities or talk to others to calm down before working" and "I believe that I can manage myself well in changing situations."

Roles of learning (SROL) refer to the desire and excitement to engage in learning in dynamically changing teaching formats, being enthusiastic, alert, and continuously prepared for learning. This involves learning readiness, mindfulness in learning, intention to learn, and time management for learning and other activities. There are five indicators: learning technology (SR1), enthusiasm (SR2), self-development (SR3), utilization of media and applications (SR4), and time allocation between learning and other activities (SR5). The t-test values range from 7.510 to 11.820. The discrimination values, assessed by item-total correlation, range from 0.550 to 0.758. The reliability analysis of the indicators, using Cronbach's alpha coefficient, ranges from 0.762 to 0.827. Sample items include "I enjoy listening to technology-related news and the constant changes in current events," and "I can use technology to learn without encountering learning difficulties."

Interaction in learning (SINL) refers to accepting differences among classmates and teachers with diverse backgrounds, demonstrating appropriate behavior, enthusiasm for learning, and fully utilizing learning potential to effectively impart knowledge to students. It comprises four indicators: accepting differences among students (SI1), appropriate student behavior (SI2), teaching peers willingly (SI3), and utilizing full potential in learning (SI4). The t-test values range from 5.980 to 9.920. The discrimination values, assessed by item-total correlation, range from 0.504 to 0.674. The reliability analysis of the indicators, using Cronbach's alpha coefficient, ranges from 0.672 to 0.818. Sample items include "I consider understanding students' knowledge as normal, whether in the classroom or online learning," and "I would suggest using technology or problem-solving methods that I know to teachers or peers."

3.3. Data Collection

For data collection in this research, the researchers prepared letters requesting data collection analysis to be distributed to 43 secondary schools. The target group comprised students in Grades 7 through 12. Due to data collection during the COVID-19 pandemic, for the convenience and safety of respondents, the questionnaire was administered online via a Google Form. The researchers created QR codes to facilitate easy access to the questionnaire for students. The data collection period spanned three months.

Additionally, this research has received approval from the Research Ethics Committee of Chiang Mai University, highlighting the significance of safeguarding and upholding the confidentiality of the sample group. The rights of research participants were defined in great detail, allowing students in the sample group to withdraw their participation at any point if they experience discomfort or unease in responding to questions. Moreover, all data gathered from the questionnaire were treated confidentially and disposed of at the conclusion of the research. Data analysis and reporting will be conducted in an aggregated manner, ensuring no association with individuals, organizations, or entities.

The data collection results indicate that the researchers distributed 1,500 sets of online questionnaires and received responses from 1,453 students, with no withdrawals during the response process. However, 158 incomplete questionnaire responses were identified, resulting in 1,295 complete and analyzable datasets. This accounts for 86.33% of the total questionnaires distributed, which is deemed a satisfactory response rate for conducting confirmatory factor analysis using the second-order CFA technique.

3.4. Data Analysis

The quality assurance procedures and preliminary statistical analyses conducted include descriptive statistics, mean ($\bar{x}$), standard deviation (SD), maximum and minimum values, skewness (skewness should fall between ±2), and kurtosis (kurtosis should fall between ±2). Additionally, Pearson's product-moment correlation analysis of indicators and components, the Kaiser-Meyer-Olkin (KMO) statistical analysis (where the KMO values should range from 0 to 1), and Bartlett's test of sphericity to assess whether all indicators form an identity matrix should be performed. The results of these analyses should be statistically significant at the .05 level [5].

To evaluate the fit of the model measuring students' adaptive learning using 2nd-order CFA, the model's goodness-of-fit indices with observed data were examined. These include chi-square (χ2), where non-significant values at the .05 level are desired, root mean square error of approximation (RMSEA) < 0.05, standardized root mean square residual (SRMR) < 0.05, comparative fit index (CFI) > 0.95, the Tucker-Lewis index (TLI) > 0.95, and goodness-of-fit index (GFI) > 0.90 [15].

4. Results

The quality assessment of the data and preliminary statistical analysis includes descriptive statistics. The indicators have means ranging from 3.617 to 4.133. The indicator with the highest mean is accepting differences among students (SI1) ($\bar{x}$=4.133), while the lowest mean indicator is also time allocation between learning and other activities (SR5) ($\bar{x}$=3.617).

Regarding the dispersion of data, the standard deviations range from 0.393 to 0.588. The indicator with the highest standard deviation is time allocation between learning and other activities (SR5) (S.D.=0.588), whereas the indicator with the lowest data dispersion is enhancing physical resilience (SH2) (S.D.=0.393).

Concerning data distribution, it was noted that all indicators have negative skewness values ranging from -0.658 to -0.197, indicating statistically significant normal distributions as they fall within the range of -2 to 2. Additionally, the kurtosis values range from -0.334 to 0.469, indicating that the indicators have distributions close to normal curves.

The development of the adaptive learning model for new pathway students, based on relevant documents and research, as well as the presentation of indicators to experts for consideration, reveals that the model consists of 4 components and 15 indicators. The components are SHCL (2 indicators), SSSL (4 indicators), SROL (5 indicators), and SINL (4 indicators). Using Pearson's product-moment correlation, we found that all indicators had statistically significant relationships at the 0.01 level, exhibiting positive correlations. The magnitudes of these correlations ranged from 0.297 to 0.745. Notably, the indicator teaching peers willingly (SI3) has the strongest correlation with appropriate student behavior (SI2), while accepting differences among students (SI1) has the weakest correlation with itself. Additionally, when analyzing the KMO index (0.943) and Bartlett's test of sphericity (Approx. $\chi2 = 14083$, df = 105, and p-value = 0.000), it was found that all component indicators have statistically significant chi-square values at the .01 level. This indicates that the correlation matrix among the indicators is not an identity matrix, particularly at the .01 level. In conclusion, the indicators exhibit relationships and suitability for second-order CFA analysis.

The results of assessing the fit of the adaptive learning model for new pathway students using second-order CFA revealed that prior to adjustment, the goodness-of-fit indices with observed data were as follows: $\chi2 = 696.522$, df = 49, p-value = 0.0000, CFI = 0.938, TLI = 0.925, RMSEA = 0.074, and SRMR = 0.045. However, after model adjustment, the fit indices were as follows: $\chi2 = 34.402$, df = 94, p-value = 0.7571, CFI = 1.000, TLI = 1.002, RMSEA = 0.000, and SRMR = 0.011. This indicates acceptance of the null hypothesis that the correlation matrix of the hypothetical model does not differ from that of the observed model, demonstrating that the model fits the observed data well.

After confirming the model's satisfactory fit to the observed data, the estimated values of the indicator component weights were analyzed. It was determined that the estimated 1st order loading weights of the indicators, measured using standardized scores, ranged from 0.649 to 0.898, and all were statistically significant at the .01 level. The indicator variable with the highest standardized loading weight was utilizing full potential in learning (SI4) (β=0.898), followed by self-solving learning issues (SL4) (β=0.881), and practicing mindfulness (SL3) (β=0.842). In contrast, the indicator variable with the lowest standardized loading weight was accepting differences among students (SI1) (β=0.649). The confidence intervals of each variable ranged from 0.422 to 0.776.

For the 2nd order loading estimates, each component exhibited a high standardized loading weight. Specifically, SSSL had a loading weight of β=0.888, followed by SROL with β=0.871, SINL with β=0.795, and SHCL with β=0.752. The confidence intervals of each variable ranged from 0.566 to 0.943, as detailed in Table 1 and Fig. 1.

Table 1 Parameter estimation in the adaptive learning model for new pathway students during the new normal of learning management following the COVID-19 pandemic (n=1,295) (The authors)

Component	Indicator	*b*	*β*	S.E.	Z-value	p-value	R^2
First Order							
1. SHCL	SH1	1.000	0.809	0.020	41.084	0.000	0.654
	SH2	0.989	0.818	0.018	44.950	0.000	0.669
2. SSSL	SL1	1.000	0.725	0.020	36.313	0.000	0.526
	SL2	1.110	0.819	0.013	65.460	0.000	0.671
	SL3	1.246	0.842	0.011	77.170	0.000	0.710
	SL4	1.313	0.881	0.011	80.826	0.000	0.776
3. SROL	SR1	1.000	0.791	0.015	53.190	0.000	0.626
	SR2	0.942	0.814	0.014	59.400	0.000	0.663
	SR3	1.028	0.814	0.013	63.065	0.000	0.662
	SR4	0.948	0.835	0.016	53.306	0.000	0.698
	SR5	0.978	0.752	0.017	44.584	0.000	0.566
4. SINL	SI1	1.000	0.649	0.023	27.801	0.000	0.422
	SI2	1.021	0.791	0.017	45.306	0.000	0.625
	SI3	1.251	0.820	0.025	33.232	0.000	0.673
	SI4	1.291	0.898	0.017	54.319	0.000	0.806
Second Order							
Learning Adaptability (SAL)	SHCL	1.000	0.752	0.023	32.935	0.000	0.566
	SSSL	1.147	0.888	0.014	63.647	0.000	0.788
	SROL	1.468	0.871	0.013	72.412	0.000	0.943

SINL	1.001	0.795	0.019	41.870	0.000	0.632

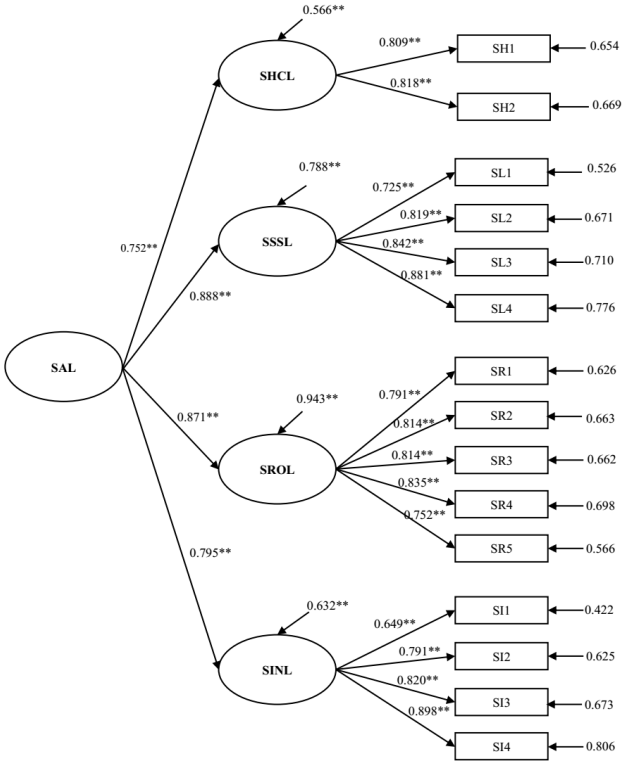

Fig. 1 Adaptive learning model for new pathway students (The authors)

5. Discussion

In light of the research findings, the researchers present a summary of the following main points:

First, the development of the adaptive learning model for students during the COVID-19 pandemic comprises four main components: health care in learning, self-sentiment in learning, roles of learning, and interaction in learning. Each component consists of 15 behavioral indicators that have been content-validated by experts. This indicates the structural relationships and theoretical appropriateness of the measurement model. Additionally, the results from the second-order confirmatory factor analysis also suggest that the developed measurement model fits well with the observed data, demonstrating its effectiveness in assessing students' adaptive learning in the context of the new learning environment after COVID-19. These findings are consistent with Kaplan's [14] study, which emphasizes the importance of studying and developing assessment tools for adaptive skills to promote students' quality of life and success in learning despite rapid change.

The second point is that the analysis of the first-order loading values of various behavioral indicators revealed that all indicators exhibited high variability associated with the main components. The indicators with the highest weights were utilizing full potential in learning and self-solving learning issues, which is consistent with the nature of online learning during the COVID-19 period, where students need to take more responsibility and have the ability to self-solve learning issues [3, 6, 16]. In particular, Ortiz [22] found that students who can solve problems and learn independently tend to have higher adaptability and learning performance than those reliant on others. Therefore, it is essential to encourage students to practice and develop the skills necessary for utilizing their potential and independently solving problems to effectively manage learning in the new era..

Conversely, the indicator with the lowest weight is accepting differences among students. This could be attributed to social distancing measures, which have reduced communication and interaction among students, resulting in fewer opportunities for them to express themselves or become acquainted with the diverse differences of their classmates [4, 13, 18, 28]. Consequently, the significance of accepting differences in adapting to learning situations may be diminished under such circumstances. However, Brooke et al. [8] and Mahoney et al. [20] suggested that the skill of accepting differences is crucial for future social interactions and work. Promoting learning activities that foster the acceptance of diversity without the necessity of physical interaction could be an intriguing approach.

The final point emphasizes that the analysis of the second-order loading values highlights the significance of components related to self-sentiment in learning and roles of learning for overall adaptation. This can be attributed to the direct impact of changes in the learning environment and formats during COVID-19 on students' mental states, emotions, and roles. These changes may induce stress and anxiety, affect technological proficiency, or increase self-management responsibility [3, 9, 16, 17, 21]. This observation aligns with Yehuda's [31] research, which underscores that mental well-being, self-confidence, and self-management skills are pivotal for students' adaptation and stress management during the COVID-19 pandemic. Therefore, prioritizing mental health care and nurturing positive attitudes toward learning should form the cornerstone of current learning management strategies.

Interaction in learning and health care in learning are considered least important in this context, which could be attributed to the emphasis on technology-driven online learning [3, 9, 17, 21], along with the flexibility of time and learning environments that prioritize learning and personal space [10, 19]. Therefore, healthcare may not be a critical factor in initial adaptation compared to self-utilization or problem-solving skills. However, Zander [32] stated that concentrating solely on learning while neglecting healthcare could have adverse effects on long-term learning outcomes. Hence, although health care may have less immediate importance in adaptation, it remains a necessity that should not be overlooked.

Educators should integrate health care-related content with learning materials to ensure a comprehensive learning experience.

This research illuminates the structure and connections of adaptive learning components and indicators in the post-COVID-19 era, revealing behavioral shifts and the vital role of student adaptation in evolving learning environments. The insights from this study are poised to significantly aid in developing learning management processes and support strategies to facilitate effective student adaptation during current and future challenges. Future research should focus on exploring causal factors influencing learning adaptation, developing effective management models, and implementing interventions to support struggling students. This enhances education quality and students' resilience in facing future transformations. Additionally, investigating comparative adaptation across diverse contexts will provide insights into challenges and enable tailored support interventions for each student group.

Finally, researchers have emphasized the importance of utilizing research findings to inform policy implications for education management, curriculum development, teaching strategies, staff capacity building, and resource allocation [11, 30], with a priority on promoting students' adaptive learning. This is vital for education to effectively address students' needs and challenges of a rapidly changing world. Establishing a strong educational foundation that fosters continuous adaptation and self-development among students is crucial for nurturing quality citizens and advancing society toward sustainable development amidst global changes.

The transformative insights gleaned from this research pave the way for a renaissance in adaptive learning, serving as a catalyst for groundbreaking causal factor studies, innovative curriculum development, and visionary policy implementation that reshape the educational landscape.

6. Conclusion

This research illuminates the intricate tapestry of adaptive learning components and indicators in the post-COVID-19 era, unraveling the enigmatic shifts in behavior and highlighting the paramount role of student adaptation in the face of evolving learning landscapes. The groundbreaking insights unearthed in this study hold the power to revolutionize learning management processes and galvanize the development of pioneering support strategies, equipping students with the tools to navigate the uncharted waters of present-day and future challenges.

By laying the foundation for an educational paradigm that nurtures perpetual adaptation and unwavering self-development among students, this research serves as a call for the cultivation of an enlightened citizenry, propelling society toward the uncharted horizons of sustainable development amid the relentless tides of global change.

Students' adaptive learning in the new normal of learning management following the outbreak of the COVID-19 pandemic can be categorized into four components of adaptive learning: 1) health care in learning, comprising two indicators: reducing disease risk and enhancing physical resilience; 2) self-sentiment in learning, consisting of four indicators: self-regulation of emotions, adaptability to learning situations, practicing mindfulness, and self-solving learning issues; 3) roles of learning, with five indicators: learning technology, enthusiasm, self-development, utilizing media and applications, and time allocation between learning and other activities; 4) interaction in learning, encompassing four indicators: accepting differences among students, appropriate student behavior, teaching peers willingly, and utilizing full potential in learning.

The analysis revealed consistent and appropriate alignment between the indicators and components of the student learning measurement model, allowing for a structural examination of congruence. This study makes an original academic contribution by proposing and validating a comprehensive four-component model of students' adaptive learning in the context of the COVID-19 pandemic's impacts on education, integrating the multiple dimensions of health care, self-sentiment, roles, and interaction into a holistic framework.

As we stand on the precipice of a new era in educational research, it is imperative to acknowledge the limitations that tether us to the present. Future research must boldly venture into the uncharted realms of causal factors that shape learning adaptation. This will entail the construction of innovative management models and the implementation of transformative interventions that lift up the struggling and empower the disadvantaged. Moreover, by intrepidly delving into the comparative depths of adaptation across diverse contexts, researchers can unearth the hidden challenges that lurk beneath the surface, armed with the knowledge to devise tailored support interventions that leave no student group behind.

7. Recommendations

Research on students' adaptive learning in the new post-COVID-19 paradigm has provided valuable insights that can be applied to improve the quality of education across different levels, including classrooms, schools, and families.

In classrooms, teachers use an adaptive learning model to assess students individually and tailor learning activities based on their strengths and weaknesses. Integrating problem-solving and technology proficiency indicators enhances adaptive skills through challenging tasks and technology use. At the school level, promoting adaptive learning, focusing

on physical, mental, and relational dimensions, is vital for academic success. Administrators should provide supportive environments and help teachers organize activities that foster problem-solving and collaboration. Family involvement is crucial; parents create conducive learning environments, encourage engagement, and model adaptability. Collaboration between home and school enhances cooperation. This research paves the way for future advancements in understanding adaptive learning through causal factor studies, curriculum development, and policy implementation.

Finally, research on post-COVID-19 student learning adaptation has yielded valuable insights, enhancing our understanding of deep adaptation and its implications for education quality in rapidly changing times. Collaboration among all stakeholders—students, teachers, administrators, parents, and institutions—is vital for applying this knowledge, driving systemic changes, fostering innovation, and bolstering resilience against future challenges. This collaboration provides a crucial foundation for societal and national development and ensures sustainable progress during uncertainties.

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