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Exploratory factor analysis-instrument for self-assessment of computation thinking skills and collaboration skills

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ABSTRACT

This study focuses on developing and validating instruments to assess the computational thinking skills (CTS) and collaboration skills (CS) of undergraduate students in Indonesia. Employing a quantitative research approach with the exploratory factor analysis (EFA) technique, the research process unfolded in three validation steps. First, face validity was established through expert judgment. Second, discriminant validity was examined using product-moment correlations and Cronbach's alpha. Finally, EFA were employed to assess the factorial structure. The instrument development process followed five phases: drafting the instrument, face validity assessment by experts, data collection involving 242 undergraduate students as samples, discriminant validity analysis (product moment and Cronbach's alpha), and EFA analysis to group items and construct dimensions. This study identified six dimensions for CTS (algorithmic thinking, cooperative thinking, problem reformulation, creativity, critical thinking, and systematic testing) and three dimensions for CS (knowledge sharing, planning, and responsibility). These findings support validating the CTS and CS self-assessment scale, making it a valuable tool for evaluating undergraduate student learning and researching computational thinking and CS in Indonesia. Researchers and educators are encouraged to utilize the CTS and CS instrument for self-assessment purposes and further exploration of these competencies among undergraduate students.

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1. INTRODUCTION

Since the COVID-19 pandemic in Indonesia, office administration education has transformed the learning process through e-learning that has been provided and developed by Universitas Sebelas Maret such as Spada, Siakad, and OCW. In addition, teachers have also used other platforms such as Zoom, Microsoft Teams, Google Classroom, WhatsApp, and WebEx to deliver their lectures. During the transformation period, problems were found in the learning process in practice-based courses in office administration education, which were caused by the limitations of an unstable internet network, expensive internet packages and students feeling bored or not liking learning in digital classes. Many teachers reduce the amount of teaching and practice or the duration of online lectures is less than scheduled and learning is not significant enough for students. Previous studies [1]–[3] indicated that many students do not have access to materials shared by their instructors. In some cases, students do not even enter the digital classroom learning system which shows the low level of student involvement in digital classroom learning.

Over time, the problems faced by students have begun to be resolved by improving the internet network, data packages that have been subsidized by the government and universities, and learning models can begin to be combined with e-learning media provided, learning begins to run normally. This is inversely proportional to the state of students' abilities which have decreased during online model learning. Research shows that the significance of digital classes is not as good as face-to-face learning due to the limitations experienced by students [4]–[6]. Mali and Lim [7], the majority of students do not like learning in digital classes compared to face-to-face learning. Gonzalez *et al.* [8] found that student achievement before and during the COVID-19 pandemic was very different by comparing student test results in 2017, 2018 and 2020 and found that their achievement in 2017 and 2018 was much better than in 2020. Ardan *et al.* [9] said that the students were affected spiritually and psychologically from the COVID-19 pandemic. They reported that almost all of the respondents experienced too much workload from the teacher.

Based on the explanation, we assume that e-learning education has been going well and students' abilities have decreased in cognitive aspects [4]–[10]. However, in previous studies, researchers did not explain specific abilities such as computation thinking skills (CTS) and collaboration skills (CS). One of the researchers who discussed CTS [11], revealed that this ability is a process of problem solving, designing systems, and understanding human behavior, by drawing on the basic concepts of computer science. This means that this ability is not limited to "computer subject matter" but the ability to flow thinking and problem solving with a computer as a tool [12]. While CS is the ability to design and collaborate, consider a different perspective and participate in a particular discussion by listening, contributing and supporting the opinions of others, as well as the ability to recognize and assess the contribution of each individual in the group [13]–[16]. This ability is an important skill at home, at work, and in the community [17], [18] and much of planning, problem solving, and decision making is done in groups or teams [19].

Based on the initial bibliometric data on the SINTA page as the highest journal indexer, we found 2,548 articles on computation and then narrowed them down with the word CTS to 25 articles. From these articles, the researcher did not find a special assessment instrument for CTS. Some experts [13]–[16] test their students' CTS abilities using only learning outcomes on computer subjects. Whereas CTS is the ability to analyze and then solve various problems not only understanding computer material. Furthermore, 2,250 articles were found with the collaboration keyword from the SINTA page, then narrowed down with the CS keyword to 121 articles. Based on these data, the researcher did not find a CS instrument that can be used to measure the CS ability of students in Indonesia. Some researchers [20]–[23], carry out CS evaluations but there is no CS instrument to measure student CS in Indonesia. CTS and CS instruments need to be developed to see and evaluate students because these two things (CTS and CS) are some of these abilities considered important by experts for individual development outside of school [17], [18], [24], [25]. For this reason, an assessment instrument that is appropriate to the characteristics of students is needed [26]–[29]. As support, the Association of Indonesian Office Administration Practitioners (ASPAPI) stated that self-assessment instruments are needed in various 21st century abilities for undergraduate student in Indonesia, including CTS and CS which can be used for research in the field of education in Indonesia. Several experts [30]–[33] recommend each country to develop an instrument that is validated with samples from that country. With this novelty, we are developing an instrument to measure the CTS and CS for students undergraduate in Indonesia. With the hope of contributing to the literature for researchers and teachers in seeing these abilities from the student's point of view.

2. RESEARCH METHOD

The sample group of this study consisted of 242 students who were studying at the undergraduate level at the Universitas Sebelas Maret, Indonesia, in the 2021-2022 academic year who had carried out distance education. The sample of this study was randomly selected from volunteer students. The sample size calculation were based on a stable factor structure model, which requires a minimum of 100 and 200 subjects, and a subject variable ratio of at least 2:1 to reduce the standard error (SE) of the correlations to negligible proportions [34]. The method used in this study is exploratory factor analysis (EFA) as convergent validity. EFA was used to determine the construct validity of instrument CTS and CS [35].

Face validity with expert judgment and discriminant validity with product moment analysis and Cronbach's alpha are not the main analysis in instrument development, both are used as reinforcement in instrument development. Taherdoost [36] revealed "face validity is the degree to which a measure appears to be related to a specific construct, in the judgment of nonexperts such as test takers" and the clarity of the language used. While discriminant validity is the extent to which latent variable A discriminates from other latent variables (e.g., B, C, D) [36]. We used five phases as a research procedure shows in Table 1, phase-1 of the draft CTS and CS self-assessment instrument was prepared based on a literature review using Indonesian by adapting a Likert scale coded 1 to 5. Phase-2, expert validation was carried out using experts or experts to assess the instrument by filling out the validation sheet with a rating scale of 1=very poor, 2=not good, 3=fair, 4=good, and 5=very good. If the item gets a score of 2 or 1 on expert validation, then the statement item will be eliminated. Phase-3, collecting data by distributing self-assessment instruments to 242 samples. Phase-4 data were tabulated and validity and reliability were carried out (product moment and Cronbach's alpha). Test the validity and reliability using product moment and Cronbach's alpha with the help of SPSS 26, using criteria: i) if the value of Sig. (2-tailed)<0.05 and the Pearson correlation is positive, then the questionnaire item is declared valid; ii) if the value of Sig. (2-tailed)<0.05 and the Pearson correlation is negative, then the questionnaire item is declared invalid; and iii) if the value of Sig. (2-tailed)>0.05, then the questionnaire item is declared invalid. After criterion "a" is met, the next step is to compare the Pearson correlation with r table df 242 (0.126). If the Pearson correlation >0.126 then the item is declared valid. Then if Cronbach's alpha >0.6 then the instrument is declared reliable.

Phase-5 carried out EFA. EFA was used in this study because the CTS and CS instruments for office administration students had never been made in Indonesia. EFA in this study uses the extraction method in the form of principal component analysis (PCA) and the rotation method in the form of Varimax to find out which statement items will then be eliminated, to group items into indicators and to find out which items have strong dimensions with computational thinking skills and CS. The first requirement that must be met to perform factor analysis is Kaiser-Meyer-Olkin (KMO) >0.50 and Sig.<0.05. The second requirement is anti-image correlation-measures of sampling adequacy (MSA) >0.50, if MSA<0.50 then the statement item must be eliminated and retested. The third condition is communalities >0.50, if communalities <0.50 then the item must be eliminated and retested. These conditions must be met before describing how many factors or dimensions appear based on the total initial eigenvalues >1, and to determine the items that are factors or dimensions through the max rotated component matrix value per dimension component that appears with a loading factor of 0.40 [35]. The instrument consists of several aspects which are interpreted and described in several indicators for each aspect. In detail, research aspects and indicators are described in Table 1.

Table 1. Instrument validation "experts"

Aspect	Indicator	Item question				
		1	2	3	4	5
Clarity	Clarity title sheet questionnaire					
	Clarity sheet statement					
	Clarity item statement					
	Clarity instruction charging					
Accuracy	Accuracy statement with expected answer					
Relevance	Statement related with indicator					
	Statement in accordance with aspect you want achieved					
Validity contents	Statement uncover correct information					
Not there is a bias	Statement have complete idea					
Language accuracy	Language used easy understood					
	Language used effective					
	Writing in accordance good Indonesian spelling and correct					

The procedure after accumulating the instruments in this study is to determine the research phase. The research phase is divided into five main sections starting from determining the instrument to assessing the validity of the instrument. The phases are described in detail in Figure 1.

3. RESULTS

3.1. Phase-1: computation thinking skills

Computation thinking skills originate from the constructionist work of Seymour [37], [38] and was first coined as a term by Wing [11]. The researcher explains that CTS is a process of "solving problems, designing systems, and understanding human behavior, drawing on basic computer science concepts." Thus, CTS represents the ability to analyze and then solve various problems. The most frequently cited definition of CTS comes from previous study [39], CTS is a thought process in which "… solutions are represented in a form that can be effectively carried out by an information-processing agent." Berland and Wilensky defined CTS as "the ability to think with a computer as a tool" [12]. In a comprehensive report by the National Research Council, CT consists of five important and universal elements across domains: i) hypothesis testing; ii) data management; iii) parallelism; iv) abstraction; and v) debugging.

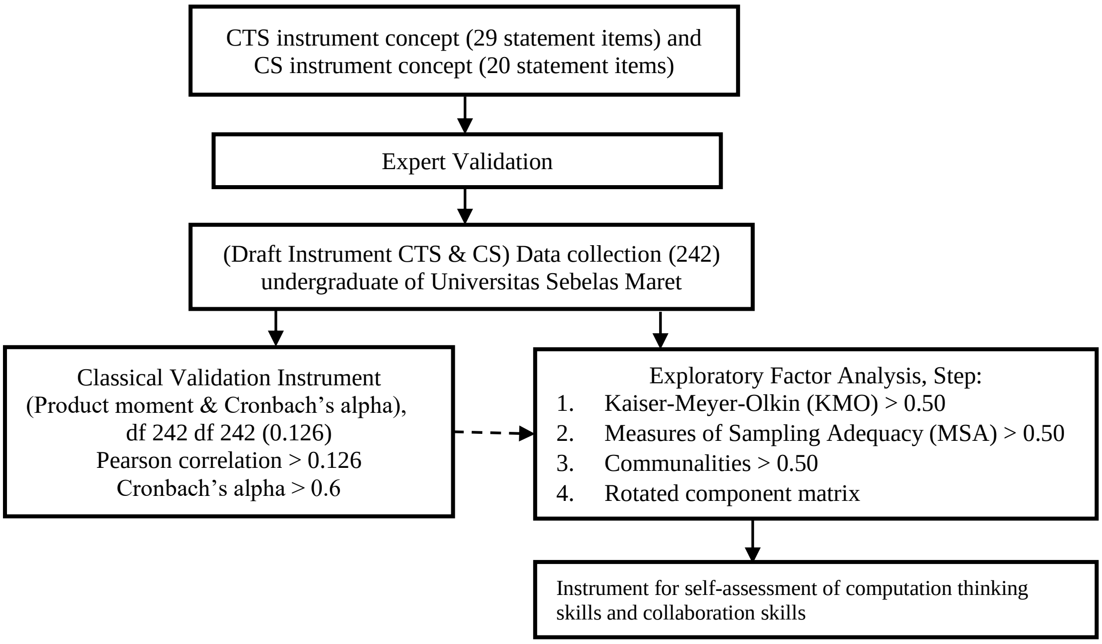

Figure 1. Research phase

Recently, Anderson [40] described five components of CT: i) problem decomposition; ii) pattern recognition; iii) abstraction (i.e., generalization of repeated patterns); iv) algorithm design for solutions, and v) evaluation of solutions (i.e., debugging). Wing [11] argued that CTS does not mean thinking like a computer, but rather to engage in five cognitive processes with the aim of solving problems efficiently and creatively. The five cognitive processes in question are: problem reformulation-reframing the problem into a solvable problem; recursion-build the system incrementally based on previous information; problem decomposition-breaking down a problem into manageable units; abstraction-modeling the core aspects of a complex problem or system; and systematic testing-taking action aimed at getting a solution.

Korkmaz *et al.* [41] revealed the indicators as measuring tools through general reflection of creativity, algorithmic thinking, cooperative thinking, critical thinking, and problem solving. Creativity is a skill that unrelated to art and lasts a lifetime, and "the ability to express oneself and use one's mind and imagination" [42]. Algorithmic thinking is the skill of understanding, applying, assessing, and generating algorithms. Critical thinking has been defined as "the use of cognitive skills or strategies that increase the likelihood of a desired behavior." Cooperative thinking learning is a learning method in which the learning of both individual and group members from small groups is tried to be maximized. The obstacles on the way one finds to reach the intended goal are called problems. If a person encounters obstacles in his efforts to achieve certain goals or thoughts, it means that there is a problem for that person [41]. Measurement of computational thinking skills can be explained through several scientific studies and documents on previous research and several reputable references and documents that are declared valid for citation. Based on the study, the researchers compiled statement items to measure student CTS in Table 2.

3.2. Phase-1: collaboration skills

Collaboration skills are skills that must be developed and assessed by the Program for International Student self-Assessment (PISA) [43]. It is widely recognized that CS is an important skill at home, at work, and in the community [17], [18] and most planning, problem solving, and decision making is done in groups or teams National Research Council [19]. The collaboration process becomes a specific social interaction and learning process, thus causing group members to be able to actively and constructively solve a problem [24]. Collaboration is about designing and collaborating, considering a different perspective and participating in a particular discussion by listening, contributing and supporting the opinions of others, as well as the ability to recognize and assess the contribution of each individual in the group [18], [24], [25], [44]. There were three aspects of student CS [45], including: i) Group cohesiveness, refers to the extent to which group members are interested and motivated to stay with the group; ii) Group effectiveness, is measured by the extent to which group members achieve their goals and complete their tasks together; and iii) Group efficacy, group or collective efficacy refers to the shared perception of group members about how capable their group is about a particular task.

Then specifically Laar *et al*. [46] stated that individual students' collaborative abilities can be measured by indicators in the form of responsibility, planning, interdependence, and knowledge sharing. CS can be measured through several aspects and indicators through implementation in the form of questions summarized in a questionnaire. Based on the study and references to some of these indicators, the researchers compiled statement items to measure student CS in Table 3.

Table 2. CTS instrument statement items

Statement	Code
I like people who believe with part big the decision	C1
I like realistic people	C2
I believe that I could solve part big the problem that I facing if I have enough time	C3
I have confidence that I could solve possible problem occur when I adapt with new situation	C4
I believe that I could apply the plans that have been I for solve problem	C5
Dream is Thing important for reach destination	C6
I trust intuition and feeling I about " truth " and "false" when I approach solution from something problem	C7
When I face problem, I stop before continue to other subjects and thinking solving problem	C8
I could quick build equity to be give solution from something problem	C9
I think I have interest special in the process of the algorithm (solve problem with Street fastest and best)	C10
I think in study more good instructions made with help symbol and draft algorithm	C11
I believe that I could with easy catch connection Among numbers	C12
I by mathematical could disclose ways solving the problem that I facing in life daily	C13
I could to do analysis problem digitally and disclose verbally	C14
I like learning cooperative thinking together with friends	C15
In learning cooperative thinking, I think that I have/will reach more results success because I work in group	C16
I like solve related problems with project group together with friends	C17
More lots of ideas happen in draft cooperative thinking	C18
I smart prepare plan regular about solution from complex problem	C19
Very pleasant for try solve complex problem	C20
I ready for study challenging things	C21
I proud can think with very precision	C22
I use method systematic moment compare choice in hand for make reach decision	C23
I do not have problem in demonstration solution from problem	C24
In complete problem I must can putting and share problem in variables X and Y in the solution	C25
I can make complicated problem becomes easy	C26
I could produce so many choices while thinking ways possible solution about something complicated problem	C27
I could develop my ideas alone in environment learning	C28
I feel enthusiastic for try learn something problem together with friend one group in learning	C29

Table 3. CS instrument statement items

Statement	Code
I could evaluate other people's useful abilities for me	CS1
I active give contribution moment attend a meeting	CS2
I could identify the ability of others in team work	CS3
I give contribution maximum for team work	CS4
I could communicate different roles to every member team work	CS5
I discuss strategy for reach destination together	CS6
I to do adjustment plan with discuss together member team	CS7
I monitor progress team in work	CS8
I complete duty I in team appropriate time	CS9
I ensure member team other could complete duty appropriate time	CS10
I discuss deadline time processing duty together member team	CS11
I exchange information with member team moment share duty	CS12
I could utilize skill me other than field main I	CS13
I give bait come back from other people's opinion	CS14
I support others in professional role	CS15
I get support work from my colleague	CS16
I share information with colleague work for progress profession	CS17
I share information for help profession colleague another job	CS18
I share source available power for help team doing duty	CS19
I experience difficulty share information related profession	CS20

3.3. Phase-2: face validity-expert judgment

The CTS instrument is arranged based on five indicators into 29 questions or statements. Meanwhile, CS is based on four indicators with twenty questions or statements. Furthermore, the instrument validity was carried out by experts in Table 1 by experts with aspects of self-assessment in the form of content accuracy, relevance, content validity, unbiasedness, and language accuracy. The results of expert validation through the validation sheet provided show that there are no items on the two instruments that get a score of 2 or 1 so that no items are eliminated or deleted from the instrument. The statement indicators are in accordance with the aspects to be achieved, writing according to good and correct Indonesian spelling, clarity of instructions for filling, and accuracy of statements with answers that are expected to obtain the highest average score of 4.2 on the CS instrument.

While on the CTS instrument, the statement indicator has a complete idea and the language used is effective and gets the highest score of 4.7. Figures 2 and 3 shows the results of expert validation based on the average of each indicator and the expert or expert providing the self-assessment. After obtaining the results of expert validation, the researchers distributed the instrument to a random sample, the data obtained were analyzed for validation, reliability, and factor analysis using the SPSS application.

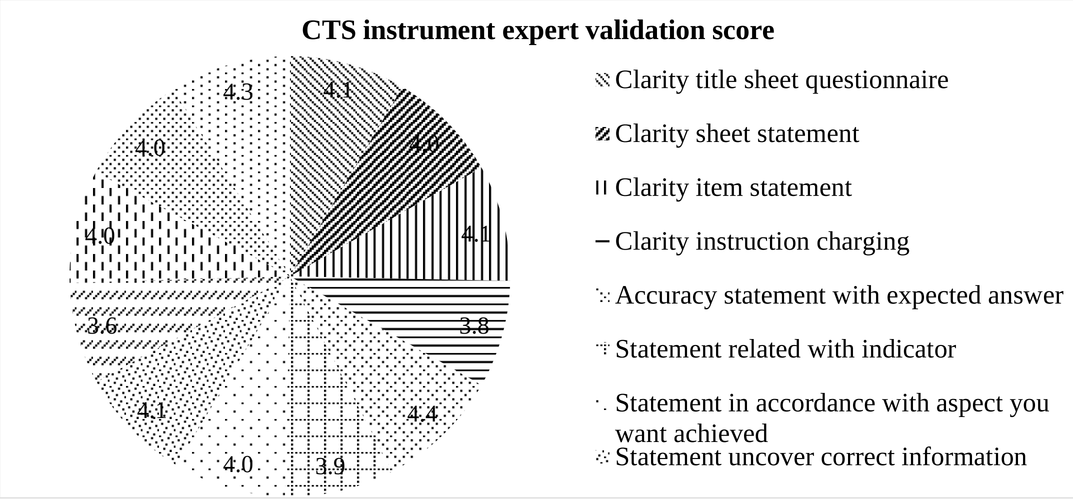

Figure 2. Result of CTS instrument expert judgment

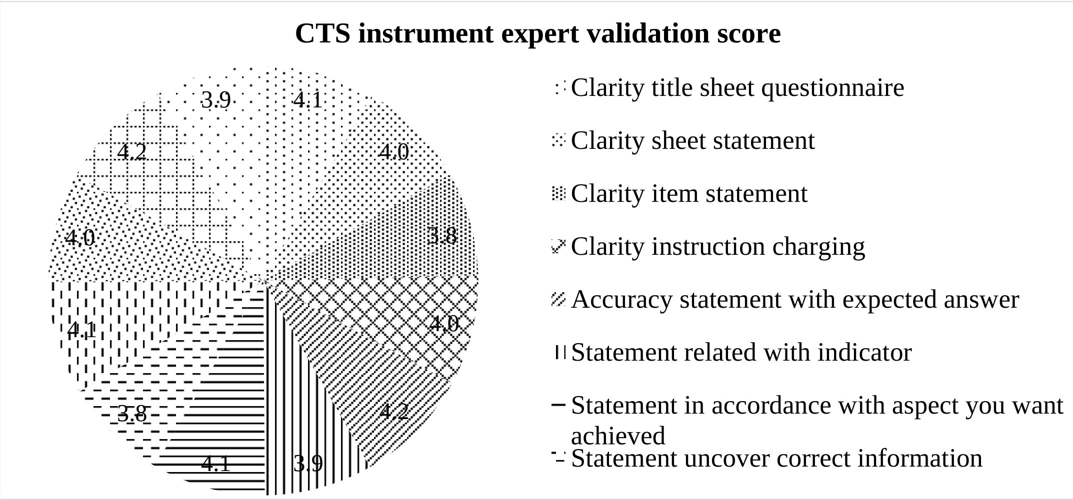

Figure 3. CS instrument expert judgement results

3.4. Phase-3: data collection

Students enrolled at participating universities were approached and given the instrument link and were asked to give their consent prior to their participation. All students are assured that neither their results nor their participation in this survey will affect their final grades in any subject. In considering external validity and the need to recruit subjects with characteristics of undergraduate students, data were collected from the 2021-2022 study year. Data was collected as many as 242 students who filled out the instrument.

3.5. Phase-4: discriminant validity

The results of the validity test of the CTS data tabulation showed that there were 28 statement items that met the criteria of Sig. (2-tailed)<0.05 and positive Pearson correlation with Pearson correlation >0.126 are shown in Tables 4 and 5. Item C2 was eliminated because the Pearson correlation (0.109)<0.126. At this stage, 1 item is eliminated, leaving 28 valid statements that represent each indicator in the CTS capability. The results of the validity test were carried out to determine the accuracy and accuracy of the instrument, which in this case was to measure computational thinking skills. The following are the details of the results of the validity of the statement items on the CTS capability Table 4.

Table 4. CTS validation results

Code Item	Results	Information	Code	Results	Information
C1	0.376 **	Valid	C16	0.262 **	Valid
C2	0.109	Invalid_	C17	0.396 **	Valid
C3	0.342 **	Valid	C18	0.428 **	Valid
C4	0.488 **	Valid	C19	0.434 **	Valid
C5	0.447 **	Valid	C20	0.406 **	Valid
C6	0.291 **	Valid	C21	0.497 **	Valid
C7	0.333 **	Valid	C22	0.443 **	Valid
C8	0.183 **	Valid	C23	0.440 **	Valid
C9	0.528 **	Valid	C24	0.402 **	Valid
C10	0.587 **	Valid	C25	0.497 **	Valid
C11	0.544 **	Valid	C26	0.469 **	Valid
C12	0.616 **	Valid	C27	0.295 **	Valid
C13	0.555 **	Valid	C28	0.365 **	Valid
C14	0.569 **	Valid	C29	0.276 **	Valid
C15	0.395 **	Valid			

The highest valid value for the computation thinking variable is found in item C12, an indicator of algorithm thinking with a statement in the form of "I believe that I can easily capture the relationship between numbers." The invalid item C02 on the creativity indicator with the statement "I like people who are realistic and neutral" has been eliminated. Then the lowest value of the valid item on this variable is held by item C8, the creativity indicator with the statement "When I face a problem, I stop before continuing to another subject and think about the problem." Furthermore, the validity of the self-assessment instrument on CS ability obtained 19 valid items from the 20 items tested. All statement items meet the criteria for the value of Sig. (2-tailed)<0.05 and the Pearson correlation is positive, but there is 1 item that does not meet the value of r table df 242 with a value of 0.126. The item is CS 20 where Pearson correlation <r table df 242 (0.91<0.126). Table 5 describes in detail the results of the validity and interpretation.

Table 5. CS validation results

Code Item	Results	Information	Code	Results	Information
CS1	0.498**	Valid	CS11	0.641**	Valid
CS2	0.509**	Valid	CS12	0.600**	Valid
CS3	0.560**	Valid	CS13	0.689**	Valid
CS4	0.656**	Valid	CS14	0.584**	Valid
CS5	0.655**	Valid	CS15	0.644**	Valid
CS6	0.678**	Valid	CS16	0.558**	Valid
CS7	0.618**	Valid	CS17	0.681**	Valid
CS8	0.663**	Valid	CS18	0.665**	Valid
CS9	0.656**	Valid	CS19	0.683**	Valid
CS10	0.702**	Valid	CS20	0.091**	Invalid

The highest valid value of the CS variable is CS10 on the planning indicator with the statement "I make sure other team members can complete the task on time." While the lowest valid value is on the CS1 statement item with the statement "I can assess the abilities of other people who are useful to me." The statement items that were eliminated at this stage were the CS 20 items of various knowledge indicators with the statement "I have difficulty sharing information related to work." The reliability of the CTS and CS variables has met the criteria in the form of Cronbach's alpha value >0.60 even both of them are close to the value 1, which shows that the items in the instrument are convincing to be used as a measuring tool. Specifically, the computation thinking instrument obtained Cronbach's alpha value (0.828)>0.60 from N of items totaling 28 (because 1 invalid item had been eliminated. Collaboration instruments obtained Cronbach's alpha value (0.916)>0.60 from N of items totaling 19 because 1 invalid item has been eliminated.

3.6. Phase-5: Exploratory factor analysis

3.6.1. Kaiser-Meyer-Olkin CTS

Factor analysis aims to find a strong item dimension in measuring a variable. The CTS capability has five indicators in Table 4 and a CS variable with four indicators in Table 5, each indicator has a statement item that has been grouped and averaged for each indicator. The next step is factor analysis using SPSS 26 and the following data are found. Table 6 shows the results of the Kaiser-Meyer-Olkin test on computational thinking skills. Table 7 shows the results of the Kaiser-Meyer-Olkin test on collaboration skills.

Table 6. Kaiser-Meyer-Olkin CTS

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin measure of sampling adequacy.		0.812
Bartlett's Test of Sphericity	Approx. Chi-Square	1544.097
	Df	201
	Sig.	0.000

Table 7. Kaiser-Meyer-Olkin CS

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin measure of sampling adequacy.		0.890
Bartlett's Test of Sphericity	Approx. Chi-Square	1201.449
	df	66
	Sig.	0.000

KMO is carried out to determine the feasibility of a factor analysis to be carried out on the CTS and CS instruments. The KMO CTS value in the initial calculation obtained a value of 0.797 with Sig 0.000 due to the elimination of statement items at the MSA and communalities stages, the KMO value became 0.812 with Sig. 0.000. Although there is a change in the value, the initial and final KMO values on the CTS ability are greater than 0.50 and the value of Sig. smaller than 0.05. In line with this, the KMO on CS ability has changed from a KMO value of 0.910 to 0.890>0.50 with a Sig value. fixed at 0.000<0.05.

3.6.2. Measures of sampling adequacy

A total of 29 items in the CTS instrument statement were analyzed using SPSS 26, resulting in data in the form of anti-image correlation–MSA "before elimination of communalities" that met the anti-image correlation criteria >0.50 so that at this stage (analysis-1, Table 8) has not been eliminated for statement items. Item C13 with a value of 0.887a becomes the highest value, then item C2 becomes the lowest value with a value of 0.623[a]. After elimination of communalities (analysis-2, Table 8), the data were reanalyzed to produce 21 statement items (anti-image correlation >0.50) on the CTS instrument with the highest scores on item C19 (0.857[a]) and item C27 (0.671[a]) be the lowest value. Based on these repetitions, the CTS instrument has met the MSA criteria. Similar treatment was carried out on statement items on the CS instrument, a total of 20 statement items were analyzed using anti-image correlation–MSA. Item C20 (0.381[a])<0.50, meaning that the item must be eliminated at the MSA stage and then re-analyzed. The result (analysis-2, Table 9) all statement items meet the MSA criteria >0.50 with CS9 items (0.966[a]) as the highest value and the lowest item. Next, the analysis was carried out again because there were several items that were eliminated. The results of the MSA analysis (analysis-3 and 4, Table 9) 12 CS statement items met the anti-image correlation criteria >0.50 with the highest score on item CS9 (0.951[a]) and item CS11 (0.836[a]) as the lowest value. Table 8 shows the results of anti-image correlation–MSA of computational thinking skill variables. Table 9 shows the results of the anti-image correlation–MSA from the collaboration skills variable.

Table 8. Results of anti-image correlation–MSA CTS

MSA-before elimination of communalities Analysis-1						MSA-after elimination of communalities Analysis-2			
Code item	Anti-image correlation	Code item	Anti-image correlation	Code item	Anti-image correlation	Code item	Anti-image correlation	Code item	Anti-image correlation
C1	0.830[a]	C11	0.818[a]	C21	0.852[a]	C4	0.829[a]	C19	0.857[a]
C2	0.623[a]	C12	0.845[a]	C22	0.847[a]	C5	0.780[a]	C20	0.790[a]
C3	0.797[a]	C13	0.887[a]	C23	0.780[a]	C10	0.830[a]	C21	0.839[a]
C4	0.813[a]	C14	0.876[a]	C24	0.771[a]	C11	0.826[a]	C22	0.808[a]
C5	0.795[a]	C15	0.796[a]	C25	0.777[a]	C12	0.847[a]	C23	0.785[a]
C6	0.640[a]	C16	0.780[a]	C26	0.806[a]	C13	0.880[a]	C25	0.800[a]
C7	0.783[a]	C17	0.745[a]	C27	0.641[a]	C14	0.879[a]	C26	0.811[a]
C8	0.510[a]	C18	0.850[a]	C28	0.737[a]	C15	0.801[a]	C27	0.671[a]
C9	0.810[a]	C19	0.810[a]	C29	0.713[a]	C16	0.800[a]	C28	0.740[a]
C10	0.822[a]	C20	0.786[a]			C17	0.777[a]	C29	0.716[a]
						C18	0.852[a]		

***(Analysis-1) MSA-before elimination of communalities: The results of the first MSA analysis of all items were not eliminated because anti-image correlation >0.50, (Analysis-2) MSA-after elimination of communalities: The results of the second analysis (repetition of data analysis) after the analysis of communalities (Table 10) (eliminated items: C1, C2, C3, C6, C7, C8, C9, C24)

Table 9. Results of anti-image correlation–MSA CS

MSA-before elimination of communalities				MSA-after elimination of communalities			
Analysis-1		Analysis-2		Analysis-3		Analysis-4	
Code item	Anti-image correlation	Code item	Anti-image correlation	Code item	Anti-image correlation	Code item	Anti-image correlation
CS1	0.857[a]	CS1	0.856[a]	CS1	0.824[a]	CS2	0.905[a]
CS2	0.892[a]	CS2	0.906[a]	CS2	0.915[a]	CS5	0.879[a]
CS3	0.905[a]	CS3	0.907[a]	CS3	0.891[a]	CS6	0.906[a]
CS4	0.959[a]	CS4	0.959[a]	CS5	0.887[a]	CS7	0.887[a]
CS5	0.913[a]	CS5	0.914[a]	CS6	0.918[a]	CS8	0.897[a]
CS6	0.924[a]	CS6	0.931[a]	CS7	0.896[a]	CS9	0.951[a]
CS7	0.890[a]	CS7	0.892[a]	CS8	0.907[a]	CS10	0.848[a]
CS8	0.918[a]	CS8	0.920[a]	CS9	0.953[a]	CS11	0.836[a]
CS9	0.962[a]	CS9	0.966[a]	CS10	0.860[a]	CS13	0.906[a]
CS10	0.883[a]	CS10	0.883[a]	CS11	0.848[a]	CS17	0.885[a]
CS11	0.872[a]	CS11	0.872[a]	CS13	0.918[a]	CS18	0.868[a]
CS12	0.941[a]	CS12	0.941[a]	CS17	0.862[a]	CS19	0.928[a]
CS13	0.919[a]	CS13	0.920[a]	CS18	0.878[a]		
CS14	0.936[a]	CS14	0.952[a]	CS19	0.914[a]		
CS15	0.924[a]	CS15	0.927[a]				
CS16	0.909[a]	CS16	0.912[a]				
CS17	0.894[a]	CS17	0.894[a]				
CS18	0.895[a]	CS18	0.895[a]				
CS19	0.921[a]	CS19	0.923[a]				
CS20	0.381[a]						

*(Analysis-1 and 2) MSA-before elimination of communalities: The results of the first MSA analysis of all items, CS20 items were eliminated because they did not meet the anti-image correlation criteria >0.50, (analysis-3 and 4) MSA-after elimination of communalities: The results of the second to fourth analysis (repetition of data analysis) after the communalities analysis (Table 11) (eliminated items: CS1, CS3, CS4, CS12, CS14, CS15, CS16)

3.6.3. Communalities

At this stage, eight CTS instrument statement items were eliminated because they did not meet the predetermined criteria (communalities >0.50). The eliminated items were C1 (0.446), C2 (0.457), C3 (0.398), C6 (0.489), C7 (0.364), C8 (0.498), C9 (0.469), and C24 (0.402)<0.50 as shown in Table 10. After elimination and re-testing, 21 items of the CTS instrument have met the specified criteria with the highest score on item C17 (0.735) and the lowest item C25 (0.515). Furthermore, the communalities analysis on the CS instrument statement items begins with 20 statement items and eliminates 1 CS20 statement item in the MSA analysis shows in Table 9. So that 19 statement items were continued to be analyzed (analysis-3 and 4 shows in Table 11). As a result, 12 items were declared to meet the criteria (communalities >0.50) and 7 items were stated (CS1, CS3, CS4, CS12, CS14, CS15, CS16). Item CS 11 (0.748) got the highest score and CS9 (0.511) got the lowest score. Table 10 shows the results of the communalities reference on the computational thinking skills variable.

Table 10. Communalities CTS

Communalities-before elimination						Communalities-after elimination			
Analysis-1						Analysis-2			
Code item	Extraction	Code item	Extraction	Code item	Extraction	Code item	Extraction	Code item	Extraction
C1	0.446	C11	0.672	C21	0.504	C4	0.611	C19	0.588
C2	0.457	C12	0.666	C22	0.594	C5	0.688	C20	0.641
C3	0.398	C13	0.549	C23	0.584	C10	0.667	C21	0.535
C4	0.540	C14	0.568	C24	0.402	C11	0.691	C22	0.690
C5	0.608	C15	0.619	C25	0.550	C12	0.658	C23	0.657
C6	0.489	C16	0.584	C26	0.530	C13	0.566	C25	0.515
C7	0.364	C17	0.694	C27	0.611	C14	0.571	C26	0.538
C8	0.498	C18	0.617	C28	0.621	C15	0.626	C27	0.623
C9	0.469	C19	0.556	C29	0.585	C16	0.592	C28	0.652
C10	0.681	C20	0.591			C17	0.735	C29	0.672
						C18	0.614		

*(Analysis-1) communalities-before elimination: The results of the first analysis prior to the communalities analysis and data elimination, (analysis-2 to 4) communalities-after elimination: The results of the second to fourth analysis (repetition of data analysis) after conducting communalities analysis and eliminating data that do not comply with the provisions (communalities >0.50).

3.6.4. Rotated component matrix

Figure 2 shows 21 components that have the possibility to become dimensions or factors in the ability of CTS, but of the 21 available components only six components have initial eigenvalues above 1 and can be expressed as a strong dimension in the research variables. Furthermore, the determination of the items that occupy the six dimensions is determined based by looking at the value of the highest rotated component matrix component per dimension. The first dimension with initial eigenvalues of 4.766 is occupied by item C11 "I think it is better to learn instructions made with the help of symbols and algorithm concepts" with a rotated component matrix value of 0.817. The general view of algorithmic thinkings is an ability to manage computers, but experts clearly argue that algorithmic thinkings is essentially a flow of thinking to solve problems with various systematic solutions available step by step [47]–[51]. The results of this study confirm that the strongest dimension in computational thinking ability is algorithmic thinking through item C11 where students like the way of thinking in learning to use symbols and algorithm concepts. Figure 4 and Figure 5 show the results and description of the screen plot of the two variables (computational thinking skills and CS).

The second dimension is occupied by item C17 "I like solving problems related to group projects with my friends" with initial eigenvalues of 2.879 and rotated component matrix value of 0.816. This second dimension reinforces the first dimension item where students like problem solving by collaborating with peers to find efficient solutions [49], [52], [53]. More specific research was conducted by Missiroli with the main findings in teaching students to get CTS skills, cooperative thinking skills need to be taught so that CTS is not individual and can be applied in social communities [53]–[55]. The third dimension is item C28 "I can develop my own ideas in a learning environment" with initial eigenvalues of 1.812 and a rotated component matrix value of 0.776. Confidence to produce ideas or ideas is a positive and useful thing in solving problems at hand.

The fourth dimension is item C5 "I believe that I can implement the plan that I have made to solve my problem" with initial eigenvalues of 1.413 and a rotated component matrix value of 0.788. The fifth dimension is simultaneously the items C22 "I am proud to be able to think with great precision" and C23 "I use a systematic method when comparing the choices in my hand to make a decision" with initial eigenvalues of 1.251 and a rotated component matrix value of 0.772. The sixth dimension C20 "It is fun to try to solve complex problems" initial eigenvalues are 1.009 and the rotated component matrix is 0.763. Table 11 shows the results of the communalities reference on the collaborative thinking skills variable. Table 12 describes the results of the rotated component matrix statistical test of computational thinking skills and CS.

Table 11. Communalities CS

Communalities-before elimination				Communalities-after elimination			
Analysis-1		Analysis-2		Analysis-3		Analysis-4	
Code item	Extraction	Code item	Extraction	Code item	Extraction	Code item	Extraction
CS1	0.586	CS1	0.743	CS1	0.465	CS2	0.617
CS2	0.619	CS2	0.607	CS2	0.591	CS5	0.547
CS3	0.362	CS3	0.616	CS3	0.403	CS6	0.611
CS4	0.499	CS4	0.487	CS5	0.574	CS7	0.632
CS5	0.535	CS5	0.552	CS6	0.562	CS8	0.657
CS6	0.608	CS6	0.592	CS7	0.614	CS9	0.511
CS7	0.681	CS7	0.679	CS8	0.637	CS10	0.673
CS8	0.602	CS8	0.597	CS9	0.517	CS11	0.748
CS9	0.511	CS9	0.515	CS10	0.678	CS13	0.538
CS10	0.593	CS10	0.621	CS11	0.740	CS17	0.723
CS11	0.684	CS11	0.717	CS13	0.532	CS18	0.681
CS12	0.481	CS12	0.475	CS17	0.699	CS19	0.637
CS13	0.546	CS13	0.546	CS18	0.568		
CS14	0.505	CS14	0.462	CS19	0.525		
CS15	0.453	CS15	0.455				
CS16	0.463	CS16	0.465				
CS17	0.659	CS17	0.671				
CS18	0.586	CS18	0.602				
CS19	0.572	CS19	0.615				
CS20	0.655						

*(Analysis-1 and 2) communalities-before elimination: The results of the first analysis (MSA) prior to the communalities analysis and data elimination, (analysis-3 to 4) communalities-after elimination: The results of the second to fourth analysis (repetition of data analysis) after conducting Communalities analysis and eliminating data that do not comply with the provisions (communalities >0.50).

Table 12. Rotated component matrix CTS and CS

Code item		Factor 1	Code item	Factor 2	Code Item	Factor 3	Code item	Factor 4	Code item	Factor 5	Code item	Factor 6
CTS	C11	0.817	C17	0.816	C28	0.776	C5	0.788	C22	0.772	C20	0.763
	C10	0.792	C15	0.773	C29	0.729	C4	0.744	C23	0.772	C19	0.708
	C12	0.783	C18	0.758	C27	0.728	C25	0.615	C21	0.514		
	C13	0.687	C16	0.749	C26	0.675						
	C14	0.664										
CS	CS17	0.807	CS11	0.805	CS2	0.768						
	CS18	0.785	CS10	0.712	CS8	0.690						
	CS19	0.683	CS7	0.701	CS5	0.566						
	CS13	0.607	CS6	0.602								
			CS9	0.530								

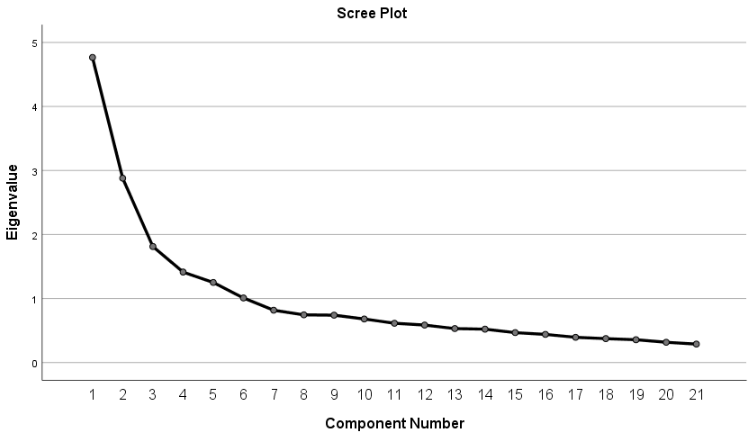

Figure 4. Scree plot CTS

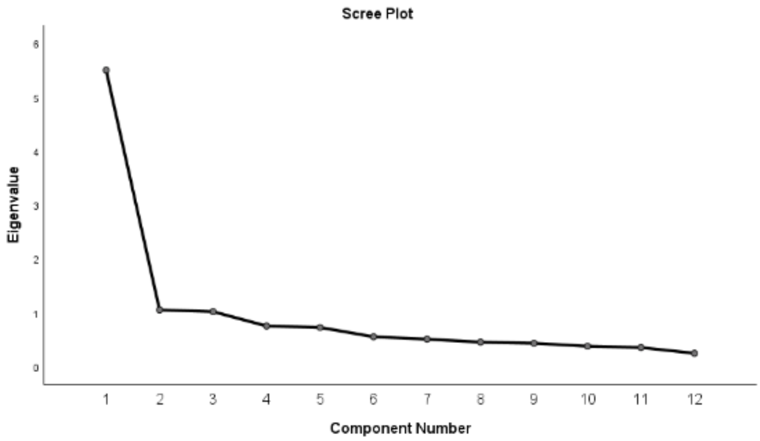

Figure 5. Scree plot CS

Furthermore, each statement item with a loading factor >0.40 [35] will be grouped into one dimension or factor, then the dimension or factor will be named according to the characteristics of the statement item in Table 13. Figure 5 shows 12 components that have the opportunity as dimensions or factors in CS ability, of these 12 components 3 components have initial eigenvalues above 1 as a strong dimension. Based on the rotated component matrix (Table 11) item CS17 “I share information with colleagues for the progress of work progress” with initial eigenvalues of 5.005 and rotated component matrix of 0.807 in the first order of component 1, item CS11 “I think it is better in learning the instructions that made with the help of symbols and algorithm concepts” with initial eigenvalues of 1.053 and a rotated component matrix of 0.805 in the first order of component 2, and the CS 2 item “I actively contribute when attending a meeting” with initial eigenvalues of 1.022 and a rotated component matrix of 0.768 in the first order of component 3.

Furthermore, each statement item with a loading factor >0.40 [35] will be grouped into one dimension or factor then the dimension or factor will be given a name according to the characteristics of the statement item in Table 14. We believe that the six indicators in Table 13 and the three indicators in Table 14 are strong dimensions or factors to measure the CTS and CS of undergraduate student in Indonesia.

Table 13. Indicators and CTS instrument items

Statement item code	Indicator
C10, C11, C12, C13, C14	Algorithmic thinking
C15, C16, C17, C18	Cooperative thinking
C26, C27, C28, C29	Problem reformulation
C4, C5, C25	Creativity
C21, C22, C23	Critical thinking
C19, C20	Systematic testing

Table 14. Indicators and CS instrument items

Statement item code	Indicator
CS13, CS17, CS18, CS19	Sharing knowledge
CS6, CS7, CS9, CS10, CS11	Planning
CS2, CS5, CS8	Responsibility

4. DISCUSSION

The results of this study indicate that the self-assessment instrument has high quality reliability and validity to assess the CTS and CS of undergraduate students in Indonesia. The CTS instrument assesses six dimensions including algorithmic thinking, cooperative thinking, problem reformulation, creativity, critical thinking, and systematic testing. Algorithmic thinking dimension is the ability to understand, apply, evaluate and think systematically (steps done sequentially) [40], [41], [56], in solving problems with explicit instructions where the starting and ending points have been determined and solving problems at each point [40]. The findings on this dimension (algorithmic thinking is formed from six statement items: C10, C11, C12, C13, C14 which are inseparable) support several experts [41], [49], [57], [58] which states that algorithmic thinking is the most important component in CTS. The dimension of cooperative thinking is the result of thinking from cooperative learning methods where students are required to be able to help each other in the "social context" of other individuals in their group [59]. Cooperative thinking is a process of describing, recognizing, describing problems and solving them computationally in teams in a socially sustainable way [53]. Often, we find problems that are so big to be solved by individuals, we need a way to break down the problem into sub-problems so that each individual can solve it [40]. This dimension is in line with thinking [41], [53] which reveals the components in the CTS measurement, which tends to be in the context of identifying a problem and making use of patterns in the group [60]. The problem reformulation dimension represents the components of the CTS where the component (problem reformulation) indicates the process of framing the problem based on alternative solutions to be solved [11]. Indirectly, this dimension can be interpreted as a "bank" of alternative solutions to various problems faced and able to choose alternative solutions that are effective and efficient to overcome problems. The dimension of creativity is the process of self-expression using thoughts and inspiration (imagination) [42]. In the context of CTS, creativity is a component to find out the novelty and imagination of students in finding solutions using computer assistance [61]. The critical thinking dimension is a high-level ability in the overall attitude, information and process skills used in justifying and assessing the status of the problem according to a scale of scientific, cultural and social standards in terms of consistency and validity.

This dimension is a component in CTS because every decision making by considering various methods can be called critical thinking [11], [41]. The systematic testing dimension is the ability to solve complex problems with a systematic pattern through processing the information obtained. The systematic pattern in question is the ability to think to do tasks according to the right, effective and efficient sequence, stages, steps, or planning. Furthermore, instrument CS assesses three dimensions including knowledge sharing, planning, and responsibility. Knowledge sharing is a process in which the distribution of information between the source and the recipient [62]. In CS getting and sharing knowledge is the most important dimension to achieve the common goals that have been planned in a team [18], [45], [46]. In addition to sharing knowledge, the next dimension is planning, where this dimension reflects the ability to plan steps that can be taken to achieve team goals and problems or possibilities that will occur [18], [63]. The last dimension that is formed is responsibility, where responsibility is a dimension that reflects individuals in the team can carry out planning well by being directly involved in implementing activities, monitoring and evaluating team activities.

5. CONCLUSION

In conclusion, the self-assessment instruments designed to measure CTS and CS among undergraduate students in Indonesia have undergone a rigorous validation process, confirming their validity and reliability. This process involved expert validation, product moment validity, Cronbach's alpha, and EFA. The results of expert validation demonstrated that the statement indicators for both CTS and CS instruments received high scores, affirming the clarity and effectiveness of the language used. Additionally, the validity and reliability analyses provided further evidence of the instrument's validity and reliability. Notably, specific statement items were identified as having the highest validity values for CTS and CS, indicating their importance in assessing these skills. These findings support the instruments' ability to measure the targeted competencies accurately. Furthermore, the EFA, employing PCA and varimax rotation, helped refine the instruments by eliminating statement items that did not meet predetermined criteria for commonalities. This process resulted in the developing of concise and focused self-assessment instruments for CTS and CS.

The final instruments, consisting of 21 statement items for CTS and 12 statement items for CS, encompass six dimensions for CTS (algorithmic thinking, cooperative thinking, problem reformulation, creativity, critical thinking, and systematic testing) and three dimensions for CS (knowledge sharing, planning, and responsibility). These dimensions are reliable indicators for evaluating undergraduate students' CTS and CS skills in Indonesia. This study's findings strongly support validating the CTS and CS self-assessment instruments tailored for Indonesian undergraduate students. We recommend the widespread use of these instruments for self-assessment, learning evaluation, and research related to CTS and CS themes among undergraduate students in Indonesia. However, it is essential to acknowledge the study's limitations, mainly its focus on instrument development within the Indonesian context. We encourage other countries to adapt and develop similar instruments, considering their respective student populations' unique characteristics and needs. Ultimately, the availability of validated self-assessment tools for CTS and CS will enhance educational and research efforts in these crucial domains.

This research can be used in further research developments. Topics suitable for further development are CTS and CS. Research on this topic was carried out using instruments that have been validated in this study. Experimental research and research in the field is one of the main recommendations in developing the results of this research to prove the validity of empirical research testing and measurement.

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