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Research Article

Questionnaire Design and Validation to Measure the Effectiveness of the Outcome-Based Teaching-Learning Process

Jyotiprava Mohanta[1] ✉, **Shyamal Kumar Das Mandal**[1]

[1]Advanced Technology and Developed Centre, Indian Institute of Technology, Kharagpur, India

Abstract
In outcome-based education, the learners know what is expected of them after the course completion. The learners here are responsible for their learning process, which increases their active learning, self-learning, collaborative learning, higher-order skills, and, in turn, life-long learning skills. This paper is designed to develop a questionnaire that measures domain-dependent and domain-independent skills like self-learning, active and collaborative learning, higher-order thinking, and the learners' satisfaction and continuous updating of the curriculum for the proposed outcome-based teaching-learning process. It also serves as a template for the steps needed to design and validate a questionnaire. During the design of the questionnaire, the content validity was established by five experts, and the CVI value of the items considered was ≥ 0.80. After designing the questionnaire, the proposed methodology was implemented and validated on the undergraduate BTech learners of "Seemanta Engineering College" as a pilot study. The preliminary and factor analysis results were applied to 220 learners, and the results were significant. The confirmatory results (RMSEA = 0.049, CFI = 0.963, TLI = 0.957, and SRMR = 0.036), considering 436 learners, also validate that the designed questionnaire is reliable and valid to measure the effectiveness of the teaching-learning process. This paper will guide the researcher step by step to design and validate the questionnaire, thus improving the quality of research.

Keywords: Active Learning, Collaborative Learning, Confirmatory Factor Analysis, Exploratory Factor Analysis, Higher-Order Thinking, Questionnaire Design, Satisfaction

✉ Correspondence
Jyotiprava Mohanta
jyotiprava@iitkgp.ac.in

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1. INTRODUCTION

In the 21st century, learners should acquire skills like problem-solving, collaboration, Creativity, Communication, Critical thinking, and lifelong learning for sustainable development (UNESCO, 2018). The industries and job profiles keep changing with some new development. The traditional teacher-centric approach made the learners unable to learn over time. So, to have a lifelong career, they should be able to learn lifelong (Aleandri & Refrigeri, 2013; Silber-Varod et al., 2019). The 21st-century education system needs to be modified so that learners are regularly equipped with new skills. The teaching methodology should be learner-centric rather than teacher-centric. Learner-centric teaching (LCT) is teaching where the learners learn and take part in the teaching-learning process as their responsibility. This can increase learner/student attendance and reduce the dropout rate. When learners follow LCT, they become active learners. The role of a teacher is only to define the goal, provide the path, test whether the student reaches the goal, or not and ultimately guide the student to reach the goal. This process increases the student's learning ability and skills needed to compete globally. The most common LCTs are flipped teaching, game-based learning, project-based learning, scientific argumentation, blended learning, and outcome-based teaching. Flipped teaching enhances student engagement and active and collaborative learning. This way of teaching-learning is more effective than traditional teaching (Divjak et al., 2022; Tomas et al., 2019). This LCT has demerits: often, the learners do not do the pre-classroom task because they are unaware of what to do. A systematically designed content with instructional objectives, materials with some activities should

be provided for the success of flip teaching (Yelamarthi & Drake, 2015; Zarrinfard et al., 2021). The problem-based and project-based learning are instructional learner-centric approach which promotes critical thinking, problem-solving capacity, and interdisciplinary learning. The limitation of this LCT is that there should be additional instructions on how to conduct the learning process. Again, it is not easy to evaluate the learner individually. The learners also find it difficult to complete the task in the given time frame. Again, not all the learners in the group contribute uniformly to the given task. A properly designed curriculum can help the instructor guide the learner effectively (Castaldi et al., 2019; Oliveira & Cardoso, 2021). Another LCT approach that has been in the limelight in these two decades is game-based learning (GBL). GBL increases engagement and decreases dropout (Zhao et al., 2022). GBL provides active learning, and when it is played with peers, it encourages collaborative learning, thinking ability, and decision-making capacities (Dassanayake et al., 2020; Krouska et al., 2022). The GBL should be well-designed, centring the learning outcomes, with lots of challenges, creativity, and competence to make the learner engaged (Zhao et al., 2022). Learners enjoyed GBL, but still, the maximum number could not answer questions related to the GBL, making it more like playing without learning (Coleman & Money, 2020; Mendonca et al., 2020). The instructor needs sufficient time to understand the requirements of the course and accordingly design the game, and then various tests need to be performed to check the designed game (Tsai et al., 2022). Scientific argumentation (SA) is another LCT where learners use scientific concepts and explanations for their claims on real-world phenomena or problems. SA starts with a claim, where learners project ample questions, evidence, and arguments to prove their claims. Instructors act as mediators, providing the environment to support SA. Communication skills, critical analysis, and higher-order thinking are developed in this process (Cinici, 2016). SA, when done in groups, increases collaborative learning. It is challenging for the instructor to use SA in every science course, and they need to have thorough knowledge of the subject of argumentation. SA works well with scientific theories (Cinici, 2016; Governor et al., 2021; Lobczowski et al., 2020). Outcome-based education (OBE) is another learner-centric approach where the outcomes of the program/course are transparent, and the learners are informed beforehand about what they need to acquire upon completion of the program. Instructors also know what they need to cover in the classroom. It can enhance problem-solving capabilities, communication skills, lifelong learning ability, self-learning, and collaborative learning, and also address various learning styles. There are both domain-dependent and domain-independent outcomes, but assessment for all the outcomes defined is not done (Dai et al., 2017; Kulkarni et al., 2016; Rao, 2020; Zeynal et al., 2017). OBE does not make the learner engaged throughout the course/program work. Many times, blended learning (BL) is preferred instead of one type of learner-centric approach. Blended learning is an effective combination of different learner-centric approaches, like traditional teaching and online learning. BL is used to deal with the drawbacks of different LCTs (Li et al., 2015). BL can increase engagement, collaborative learning, pass rates, and student performance. BL can be used along with a learning management system (LMS) (Goh & Yang, 2021). Sometimes, blending the course becomes too tedious for both learners and instructors, and due to this, the learners prefer the old teacher-centric approach (A. Singh et al., 2019; Wei et al., 2019). So, a learner-centric approach needs to be modified to ensure learners' engagement throughout the coursework, and again, they need to acquire both domain-dependent and independent skills too. The proposed LCT should also be applicable in a large classroom.

The proposed teaching-methodology process (TLP) is a methodology where a well-designed curriculum for the course outlines the course overview, and related objectives/outcomes, and a matching problem set is provided to the learners before the class. Then, to ensure that everyone possesses general skills and attitudes, flip teaching and learning approaches were adopted. The proposed methodology states to increase student engagement and self-learning so that students can follow their own pace within certain parameters, and that individual learning preferences are generally accommodated. The TLP states that to develop the attitudes and skills necessary for the twenty-first century, UG engineering students must assume much more responsibility for their studies than is now the case. Along with higher-order thinking abilities and subject-specific knowledge, learning how to learn, communicating effectively, and cooperating in groups are crucial learning outcomes. Again, the teaching and learning methodology can be applied in a large classroom. In this Teaching-learning methodology, we are measuring the quantitative data collected through a questionnaire. The quantitative data method is here as the TLP is deductive. Here we start with the assumption that this TLP can provide the attitude, skills, and knowledge that are needed in the 21st century.

This paper describes the design and quantitative validation of the questionnaire to measure the effectiveness of the outcome-based learner-centric teaching-learning process. The effectiveness of this TLP is measured by measuring the students' self-learning, active and collaborative learning, higher-order thinking ability, and satisfaction. There is another parameter known as "continuous Updation promotion" which addresses the designed curriculum and how much further modification is needed. So, a total of five-parameter questionnaire is designed, and the details for each parameter are explained below. The number of items was kept to keep minimal.

2. DESIGNING OF QUESTIONNAIRE

To develop a solution for the given research statement, a methodology is selected, and then data is collected. Quantitative research quantifies the data collected and analyzes it. The data can be collected either as quantitative or qualitative data. When the number of data is in the hundreds and above, we go for quantitative data. For qualitative, we go for very little data. Quantitative data is used to deduce an intervention, and qualitative analysis is done to find the cause or reason for the result. Qualitative data is used to study human behaviour. Quantitative data are analysed rigorously using statistical tools. Quantitative analysis uses statistical tools to quantify the observations. It also helps to find the relationship between the variables. This research tests the existing theories and finds the conditions under which theories can be applied, so quantitative data is used (Stockemer, 2019). Quantitative research is mostly questionnaire-based, deductive, and theory-driven.

Data is collected to test the hypothesis. The data can be nominal, dichotomous, or ordinal, measured in a quasi-continuous scale or continuous, which can take any value (Mertens et al., 2017). The data can be collected by (a) Observation, where the investigator observes the scenario, which is an expensive method even if the information found is limited and does not depend on past or future data (b)Personal interview, where the researcher asks a set of question personally to the individuals, this is not suitable for extensive data (c) telephonic interview when the survey is done in limited time (d) Questionnaire provided to respondents through the mail, Google form or printout which has to be collected after filled up by respondents. It is most extensively used (e) schedules, which depend on the enumerator's capability (Kothari, 2004). The questionnaire is either open-ended, where the respondent can freely express their opinion, or closed-ended, where the respondent needs to choose one or more from the available choices. A Likert scale of 5-point or 7-point is commonly used. The research design starts with a question, then the intervention is done, and data is collected to answer the research question. Generally, to test the intervention, quantitative methods are used. The survey method, done by designing a questionnaire from an existing validated survey, is a better option. The survey method has many benefits, such as large population coverage in less time, unbiased responses, low cost, and user convenience. When no existing survey questionnaire is designed, it is necessary to self-design and validate it to ensure that it can record the intended information (Fonseca et al., 2013; Mat Roni et al., 2020; Elangovan & Sundaravel, 2021). A questionnaire should be well-designed to gather the required information. The question sequence should be precise and straightforward, not give rise to any misunderstanding, and convey one thought at a time. The questionnaire should be able to generate accurate information with no bias (Haukås et al., 2021). After the questionnaire is formed, the content analysis is done, where the experts evaluate each item. Content validity is the process that justifies the items used in the questionnaire for measuring the construct. The experts assess each item with the definition of each construct, whether it is trivial or non-trivial, or whether the item needs some modification to become trivial. For content validity, a group of experts evaluates the questionnaire; the number of experts is in the range of 3 to 10. With the increase in the number of experts, the agreement chance decreases, so the upper range is considered as 10 (Almanasreh et al., 2019). The Content Validity Index (CVI) is calculated by the number of experts who agreed on the item divided by the total number of experts; a value ≥ 0.80 is fair (Elangovan & Sundaravel, 2021a).

The questionnaire should be pilot tested, and the poor questions should be modified. To determine the factors of the questionnaire, exploratory analysis is done. To examine the construct validity, the item-scale correlation matrix is used. Cronbach's alpha determines the reliability, and the intra-class correlation coefficient examines the stability of the questionnaire (Artino et al., 2014; Kazemi et al., 2020). Figure 1 shows the steps followed to design and validate the questionnaire.

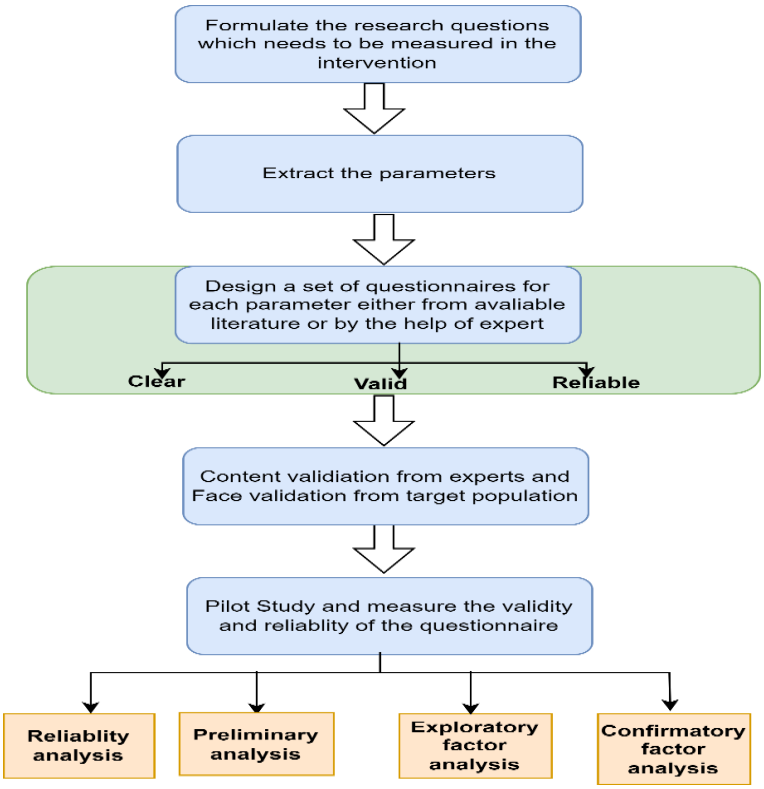

Figure 1. Steps to Design and Validate the Questionnaire

2.1. Defining the Parameter

The questionnaire is designed keeping in mind what to measure from the TLP. The following parameters were considered to measure the domain-independent skills of the learner acquired in this process.

2.1.1. Self-Learning and Engagement

The industries and job profiles keep changing from time to time with some new development. The traditional teacher-centric approach made the learner unable to learn by his/herself. Without self-learning ability, the individual may not be employable after a specific time. So, to have a lifelong career, he/she should be able to learn lifelong. Self-directed learning or self-learning is the skill needed for lifelong learning. A lifelong learning attitude is a must for 21st-century learners, as new technology is developed. A self-learning attitude means the learner understands learning is self-responsible, the learner should be involved in solving problems, and have studying skills (Ayyildiz & Tarhan, 2015; Tekkol & Demirel, 2018). Self-learners possess more willingness to achieve the learning outcomes. Based on the definition of self-learning and literature (Carini et al., 2006; Geng et al., 2019; NSSE 2017 Engagement Indicators, 2017; Yazzie-Mintz Ethan, 2012), a four-item measurable scale was developed to measure self-learning attitude and engagement. There were four questionnaires to measure self-learning and student engagement. Almost all experts agreed that all the questionnaires are important, so all the questionnaires, with little modification as suggested by them, were done.

2.1.2. Active and Collaborative Learning

Active and collaborative learning is another important skill a learner should have in the 21st century. The active and collaborative learner learns from the environment or by discussing with peers. Drini (Drini, 2018) has designed 11 questions to measure this parameter, out of which five questions appear to be more relevant. NSSE (Carini et al., 2006; NSSE 2017 Engagement Indicators, 2017) contains four items to

measure collaborative learning, which were modified and used here to measure this parameter. We have studied both the questionnaire and formulated seven items, which were clear and simple to understand.

Here, the experts agreed that all seven questionnaires are important, but should be presented in simplified form, so all the questionnaires were kept with some modifications.

2.1.3. Higher-Order Thinking

Learners should have the skills of higher-order thinking, where they can reason and relate the cause of a given problem and state and justify a solution for the given problem. NSSE (NSSE 2017 Engagement Indicators, 2017) has four items related to it. Here, the four items are modified and used in the given teaching-learning frame. This questionnaire is related to (a) solving ability, (b) analyzing ability, (c) evolution ability, and (d) synthesis ability, which are higher-order cognitive abilities. For the higher-order thinking parameter, most of the experts suggested modifying the questionnaire into a simpler form so that it would be easier to understand, and they also agreed that all the questionnaires are important to measure this parameter.

2.1.4. Satisfaction

Douglas et. al. designed sixty test items to measure student satisfaction and found that the most important items were related to the teaching-learning process (Douglas et al., 2006). Here, in these findings, we are concerned with the teaching-learning process. NSSE has two items related to satisfaction (NSSE 2017 Engagement Indicators, 2017). The questionnaire design contains five items in this parameter; two items are from NSSE, and three items were designed with reference to (Douglas et al., 2006). For parameter satisfaction, the experts felt that the second and fifth questionnaires are similar, so one of the two questionnaires is omitted and eliminated, and the rest 4 are considered with little modification.

2.1.5. Continuous Updating and Promotion

Three questionnaires were self-designed to continue updating the designed curriculum and modify the reference materials. There should be a feedback loop so that the curriculum gets continuously updated. The updating may be done by adding more reference materials, practice problem sets, etc.

2.2. Content and face validation

After deciding the parameters and items related to each parameter, content and face validation are done, that is, qualitative validation for the prepared questionnaire. This is the first step to check whether the questionnaire can measure the intended parameter. In content and face validation, the logic between the items and the objectives is checked. This process is a qualitative method where the opinions of different people may be different or may be the same (Camelia & Ferris, 2018). This method of validation is a very essential step to avoid a mismatch between the communication of the requirement and the received feedback, and unnecessary items (Wijnen et al., 2021).

2.2.1. Content Validity

Content validity is a qualitative validation process conducted by experts in a specific domain. The content validity index (CVI) is the measurement process that states the ratio of the number of experts who agree on the item divided by the total number of experts (Elangovan & Sundaravel, 2021a). The formulated questionnaire was given to five experts in this domain. Their response is represented in tabular form. Table 1 shows their response.

2.2.2. Face Validity

After completing the content validity and finalising the final draft of the questionnaire, the questionnaire was given to 27 first-year Undergraduate BTech learners for face validation. They have carefully reviewed each item and expressed their understanding of the given items. Most of them could easily comprehend what was asked in the given questionnaire. There was a bit of confusion in two questionnaires, which were later modified and again given back for further suggestions. All participants could easily understand what the items were asking. Table 2 represents the questionnaire along with its corresponding parameter after the modification is done. It is assumed that each statement has equal attitudinal value and importance.

Table 1. Expert's Response to Parameters

	Questionnaire	Expert1	Expert2	Expert3	Expert4	Expert5	No.of Agreement	I-CVI
Self-Learning and Engagement								
1	Q1	E	NE	E	E	E	4	0.80
2	Q2	E	E	E	M2	E	5	1
3	Q3	NE	E	M2	M2	E	4	0.80
4	Q4	E	E	E	M2	E	5	1
Active and Collaborative Learning								
1	Q1	E	NE	E	E	E	4	0.80
2	Q2	E	E	E	M2	E	5	1
3	Q3	E	E	E	M2	E	5	1
4	Q4	E	E	E	M2	E	5	1
5	Q5	E	E	E	M2	E	5	1
6	Q6	NE	M2	E	E	E	4	0.80
7	Q7	NE	E	M2	M2	E	4	0.80
Higher-Order Thinking								
1	Q1	M2	E	E	E	E	5	1
2	Q2	E	E	E	E	E	5	1
3	Q3	M2	NE	E	M2	E	4	0.80
4	Q4	M2	E	E	M2	E	5	1
Satisfaction								
1	Q1	M2	E	E	E	E	5	1
2	Q2	E	E	E	M2	E	5	1
3	Q3	E	E	E	M2	E	5	1
4	Q4	E	NE	E	M2	E	4	0.80
5	Q5	E	NE	E	M1	M1	2	0.40
Continuous Updating and Promotion								
1	Q1	E	E	E	E	E	5	1
2	Q2	M2	E	E	E	E	5	1
3	Q3	M2	E	E	E	E	5	1

Note: NE is non-essential and is valued as 1, M1 is Modify Major and is valued as = 2, M2 is Modify Minor and is valued as= 3, and E is Essential and is valued as= 4. The index of CVI = total number of scores '3' or '4' divided by the total number of experts, I-CVI ≥0.80 is accepted (Elangovan & Sundaravel, 2021a).

3. DATA COLLECTION AND INTERVENTION

3.1. Intervention

An outcome-based curriculum for the courses Basic Electronics Engineering, Basic Civil Engineering, and Electromagnetic Theory was prepared using the open web-based framework. The curriculum may be designed at the institute level, starting with defining the mission, vision, and PEOs, and then designing the course. The instructor can also individually design the course. The course is divided into four parts: course overview, course-level outcomes, course-level practice problems, and course modules (Mohanta & Mandal, 2019; Ray, 2013). The outcomes are stated, and the practice-level problems are attached to each outcome, and both fall in the same cognitive level. The reference materials are also attached so that the learner can learn on their own, in their own space. They were provided with these designed curricula at least a week before the actual class started, and they are instructed to come prepared for the

class. The practice problem helped them to assess their learning. For face-to-face classes, the instructor summarises the topic to be covered in the first 10-15 minutes. The rest time is used for discussing the topic and clearing doubts. The learners were encouraged to clear each other's doubts, and when they could not, the instructor cleared them. For online classes, the platform used was Google/Zoom.

At the end of the course, the questionnaire was given to learners as a printout for face-to-face classes and a Google Form for online classes. The filled forms without any missing data were only considered. It took about 2- 3 minutes to fill out the given form. There were 220 (greater than 200) participants for preliminary and exploratory analysis, and 436 (greater than 300) participants for confirmatory analysis, so the number is good for analysis (K. Singh et al., 2016).

Table 2. The Tabular Form of Items and Parameters

No	Item	Parameter
1	After reading the lecture materials, how many classes have you attended?	Self-learning and engagement
2	After reading the lecture materials, how many of the problems in the proposed curriculum were you able to solve by yourself?	Self-learning and engagement
3	Does the proposed course emphasize spending significant time studying and doing academic work?	Self-learning and engagement
4	Does this method of learning make you more engaged or understand the subject better?	Self-learning and engagement
5	How often have you asked questions in class or participated in class discussions?	Active and collaborative learning
6	How often did you discuss with your friends to solve the problem given in the course/subject?	Active and collaborative learning
7	How often have you worked with other students to complete the given assignment?	Active and collaborative learning
8	How many times have you worked with your classmates outside of class to complete the given assignment?	Active and collaborative learning
9	How often have you tutored or taught other students during this course/subject learning?	Active and collaborative learning
10	How often have you referred to electronic mediums (Google, chats, blogs, open courses, etc.) to complete your given assignment?	Active and collaborative learning
11	How many course-level problems have you solved by yourself?	Active and collaborative learning
12	How often have you solved problems using the theory of your course?	Higher-order thinking
13	How often have you analysed a problem?	Higher-order thinking
14	Do the assignment problems relate to design and synthesis?	Higher-order thinking
15	Have you been familiar with any design tools/ software related to your course/subject?	Higher-order thinking
16	Is this way of teaching effective in clearing your doubts?	Satisfaction
17	How would you rate this course/subject in terms of your overall educational experience?	Satisfaction
18	How do you rate your skill as desired from the subject?	Satisfaction
19	If you could start over again, would you go for the same method of learning?	Satisfaction
20	How well does the course provide reference materials for achieving the intended outcomes?	Continuous Updation and promotion
21	Do the reference materials provided in the course cover your learning strategy and learning approaches?	Continuous Updation and promotion
22	Does the curriculum include relevant reference materials in the context of the current requirement?	Continuous Updation and promotion

3.2. Dataset

A study is conducted to assess the effectiveness of the intervention, which helps identify the drawbacks of the research method and make necessary modifications accordingly. The pilot study is related to the primary research context and applied to a similar demographic. A valid questionnaire can help us collect reliable information (Aljandali, 2016).

The participants were undergraduate BTech learners of "Seemanta Engineering College" affiliated with Biju Patnaik University of Technology, Odisha, India, enrolled in the course Basic Electronics Engineering (RBL1B002/RBL2B002) and Basic Civil Engineering (RBC1B002/RBC2B002) during the first year odd semester in the year 2019 and even semester 2020. For Basic Electronics Engineering, odd semester 60 took part out of which 9 were female, and for even semester 52 learners participated out of which 15 were female. For Basic Civil Engineering during the odd semester, 53 participated, 16 were female, and in the even semester, 55 participated, out of which 9 were female. The Participants considered here were in the age group of 17 years to 21 years and completed the questionnaire with no missing data. For the odd semester, the class was a face-to-face class, but for the even semester, half of the class was in online mode during the COVID-19 pandemic. These Data were used for preliminary analysis and exploratory factor analysis.

Due to the pandemic, the research could not continue for the year 2020-2021. Again, the research was applied during the academic year 2021-2022 to the first-semester, second-semester, and fourth-semester undergraduate learners of the same institution. In the first semester, there were 56 learners (female-5) for the course Basic Electronics Engineering (RBL1B002) and Basic Civil Engineering (RBC1B002) there were 137 learners (female-26). For the second semester, in Basic Electronics Engineering (RBL2B002), 129 learners participated, 27 female, and in Basic Civil Engineering (RBC2B002), 52 learners participated, out of which 6 were female. There were 58 learners (female-10) for the course electromagnetic Theory (REE4D001/REL4D001/REC4C001). First and second-semester learners were in the range of 17-22 years, and for the fourth semester, they were in the range of 18-23 years. For the first semester of 2021, the classes were mostly synchronous online classes, but they appeared for offline examination. The questionnaire, which was filled out without any missing data, was only considered. The data collected in this phase were used for confirmatory analysis. All the courses Basic Electronics Engineering (RBL1B002/RBL2B002), Basic Civil Engineering (RBC1B002/RBC2B002), and Electromagnetic Theory (REE4D001/REL4D001/REC4C001) were conducted three hours/week, and the semester ran about 10 weeks per semester.

Table 3. The Preliminary Data Analysis Results

	N	Mean	Std. Deviation	Skewness		Kurtosis		Corrected Item-Total Correlation
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error	
SL01	220	3.57	1.034	-0.660	0.164	-0.096	0.327	0.555
SL02	220	3.00	1.034	-0.375	0.164	-0.846	0.327	0.635
SL03	220	3.04	1.004	-0.301	0.164	-0.870	0.327	0.594
SL04	220	3.43	1.034	0.084	0.164	-1.040	0.327	0.560
ACL01	220	2.61	1.016	0.649	0.164	0.250	0.327	0.611
ACL02	220	2.75	1.031	0.533	0.164	-0.609	0.327	0.636
ACL03	220	2.87	1.226	0.179	0.164	-0.872	0.327	0.649
ACL04	220	2.69	1.129	0.315	0.164	-0.533	0.327	0.551
ACL05	220	2.67	1.008	0.181	0.164	-0.326	0.327	0.628
ACL06	220	2.42	1.001	0.186	0.164	-0.794	0.327	0.617
ACL07	220	2.47	1.049	0.529	0.164	-0.191	0.327	0.562
HOT01	220	3.21	1.001	-0.385	0.164	-0.901	0.327	0.440
HOT02	220	3.24	1.015	-0.039	0.164	-0.646	0.327	0.458
HOT03	220	3.32	1.002	-0.040	0.164	-0.536	0.327	0.437
HOT04	220	3.25	1.014	-0.015	0.164	-0.908	0.327	0.303
SAT01	220	3.87	1.018	-0.622	0.164	-0.372	0.327	0.533
SAT02	220	3.55	1.099	-0.169	0.164	-0.982	0.327	0.525
SAT03	220	3.63	1.071	-0.313	0.164	-0.807	0.327	0.588
SAT04	220	3.86	1.055	-0.571	0.164	-0.600	0.327	0.517
CUP01	220	3.39	1.115	-0.270	0.164	-0.775	0.327	0.600
CUP02	220	3.39	1.065	0.014	0.164	-0.913	0.327	0.606
CUP03	220	3.53	1.079	-0.379	0.164	-0.477	0.327	0.618
Valid N (listwise)	220							

The data collected were closed-end quantitative ordinal data (5-point Likert scale). The learners were asked to rate their feedback for different statements ranging from strongly disagree to strongly agree. For preliminary and exploratory analysis, SPSS22 was used, and for confirmatory analysis, RStudio version 4.2.2. was used. The validity and reliability of the questionnaire are then checked. Validity ensures that the set of questionnaires designed to measure the effectiveness of the methodology measures or not. Similarly, reliability checks the consistency of measures.

4. RESULT ANALYSIS

4.1. Preliminary Data Analysis

Preliminary data analysis is done to decide which items need to be eliminated. Means, standard deviation, skewness, kurtosis, and item-total correlation are analysed as preliminary data analysis. Table 3 shows the result of preliminary data analysis, the mean is between 2.47and 3.87, the standard deviation of all items is greater than 1.00, the skewness is less than 3, and the kurtosis <7, and the item-total correlation is greater than 0.3, so they are in an acceptable range (K. Singh et al., 2016).

4.2. Exploratory Analysis

Exploratory factor analysis is done to assess construct validity, and it defines the underlying structure between the items in a questionnaire. Bartlett's test of sphericity tested the overall significance of all correlations within a correlation matrix. It states the sufficiency of correlation among some or all items. The KMO value is 0.894 (>0.8), and Bartlett's Test of Sphericity ($\chi 2 = 3352.919$). Table 4 shows the KMO and Barlett's test for the pilot study (K. Singh et al., 2016).

Table 4. The KMO and Barlett's Test for the Pilot Study

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.894
Bartlett's Test of Sphericity	Approx. Chi-Square	3352.919
	df	231
	Sig.	.000

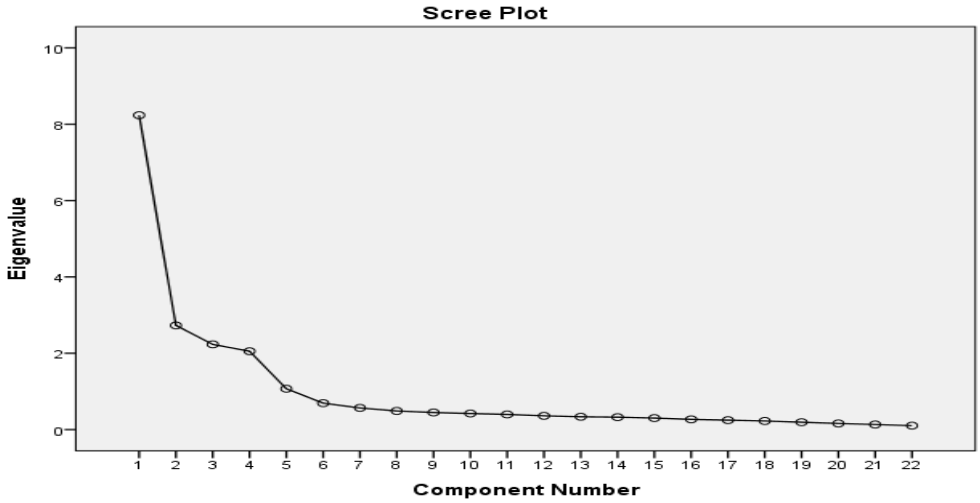

Figure 2. The Scree Plot

Communality for each item is greater than 0.4. The scree plot shows how many parameters will be extracted from factor analysis. Figure 2 shows the Scree plot. The latent roots are plotted against the number of factors to derive the scree test, and the cutoff point is calculated by the shape of the resulting curve.

The items having communalities greater than 0.50 are considered. Figure 2 shows the communalities greater than 0.50. Table 5 shows the Communalities extraction value for all items. Table 6 explains the total variance, suggesting five parameters from the designed questionnaire.

The correlation between each variable and the factor is known as factor loading. The higher the loading of a variable on a factor, the more representative the variable is of the given factor. Here, the variable having an eigenvalue > 1 is extracted.

Table 5. Communalities Extraction Value for All Items

Communalities		
	Initial	Extraction
SL01	1.000	.804
SL02	1.000	.895
SL03	1.000	.869
SL04	1.000	.674
ACL01	1.000	.557
ACL02	1.000	.666
ACL03	1.000	.731
ACL04	1.000	.734
ACL05	1.000	.739
ACL06	1.000	.752
ACL07	1.000	.599
HOT01	1.000	.811
HOT02	1.000	.813
HOT03	1.000	.712
HOT04	1.000	.784
SAT01	1.000	.731
SAT02	1.000	.602
SAT03	1.000	.637
SAT04	1.000	.684
CUP01	1.000	.821
CUP02	1.000	.856
CUP03	1.000	.850
Extraction Method: Principal Component Analysis.		

Table 6. The Total Variance Suggests Five Parameters from the Designed Questionnaire

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.235	37.431	37.431	8.235	37.431	37.431	4.626	21.030	21.030
2	2.729	12.405	49.836	2.729	12.405	49.836	3.330	15.138	36.167
3	2.233	10.149	59.985	2.233	10.149	59.985	3.110	14.134	50.301
4	2.053	9.331	69.316	2.053	9.331	69.316	2.815	12.796	63.097
5	1.071	4.868	74.185	1.071	4.868	74.185	2.439	11.087	74.185
6	.693	3.150	77.335						
7	.568	2.582	79.917						
8	.489	2.222	82.139						
9	.449	2.040	84.179						
10	.423	1.921	86.100						
11	.398	1.809	87.909						
12	.362	1.644	89.553						
13	.337	1.532	91.085						
14	.326	1.482	92.567						
15	.302	1.372	93.940						
16	.269	1.223	95.162						
17	.247	1.123	96.286						
18	.226	1.027	97.313						
19	.194	.881	98.194						
20	.160	.729	98.923						
21	.134	.608	99.531						
22	.103	.469	100.000						
Extraction Method: Principal Component Analysis.									

The factor rotation method used here was orthogonal Varimax rotation. The varimax rotation method focuses on simplifying columns in the factor matrix and is commonly used. Varimax rotation increases the loading having large values and weakens the loadings with lesser values (K. Singh et al., 2016). From factor analysis, the highly correlated items were grouped into one parameter. The factor analysis helps in reducing the number of items. It helps to break the total data into smaller sets of parameters. The loading below 0.40 was suppressed, and there was no cross-loading. Table 7 shows the rotated component matrix, which shows the designed questionnaire's factor loading.

Table 7. The Rotated Component Matrix Shows the Factor Loading of the Designed Questionnaire

Rotated Component Matrix[a]					
	Component				
	1	2	3	4	5
SL01		.857			
SL02		.885			
SL03		.883			
SL04		.754			
ACL01	.616				
ACL02	.738				
ACL03	.805				
ACL04	.826				
ACL05	.828				
ACL06	.838				
ACL07	.741				
HOT01			.877		
HOT02			.869		
HOT03			.804		
HOT04			.879		
SAT01				.805	
SAT02				.713	
SAT03				.692	
SAT04				.772	
CUP01					.822
CUP02					.836
CUP03					.806
Extraction Method: Principal Component Analysis.					
Rotation Method: Varimax with Kaiser Normalization.					
a. Rotation converged in 6 iterations.					

Table 8. Cronbach's Alpha Value for All Five Parameters

E	**Parameters**	**No. of Items Per Parameter**	**Cronbach's Alpha (.918)**
1	Self-learning and engagement	4	0.918
2	Active and collaborative learning	7	0.913
3	Higher-order thinking	4	0.898
4	Satisfaction	4	0.827
5	Continuous Updation and Promotion	3	0.906

Cronbach's alpha, a measure of reliability, ranges from 0 to 1; a value greater than 0.70 is acceptable. Here, Cronbach's alpha is 0.918, and for the individual parameter range is between 0.827 and 0.918 (Hair & Black, 2014). Table 8 shows Cronbach's alpha value for all five parameters.

Convergent validity (average loading should be greater than 0.7) here for all the parameters is more than 0.7; Convergent validity is confirmed. The discriminant validity scale is calculated by comparing half of the total number of comparisons with the total number of violations. Here, the total number of comparisons is 106, the total number of violations is 3, and $106/2 >> 3$, so discriminant validity is affirmed (Campbell & Fiske, 1959).

4.3. Confirmatory Factor Analysis (CFA)

The confirmatory factor is used to confirm and refine the instrument. CFA considers both the measured variable and the latent variable (the variable that is inferred mathematically from measured variables). The CFA is calculated from the 436 learners' responses for odd and even semesters in the year 2021-2022. CFA is calculated using RStudio 4.3.0.

4.4. Model Fit Indices

The Chi-squared test (χ^2) measures the gap between the observed and expected covariance matrices. The $\chi^2 = 403.948$ here and degree of freedom df = 199, the model will be considered if $\chi^2/df < 3.0$; here it is 2.02, so the model is well fitted. Tucker-Lewis index (TLI) and the comparative fit index (CFI) above 0.9 are acceptable; here, they are 0.957 and 0.963, respectively. RMSEA value equal to or less than .05 is used as an indication of a close fit of the data with the assumed model, and less than .08 is considered an acceptable fit. Here we have RMSEA at 0.049. The standardised root mean square residual (SRMR)is the square root of the difference between the sample covariance matrix and the model covariance matrix, and the value of SRMR is 0.036 (Michalopoulou, 2017; Singh et al., 2016; Abrahim et al., 2019; Griffioen, 2022). Figure 3 shows the standardised solution for the Model based on CFA analysis (n=436). Table 9 presents the model fit indices for the measurement model, and Table 10 shows the average variance extracted (AVE) and composite reliability (CR) analysis. Table 11 shows the correlation matrix with the square root of AVEs on the diagonal. To become valid, the square root of AVEs should be the highest in comparison with its vertical and horizontal values of the correlation matrix.

Table 9. Model Fit Indices for the Measurement Model

	N	χ2	df	χ²/df	GFI	AGFI	NFI	CFI	RMSEA	SRMR	TLI
Model	436	403.948	199	2.02	0.921	0.900	0.930	0.963	0.049	0.036	0.957

Note: N= sample size, GFI= fit index, AGFI=, NFI=,CFI= Omparative Fit Index, RMSEA=Root Mean Square Error of Approximation, SRMR= Standardized Root Mean Square Residual, TLI= Tucker-lewis Index

Table 10. The Average Variance Extracted (AVE) and Composite Reliability (CR) Analysis

	Loading	Square Loading	AVE	Errors	Sum of Square Loading	Sum of Errors	CR
SL01	0.807	0.651249	0.650105	0.348	9.903609	1.514	0.867398
SL02	0.788	0.620944		0.379			
SL03	0.711	0.620944		0.495			
SL04	0.841	0.707281		0.292			
ACL01	0.807	0.651249	0.586507	0.349	28.68674	2.896	0.908304
ACL02	0.79	0.6241		0.376			
ACL03	0.757	0.573049		0.427			
ACL04	0.783	0.613089		0.387			
ACL05	0.763	0.582169		0.419			
ACL06	0.697	0.485809		0.514			
ACL07	0.759	0.576081		0.424			
HOT01	0.806	0.649636	0.63326	0.351	10.13149	1.468	0.873443
HOT02	0.794	0.630436		0.37			
HOT03	0.795	0.632025		0.367			
HOT04	0.788	0.620944		0.38			
SAT01	0.822	0.675684	0.600923	0.324	9.566649	1.595	0.8571
SAT02	0.812	0.659344		0.34			
SAT03	0.683	0.466489		0.534			
SAT04	0.776	0.602176		0.397			
CUP01	0.81	0.6561	0.693657	0.345	6.240004	0.919	0.87163
CUP02	0.834	0.695556		0.304			
CUP03	0.854	0.729316		0.27			

Table 11. The Correlation Matrix, the Diagonal Values Are The Square Root of AVEs

	SL	ACL	HOT	SAT	CUP
SL	0.806291				
ACL	0.641	0.765837			
HOT	0.53	0.503	0.795777		
SAT	0.528	0.536	0.53	0.775192	
CUP	0.441	0.413	0.529	0.612	0.832861

5. DISCUSSION AND IMPLICATION

The paper presents valid steps to design a questionnaire that can measure the skills a learner needs to acquire to contribute to the demand of the 21st century. The paper also validates the questionnaire so that it can be further used for other TLPs that intend to measure the skills, i.e., self-learning, active and collaborative learning, higher-order thinking, satisfaction, and the continuous updating of the TLP.

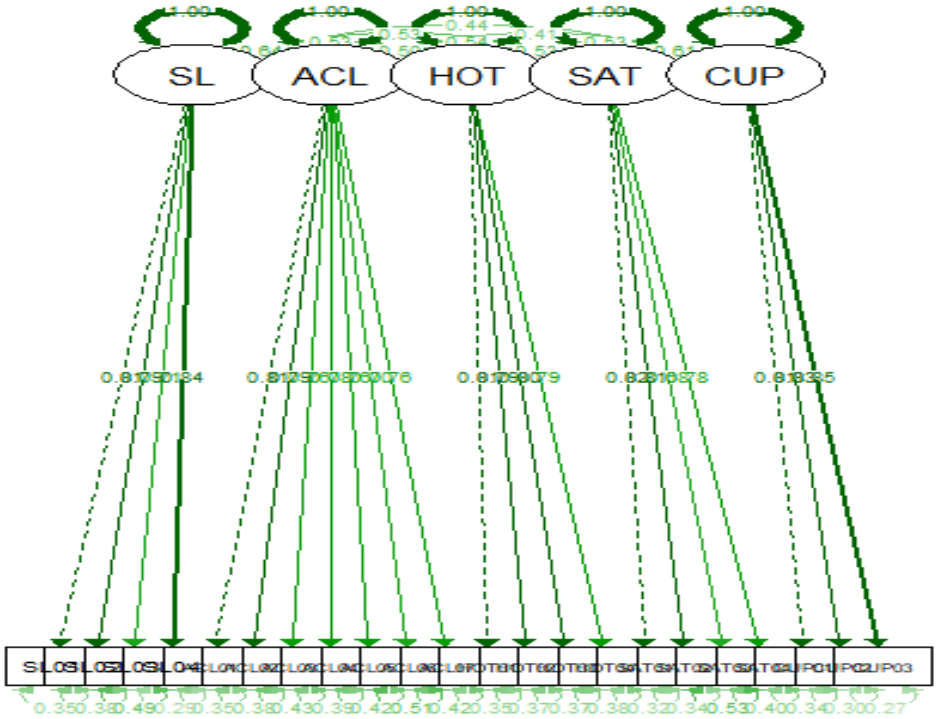

Figure 3. Standardized Solution for Model-Based on CFA Analysis (n=436)

The data collected in four semesters were divided into two parts, the first odd and even semesters, consisting of 220 learners, and were analysed using descriptive statistics. It is found that all the items were in range as stated and are functional. The exploratory factor analysis and reliability were also done on these 220 learners, and it was found that there are five district constructs (parameters). The CFA was calculated from 436 learners, and the result was in the desirable range and had a good fit.

The results obtained from the validation process are compared with the existing studies that also aimed to measure the same parameter. Table 12 shows the comparison between the results obtained and the results presented in the available papers. The result of the first parameter, "Self-learning", was compared with the available papers (Geng et al., 2019; Carini et al., 2006), and the mean of the self-learning in the proposed questionnaire was similar to other papers. The reliability, CR, and AVE of the stated parameter are better than those of the other two papers. The construct achieves a mean score of 3.26, indicating moderately positive responses from participants. The reliability analysis shows excellent internal consistency, with Cronbach's Alpha (0.918) and Composite Reliability (0.860) both exceeding recommended thresholds. The AVE value of 0.60 further confirms strong convergent validity, indicating that the items effectively represent the underlying construct.

For Active and collaborative learning, there were four available papers (Barari et al., 2022; Carini et al., 2006; Carr et al., 2015; Kember & Leung, 2008). The mean, reliability, CR, and AVE were compared, and seen that the parameter designed has similar results for mean and AVE, and the highest value for reliability (0.913) and CR (0.908). The construct shows a mean score of 2.64, suggesting that respondents hold moderately low or neutral perceptions toward the measured dimension. Reliability indicators demonstrate excellent internal consistency, with Cronbach's Alpha (0.913) and Composite Reliability (0.908) both exceeding recommended thresholds. The AVE value (0.586) indicates strong convergent validity, confirming that the items adequately represent the underlying construct.

Table 12. The Comparison Between the Results Obtained and the Results Presented in the Available Papers

	Paper	No of question Correlated	N	Mean	α	CR	AVE
Self-Learning	(Geng et al., 2019)	3 (10)	207	3.426 (3.555)	0.703	0.834	0.625
	(Carini et al., 2006)	4 (11)	1034		0.70		
	Proposed method	4	220 436	3.26	0.918	0.860	0.60
Active and collaborative learning	(Kember & Leung, 2008)	5 (3)	662		0.87		
	(Barari et al., 2022)	9	135	2.58			
	(Carr et al., 2015)	11	5887	2.66			
	(Carini et al., 2006)	7	1045		0.62		
	Proposed method	7	220 436	2.64	0.913	0.908	0.586
Higher-order Thinking	(Carini et al., 2006)	4	1052		0.74		
	(Sukla & Dungsungneon, 2016)	27 (14)	659	3.06	0.81		
	(Lu et al., 2021)	9	217		0.88		
	Proposed paper	4	220 436	3.255	0.898	0.873	0.633
Satisfaction	(Carini et al., 2006)	2	1053		0.75		
	(Napitupulu et al., 2018)	14	84	3.27	0.83		
	(Gopal et al., 2021)	6	544	3.7	0.73	0.924	
	(Khanna et al., 2021)	7	121		0.74		
	Proposed Paper	4	220 436	3.727	0.827	0.857	0.600
Continuous updating	Proposed paper	3	220 436	3.43	0.906	0.871	0.693

The third parameter, "higher-order thinking", was compared with the paper measuring the same parameter (Carini et al., 2006; Sukla & Dungsungneon, 2016; Lu et al., 2021). The result obtained from the designed questionnaire is found to have a good mean (2.64), reliability (0.898), CR (0.873), and AVE (0.633). The construct has a mean score of 3.255, reflecting moderately positive perceptions among respondents. Reliability results are strong, with Cronbach's Alpha (0.898) and Composite Reliability (0.873) indicating high internal consistency. The AVE value of 0.633 demonstrates strong convergent validity, confirming that the parameter adequately represents the construct.

The parameter "satisfaction" was compared to these available papers (Khanna et al., 2021; Gopal et al., 2021; Napitupulu et al., 2018; Carini et al., 2006). The mean and reliability found were similar to the available values in the papers. The parameter has a mean of 3.727, reflecting a clearly positive acceptance. The reliability statistics are strong, with Cronbach's Alpha (0.827) and Composite Reliability (0.857)

confirming good internal consistency. The AVE value of 0.600 further demonstrates strong convergent validity, indicating that the parameter effectively represents the underlying construct.

The fifth parameter was self-developed, and there was no available questionnaire developed for this parameter; the mean (3.43), reliability (0.906), CR (0.871), and AVE (0.693) were in the acceptable range. The parameter has a mean of 3.43, indicating that students have positive perceptions toward the measured dimension. Reliability analysis shows excellent internal consistency, with Cronbach's Alpha (0.906) and Composite Reliability (0.871) both exceeding recommended thresholds. The AVE value of 0.693 further indicates strong convergent validity, confirming that the items effectively represent the underlying construct.

Overall, the Questionnaire demonstrates strong psychometric properties. The mean scores, ranging from 2.64 to 3.727, indicate that respondents' perceptions vary from neutral to moderately positive across the constructs. Reliability assessment shows excellent internal consistency, with Cronbach's Alpha values between 0.827 and 0.918 and Composite Reliability (CR) values between 0.860 and 0.908, all surpassing the recommended minimum threshold of 0.70 (Hair et al., 2019). Convergent validity is also well established, as reflected by Average Variance Extracted (AVE) values between 0.586 and 0.693, exceeding the benchmark of 0.50 and confirming that each construct explains a substantial proportion of variance in its indicators. These results collectively affirm that the constructs are measured reliably and validly, providing a sound foundation for subsequent structural analysis.

6. CONCLUSION

The 21st century has been a technologically developed era: resources are easily available at the fingertips. The role of the instructor and the learners also needs to be modified accordingly. The learners are now the centre of TLP and are responsible for their learning and the skills acquired. While developing a TLP process, the skills acquired through the process should also be considered for studying the effectiveness. The most widely used method to measure effectiveness is through a questionnaire. The questionnaire should be valid and reliable so that it can measure the desired parameter. With the help of all the analysis, validity, and reliability tests, we found that the designed questionnaire can measure the parameter as stated during the formation of research objectives. The five parameters of self-learning and engagement, active and collaborative learning, higher-order thinking, satisfaction, and continuous updation of the curriculum were found to be reliable instruments to study the effectiveness of the TLP. This questionnaire (instrument) can be used to assess any TLP that will be designed to provide the learners with 21st-century skills. The EFA and CFA confirm the constructs of the questionnaire. For these 22 items, the 5-parameter questionnaire has valid fit indices. This paper will also guide the researcher step by step to design and validate the questionnaire, thus improving the quality of research.

The questionnaire developed was effective for undergraduate learners within the institution. Its strong reliability and validity indicators suggest that it can be confidently adapted and applied in other institutional contexts to further establish its robustness. The instrument also offers potential for broader use across diverse teaching–learning processes to evaluate the effectiveness of various pedagogical approaches. Future research may strengthen its psychometric soundness by conducting test–retest reliability studies to assess the stability of responses over time. Overall, the questionnaire serves as a valuable tool for continued exploration and enhancement of teaching and learning practices.

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Research Ethics. The authors have followed the ethical considerations.

Data Availability Statement. All the data can be obtained from the corresponding author.

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