Development and Validation of Conceptual Understanding Test for Socio-Scientific Issues (CUT-SSI) in Science

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Abstract:

This paper outlines the development and validation of a Conceptual Understanding Test (CUT-SSI) for assessing students' proficiency in Socio-Scientific Issues engagement. Traditional assessment methods often fail to capture the complexity of SSI learning, necessitating a new approach. The test development process comprised four stages: Planning, Construction, Evaluation, and Validation. During planning, the test's scope, objectives, and content were defined, guided by expert opinions and literature review. Content selection focused on two chapters from a standard 10 science textbook, with a blueprint detailing question distribution based on instructional goals. Construction involved drafting 71 items, including multiple-choice and true-false questions. In the evaluation stage, student feedback identified and addressed ambiguous or challenging items, leading to revisions in consultation with supervisors and experts. Validation aimed to establish reliability, validity, fairness, and utility. Pilot testing with 108 students, followed by item analysis, confirmed internal consistency and reliability through split-half reliability analysis. Face and content validity were ensured through expert consultations. The final test comprised 25 multiple-choice and 25 true-false items, selected based on appropriateness, difficulty, and discrimination properties, accommodating varying proficiency levels. This research will to develop a concern for developing tools in consonance to the instruction techniques that are used. Further the process for developing CUT-SSI elaborated in the paper will also work a guiding tool to develop such tests. It will also provid educators with a validated assessment tool to measure students' conceptual understanding and critical thinking skills. It informs curriculum development, instructional practices, and assessment strategies in science education, particularly in SSI instruction.

Keywords: Socio-scientific issues, Conceptual understanding, Assessment, Test development, Validation

Introduction

Socio-scientific issues (SSI) are complex, real-world problems that demand an integration of scientific knowledge with societal values and ethical considerations (Zeidler, Sadler, Simmons, & Howes, 2005; Zeidler & Nichols, Socioscientific issues: Theory and practice, 2009; Presley, et al., 2013). These issues, such as climate change, genetic engineering, and vaccination policies, transcend disciplinary boundaries, requiring learners to engage in critical thinking, ethical reasoning, and decision-making (Zeidler D. L., 2014). Effective instruction in SSI fosters students' conceptual understanding of scientific principles while promoting their ability to analyze, evaluate, and respond to socio-scientific dilemmas. (Presley et al., 2013).

Assessment plays a crucial role in evaluating students' proficiency in understanding and engaging with socio-scientific issues (Zeeuw, Craig, & You, 2013). However, traditional assessment tools may fall short in capturing the multifaceted nature of SSI learning. Therefore, there is a pressing need for the development of valid and reliable assessment instruments tailored specifically for assessing students' conceptual understanding in the context of socio-scientific issues.(Zeidler et al., 2005). The development of a Conceptual Understanding Test for Socio-Scientific Issues (CUT-SSI) in science addresses this need by providing educators with a tool to measure students' knowledge, comprehension, and application of scientific concepts within real-world contexts (De Zeeuw et al., 2013).

This research Paper presents the process of developing and validating such test, with the aim of enhancing assessment practices in SSI education and supporting educators in fostering students' critical thinking and decision-making skills. The paper is developed by establishing the reliability, validity, fairness, and utility of the conceptual understanding test, ensuring that it accurately measures students' proficiency in understanding and engaging with socio-scientific issues (Uchat, 2012). The findings of this research have implications for curriculum development, instructional practices, and assessment strategies in science education, particularly in the context of SSI instruction.

By providing educators with a validated assessment tool, this research contributes to the ongoing efforts to enhance SSI education and equip students with the knowledge and skills needed to address the complex challenges facing society in the 21st century.

Objectives of the study

1.   To develop a Conceptual Understanding Test for Socio-Scientific Issue (CUT-SSI) in Science.
2.   To validate a Conceptual Understanding Test for Socio-Scientific Issue-(CUT-SSI) in Science.

The aim of the research was to develop and validate a Conceptual Understanding Test for Socio-Scientific Issues (CUT-SSI) through scientific approach of tool development. The researcher has made effort to achieve the listed objectives and provide educators with a valuable tool to assess students' understanding in reference to the engagement in SSI, advancing SSI education and informing curriculum and instructional strategies in science education.

Process of Developing Conceptual Understanding Test for Socio-Scientific Issues (CUT-SSI) in Science

The steps followed for developing the CUT-SSI include four stages. (1) Planning for developing CUT-SSI based instruction and assessment, (2) Developing draft CUT-SSI, (3) Evaluation of CUT-SSI and (4) Validation of CUT-SSI (Akarsu, 2012; Chiu, Guo, & Treagust; Mazzolini)

1. Planning for developing CUT-SSI

Designing a test requires determining what to measure and why to measure. Before designing the test, it is necessary to study the important points related to the test diligently. The planning of this test needs to include the number of items to be included in the test, the content chosen for it, the type of test, the length of the test, etc.(Kothari, 2004)

The primary stages through which the researcher has developed the CUT-SSI are presented in the succeeding paragraphs.

a) Establishing the scope and objective of the CUT-SSI

The objective of CUT-SSI was to design a test to know the conceptual understanding of students in a science subject of secondary school students studying in Standard 10. Before the development of this test, the theoretical background and the review study of previous research and reference literature was carried out.

b) Content Analysis and Identification of SSI

The textbook of Standard 10 of Science subject was referred, and content analysis was done for selecting SSI incorporated in textbook (Dave, Raval, & Amin, 2020). Initially 20 socio-scientific topics spanning 7 chapters were identified. After discussion and expert reviews two chapters having 12 socio-scientific topics were selected for test development on the basis of the opinions and suggestions of the subject expert. The preliminary test was prepared at this stage.

The content selected for the developing the test was from Standard 10 Science Textbook of Gujarat Secondary Education Board. Title of two chapters selected are: Heredity & Evaluation, and Sustainable Management of Natural Resources. The socio-scientific topics emerging from the content and therefore identified are listed in Table-1.

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Table 1: Selected Socio-Scientific Topics

Chapter		Identified SSI
Heredity and Evaluation	1	Sex determination
	2	Inherited Traits like Skin and Hair colour
	3	Evolution
	4	Gender Ratio
	5	Gender Bias
Sustainable Management of Natural Resources	6	Judicial use of natural resources
	7	Pollution
	8	Forest conservation
	9	Water conservation
	10	Dam and its effect
	11	Coal and Petroleum related issues
	12	Green House Effect and Global Warming

c) Blueprint for the CUT-SSI

Following the examination of the subjects to be addressed and the determination of the domain of objectives, the researcher determined the quantity of items to incorporate in the test. For preparing a CUT-SSI questions for each Socio-Scientific Topic was aligned according to instructional objectives and a blueprint was formulated according to the specifications outlined in Table - 2 (Anderson & Krathwohl, 2000).

Table 2: Blueprint of CUT-SSI

Chapters		Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation	Total
Evaluation and Heredity	No. of Ques.	-	9	5	7	8	1	30
	% of Ques.	**-**	**13**	**7**	**10**	**11**	**1**	**42**
	MCQ	-	7	2	5	5	1	20
	MCQ %	**-**	**10**	**2**	**7**	**7**	**1**	**28**
	True/False	-	2	3	2	3	0	10
	True/False %	**-**	**3**	**4**	**3**	**4**	**0**	**14**
Sustainable Management of Natural Resources	No. of Ques.	-	17	6	11	3	4	41
	% of Ques.	**-**	**24**	**9**	**16**	**4**	**6**	**58**
	MCQ	-	8	4	5	0	4	21
	MCQ %	**-**	**11**	**6**	**7**	**0**	**6**	**30**
	True/False	-	9	2	6	3	0	20
	True/False %	**-**	**13**	**3**	**9**	**4**	**0**	**28**
Total	Total Que	-	26	11	18	11	5	71
	Total Que %	**-**	**37**	**16**	**25**	**16**	**7**	**100**
	MCQ	-	15	6	10	5	5	41
	MCQ %	**-**	**21**	**9**	**14**	**7**	**7**	**58**
	True/False	-	11	5	8	6	0	30
	True/False %	**-**	**16**	**7**	**11**	**9**	**0**	**42**

2. Development of Draft of CUT-SSI

The first draft of total 71 items consisting of two types of questions were kept in the CUT-SSI under two sections.

- **Section-1: Multiple Choice Questions (MCQ)** – 41 items were prepared under this section specially designed to evaluate the scientific skill, concepts and higher order thinking of students related to socio-scientific issues of selected content. Two such sample Multiple Choice Question questions are given in Table – 3. Care was taken to develop the test items that not only evaluate the conceptual understanding but also are able to assess the sensitization of the learners for the socio-scientific issue.

Table 3: Sample Multiple Choice Questions from Draft CUT-SSI

No.	Question with Multiple Choice		Identified SSI
1	Choose the correct statement from the following for carbon dioxide emissions.		Green House Effect and Global Warming
	A	The amount of carbon dioxide in the atmosphere does not change under any circumstances.	
	B	Decreasing the number of trees has no effect on the amount of carbon dioxide.	
	C	Smoke from vehicles is also responsible for increasing the amount of carbon dioxide in the atmosphere.	
	D	Carbon dioxide gas is not responsible for the greenhouse effect.	
2	Global environmental problems are problems that		Pollution
	A	Affects only the environment of our village or city.	
	B	It cannot affect the environment of our village or city.	
	C	It affects the environment of the whole world.	
	D	It cannot change the environment of the whole world.	

- **Section -2: True False type questions** – 30 items were prepared under this section based on concept of socio-scientific issues under study. The statements prepared were designed to measure higher order thinking including comprehension, application, analysis and synthesis. Two such sample True/False type of sample questions are given in Table-4 (Gronlund & Linn, 1990).

Table 4: Sample True-False Questions from Draft CUT-SSI

No.	Question with Multiple Choice	Identified SSI
1.	We should use our natural resources in such a way that the resources can be nourished, and we can also protect our environment.	Judicious use of Natural Resources
2.	Indiscriminate use of natural resources leads to environmental problems.	

Each Multiple-choice questions had four options, and it was a single answer type multiple choice item test. To mark the correct answer student has to darken the circle indicating the correct option given against the question number in the answer sheet. The initial section of CUT-SSI consisted of preliminary information.

1. Evaluation of CUT-SSI

The answer sheets were evaluated based on the answer key. For each right answer a score of 1 was given and for each wrong answer a score of 0 was given. The researcher obtained the answers to the tests from the students and noted the average time taken to complete them. The items which were not understood by the students were modified in terms of language, content and other specifications. After discussion with the supervisor and subject experts, necessary corrections were added and the final draft was developed.

2. Validation of CUT-SSI

This stage was performed by keeping in mind following steps: Administration, Item analysis by Difficulty analysis and Discrimination analysis, reliability, Validity, and preparing the final CUT-SSI. (Kothari, 2004)

a) Administration of CUT-SSI

For the pilot testing phase, the test was administered to a representative sample of 108 students from selected secondary schools in Gujarat. It was ensured that they possessed knowledge of the test content and had previously encountered the material. The draft CUT-SSI comprised 71 items, including 41 multiple-choice questions (MCQs) and 30 true-false type questions. Participants were required to mark their answers on an OMR sheet by darkening the appropriate circle representing A, B, C, or D for the Multiple-Choice Questions, and indicating "True" or "False" for the true-false type questions. Based on pre-piloting a time of 60 minutes was given for marking response of test. Scoring was conducted using a scoring key. Each correct

response of Multiple-Choice Questions and True-False type question was given 1 marks and incorrect response was given 0 marks. Thus, total minimum scoring of CUT-SSI was 0 marks and maximum scoring of CUT-SSI was 71 marks.

b) Item analysis of CUT-SSI

According to (Tuckman, 1978), "Item analysis means the process of evolution of single test items by determining the difficulty value and discriminating power of the item and often its correlation with some criteria."

The scores were arranged in descending order of total score. Then the top 27% of the total number i.e. the group of students with the highest scores was designated as the upper group and the bottom 27% i.e. the group of students with the lowest scores was designated as the lower group.

Calculation of Difficulty Value (DV)

Difficulty Value (DV)$= \frac{Ru+Rl}{2N} \times 100$

Ru = Number of correct respondents in the upper 27% group

Rl = Number of correct respondents in the bottom 27% group

N = Number of respondents included in each group

Thus, the Difficulty value of the test for true measurement was found.

Calculation of Discrimination Index (DI)

Discrimination index is mainly based on the degree to which students can successfully and accurately differentiate between high and low students. If all the students answer a question correctly or all the students answer it wrong, then the discriminant value of that question is zero.

The discrimination index was found in the following formula.

Discrimination index $= \frac{Ru-Rl}{N}$

Ru = Number of correct respondents in the upper 27% group

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Rl = Number of correct respondents in the bottom 27% group

N = Number of respondents included in each group (Roid & Haladyana, 1982)

According to each component selected for this test, the Difficulty Value, Discrimination index was calculated and items were selected items for the final test. For the conceptual understanding in science (Section-1: Multiple Choice type questions) out of 41 questions 25 questions were selected. And 16 rejected. For conceptual understanding in science (Section – 2: True – False type questions) out of 30 items 25 were selected and 25 were rejected. Thus, the final Conceptual Understanding Test for Socio-Scientific Issues (CUT-SSI) in Science consisted of 50 items. The minimum marks for the test were zero and 50 were the maximum marks.

c) Reliability of CUT-SSI

According to (Kahn & Best, 2016), "Reliability of a tool refers to the consistency with which a tool measures what it proposes to measure."

The reliability of a tool can be determined through various methods like Internal-consistency method, Test-retest reliability, Alternate/ Parallel Forms reliability, and Split-Half reliability. (Shukla, 2019)

For the present study reliability was determined by using split-half method.

The test items score was divided in two parts i.e. odd numbers and even numbers. The scoring was done separately for both the parts and then the coefficient of correlation was calculated in two halves.

The reliability of half test indicates the coefficient of correlation. By using Spearman-Brown formula, the self-correlation coefficient of the whole test is obtained. In order to ascertain the reliability for the tool, spilt-half reliability co-efficient was computed.

The value of reliability coefficient for Multiple Choice Questions of CUT-SSI was obtained 0.82. The value of reliability coefficient for True-False type questions of CUT-SSI was obtained 0.82. This indicates that the CUT-SSI has good reliability.

d) Validity of CUT-SSI

When crafting the blueprint and composing test items, the test's face validity and content validity were ensured by assigning appropriate importance to the content and objectives. The perspectives of experts in the relevant field were consulted during the test item preparation, and essential adjustments were implemented based on their recommendations.

e) Final CUT-SSI

After a trial of the preliminary test for the final test 25 Multiple Choice Questions out of 41 Multiple Choice Questions having a Difficulty Value from 0.25 to 0.75 and a Discrimination Index from 0.21 to 1.00 were selected through the item analysis stage.

After a trial of the preliminary test for the final test 25 True/False items out of 30 True/False items having a Difficulty Value from 0.56 to 0.75 and a Discrimination Index from 0.15 to 1.00 were selected through the item analysis stage.

In the final test, the test items were arranged from easy to difficult based on the Difficulty index considering the level of the students. The test is formatted to ensure clarity, consistency, and ease of administration, taking into account logistical considerations such as time constraints and available resources (Patel, 2012).

Thus the Conceptual Understanding Test for Socio-Scientific Issues (CUT-SSI) in Science is a valid and reliable test and can be used by the teachers for transacting the curriculum in consonance with the socio-scientific issues. Further CUT-SSI can be used for evaluating the achievement of the learners.

Conclusions

The research focuses on developing a rigorous assessment tool that has undergone validation processes to ensure its reliability and accuracy. By equipping educators with such a tool, the research aims to enhance the quality of instruction and learning experiences surrounding SSI. Ultimately, the goal is to empower students with the knowledge and skills necessary to address contemporary societal challenges effectively. The research contributes to ongoing efforts aimed at improving education and addressing complex societal issues collaboratively. It recognizes the collaborative nature of enhancing SSI education, involving educators, researchers, policymakers, and other stakeholders. By providing validated assessment tools, the research makes a tangible contribution to these collective efforts, aiming to create a more informed and empowered citizenry capable of addressing the multifaceted challenges of the modern world.

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