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Research Article

ESTABLISHING THE FACTORIAL VALIDITY, RELIABILITY AND USABILITY OF META-COGNITIVE AWARENESS INVENTORY IN PHYSICS (MAIP) FOR MALE AND FEMALE STUDENTS IN NIGERIA

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Abstract

The study was on establishment of factorial validity, reliability and usability of Meta-cognitive Awareness Inventory in Physics (MAIP) for male and female students in Nigeria. Three research questions which guided the study were answered. One null hypothesis was formulated and tested at 0.05 level of significance. The study adopted instrumentation research design. The population for the study comprised all the 15030 Senior Secondary Two (SSII) science students in the 2319 Secondary Schools. Construct validation was carried out on the Meta-cognitive Awareness Inventory in Physics (MAIP) for secondary schools to establish its construct validity using factor analysis. This is based on the extraction method of principal component analysis and rotation method of Varimax with Kaiser Normalization. The item selection was done using the rotated component matrix. The items with factor loading of 0.40 and above on any of the factors were identified and selected to form part of the instrument. Research question 3 was answered using mean and standard deviations. The null hypothesis was tested using independent t-test at 0.05 level of significance. The findings revealed that Meta-cognitive Awareness Inventory in Physics (MAIP) for Senior Secondary students in Benue State has 52 factorially simple or pure items and 23 factorially complex items in terms of their factor loadings. It was recommended among others that Physics teachers should use the Meta-cognitive Awareness Inventory in Physics (MAIP) to determine their students' level of meta-cognitive awareness in the schools. This may enable them to gain awareness and control over themselves as learners for effective learning of Physics in secondary schools irrespective of their gender.

Keywords: Construct validity, Factor Analysis, Instrumentation, Meta-cognition, Meta-cognitive Awareness, Reliability, Usability of an instrument.

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INTRODUCTION

Meta-cognition plays an important role in the learning of Physics because, it may help students to be capable of planning, monitoring and evaluating how much learning is effective. It can answer questions related to the development in cognitive and affective areas. Meta-cognition also, has been described as one's ability to know and regulate cognitive processes, calibrate or monitor one's performance and chart learning plans based on learning and performance estimate and what we know about our cognitive processes and how we use these processes in order to learn and remember (Salari Tarmizi, hamzah & Hambali, 2013). Meta-cognition also enables students to solve new problem by retrieving and deploying strategies that they have learnt with reference to similar context (Ozturk, 2017). Therefore, to help students learn Physics effectively, teachers need to enhance their students' use of meta-cognition so that they gain control and awareness over themselves as learners.

Meta-cognitive awareness is a crucial factor in the attainment of a reasonable academic excellence. Meta-cognitive awareness is the personal understanding of one's cognitive and affective state and how to specify conscious thinking of one's own learning. The impact of meta-cognitive awareness on students' academic achievement was found to be statistically significant (Mohammed, 2015; Dogra, 2016; Aurah, 2018). Also, Sawhney and Bansal (2015) found significant differences between high and low meta-cognitive awareness groups of undergraduate students and their academic achievement. However, Yilmaz and Yalcin (2012) found that students' success levels do not reflect their knowledge levels, that students experienced some problems while converting procedural knowledge into declarative knowledge and due to the problem, they failed to understand Newton's laws of motion adequately. Students are unable to solve non-routine Physics problems due to low meta-cognitive awareness.

In order to measure meta-cognition, Meta-cognitive Awareness Inventory (MAI) developed by Schraw and Dennison (1994) and Junior Meta-cognitive Awareness Inventory (Jr.MAI) developed by Sperling, Howard, Miller and Murphy (2002) are widely used. They could be considered as domain general meta-cognitive instruments rather than domain-specific instruments to Physics. However, the domain-general or domain-specific issue in meta-cognitive awareness remains unsolved. With reference to the domain-specific property of meta-cognitive awareness, the development of Meta-cognitive Awareness Inventory specific to Physics becomes imperative

The development of an instrument is the most important part of conducting a quality instrumentation or developmental research study. Developmental study takes cognizance of some salient steps. These are content outline, objective of the instrument, construction of items, face validation, item selection, trial testing, item analysis, reliability of the instrument, item selection, norming, inventory manual, final production and marketing of the inventory and its manual among others (Emaikwu, 2011; Nworgu, 2015). Therefore, development and factorial validation of Meta-cognitive Awareness Inventory in Physics (MAIP) for Senior Secondary school students in Benue State involved this number of steps beginning with content outline.

The content outline of the Meta-cognitive Awareness Inventory in Physics (MAIP) was prepared based on the components of meta-cognitive awareness. These are declarative, procedural and conditional knowledge. Others are planning, monitoring, evaluation, debugging, and information management. After the content outline, comes the objective of the instrument. The objective of the instrument was specified in order to develop a valid and reliable Meta-cognitive Awareness Inventory in Physics (MAIP) and use the instrument base on school location, students' gender and school type. The items on the Meta-cognitive Awareness Inventory in Physics (MAIP) are constructed to reflect the components of meta-cognitive awareness. The instrument was then submitted to experts for critiquing and weighting

to ensure face validity. The criticisms, suggestions and inputs of the experts were articulated to produce a working instrument which was used for trial testing to generate data for item analysis and internal consistency of the Meta-cognitive Awareness Inventory in Physics (MAIP) for Senior Secondary school students in Benue State (Emaikwu, 2011).

Item analysis was carried out to establish the construct validity of Meta-cognitive Awareness Inventory in Physics (MAIP). Construct validation was done using factor analysis. Having executed the item analysis, the items that have satisfactory statistical qualities are selected for inclusion on the final form of the instrument. Then the instrument is assembled in the form that it should be. The assembly is based on the ease with which students can understand what to do, when and where to respond as well as the ease with which the researcher can locate and rate students' responses. The responses are used for the establishment of reliability index of the instrument. Having selected and assembled the inventory items, the next thing is to go for final testing by administering the inventory on a fairly large sample of students similar to those whom the inventory is intended (Nworgu, 2015). However, the present study would be limited to establishing the construct validity of Meta-cognitive Awareness Inventory in Physics (MAIP).

The validity of an instrument refers to the extent an instrument measures what it is designed to measure (Nworgu, 2015). Validity of an instrument is purpose dependent; this implies that, an instrument which is valid for one purpose may not be valid for another. For instance, construct validity is the extent to which a particular test can be shown to measure a hypothetical construct or trait (Nworgu, 2015; Emaikwu, 2019). It is also the purity with which an instrument measures any construct it is designed to measure. Establishing construct validity involves a statistical procedure called factor analysis.

Factor analysis is a mathematical procedure which can be used in describing certain areas of nature. According to Emaikwu (2011) factor analysis refers to a variety of statistical techniques whose common objective is to present a set of variable in terms of smaller number of hypothetical variables. The rationales for factor analysis are to investigate pattern of relationship

to identify whether the correlation between a set of observed variables stem from their relationship to one or more variables in the data, analyze the structure of a phenomena and development of measurement scale which is Meta-cognitive Awareness Inventory in Physics (MAIP) (Geisinger, 2016). This is because, meta-cognitive awareness is a construct that does not lend itself to experimental manipulations.

The initial consideration involves sample size. The initial considerations according to Andy (2006) involves Kaiser-Meyer-Olkin Measure of sampling adequacy (KMO) and Bartlett's Test of Sphericity to check for sampling adequacy, assumption of sphericity respectively and communality which is the proportion of common variance present in a variable. The factor extraction is either based on Kaiser recommendation of retaining all factors with eigenvalues greater than 1 or Jollife suggestion of retaining all factors with eigenvalues more than 0.7 (Andy, 2006). The use of Scree plots is important because factor rotation should not be based on these criterions alone. It is pertinent to note that, the minimum number of factors that will best explain the data set or structure of the instrument as well as the factor loading of each item on each of the factors will emerge after rotation.

Factor loading are the relative contributions that a variable makes to a factor. Based on a predetermined minimum loading, the researcher selects only those items that are highly loaded on any factor. An item that loads highly on one factor is said to be pure or factorially simple. On the other hand, if an item loads highly on two or more factors, it is said to be factorially complex. The quality of the items of Meta-cognitive Awareness Inventory in Physics (MAIP) is also ascertained in terms of its internal consistency which is the reliability index.

Reliability of an instrument is the degree of consistency with which a measuring instrument measured what it is supposed to measure (Nworgu, 2015). For an instrument to be reliable, it has to show consistency between independent measurements of the same phenomena over times. Thus, it is the stability, dependability and predictability of a measuring instrument in producing consistent set of results in subsequent measures (Emaikwu, 2011; Nworgu, 2015). In this study, the reliability index of Meta-cognitive Awareness Inventory in Physics (MAIP) for students is established using Cronbach's Alpha. The estimate of internal consistency provides a measure of how homogenous or otherwise the items are. As a result, the present study took the position that, research instrument is best served by improvement in its reliability and usability.

The usability of an instrument refers to the extent to which the majority of the people meant to use the instrument can easily use it given the realities and practical conditions around (Emaikwu, 2011). In other words, usability of a test refers to the degree to which a test can be successfully used by the classroom teachers and administrators without undue expenditure of time, money and energy and the extent to which the examinees can understand the items and finish the test without experiencing fatigue, stress or boredom. Therefore, the degree to which Meta-cognitive Awareness Inventory in Physics (MAIP) can be successfully used by male and female students without undue expenditure of time, money and energy deserves research attentions.

In reference to gender, Nwosu (2011) opines that, gender is a dimension of social organization which shape how people interact with others and how people behave or act and think about themselves. Nworgu, Ellah and Oparah (2019) state that, gender is socially constructed for the purpose of allocating powers, duties, responsibilities, status and roles in any social context. Gender is the societal meaning assigned to male and female with a particular role that each should play. This is verifiable in relation to students' level of meta-cognitive awareness in Physics because, there is a general belief among Nigerians that male are superior to female in terms of physical physique, cognition, logical reasoning and academic achievement. Therefore, the extent to which the male and female students can understand the items of Meta-cognitive Awareness Inventory in Physics (MAIP) and finish the inventory without experiencing fatigue, stress or boredom also need investigation.

One of the basic problems of the study in the field of meta-cognition is the development and use of valid and reliable instrument for determining the level of students' meta-cognitive awareness. Literature is replete with evidence which suggests that, students irrespective of their gener are unable to solve non-routine Physics problems due to low meta-cognitive awareness. Students that are aware of their thinking may be more strategic to perform better than those who are unaware. But how can students use meta-cognitive strategies in Physics while learning if they are not aware of their meta-cognition? The awareness of meta-cognition plays an important role in education because, it helps learners to develop a plan on how to monitor and evaluate their learning processes. With reference to the domain-specific property of meta-cognitive awareness, the development of Meta-cognitive Awareness Inventory (MAI) specific to Physics is imperative.

RESEARCH METHOD

The following sections detail the systematic approach used to develop and validate the meta-cognitive awareness instrument for Physics students at the secondary level.

Research Design

This study adopted an instrumentation research design. This design was specifically chosen because the primary focus of the research was the development, testing, and validation of a reliable measurement tool. In this context, the study aimed to produce a psychometrically

sound "Meta-cognitive Awareness Inventory in Physics" (MAIP) suitable for use in high school science education settings.

Research Target/Subject

The primary objective of this research was to develop and validate the MAIP instrument to accurately measure students' meta-cognitive awareness. The study targeted the establishment of face validity through expert review and construct validity through factor analysis. By determining the internal consistency of the instrument, the research aimed to provide educators with a valid evaluative tool to understand how students monitor and regulate their thinking processes while learning physics concepts.

The population for this study comprised all 15,030 Senior Secondary Two (SSII) science students across 2,319 secondary schools. From this population, a sample of 1,382 male and female students who offered Physics as a subject was selected. This large sample size was utilized to satisfy the data requirements for robust factor analysis and to ensure that the findings were representative of the broader student population.

Research Procedure

The procedures began with the initial drafting of the MAIP instrument, which then underwent face validation by five experts. Their observations were used to review and refine the instrument items. Subsequently, field testing was conducted to gather data for construct validation. Following data collection, statistical analyses were performed to answer the research questions and test null hypotheses regarding differences between self-determining groups, such as gender-based comparisons.

Instruments, and Data Collection Techniques

The primary data collection tool was the Meta-cognitive Awareness Inventory in Physics (MAIP). Construct validation was established using Factor Analysis based on the Principal Component Analysis extraction method and the Varimax rotation method with Kaiser Normalization. Item selection was strictly governed by the rotated component matrix, where only items with a factor loading of 0.40 or higher on any of the identified factors were retained for the final version of the instrument.

Data Analysis Technique

Data were analyzed using several statistical techniques aligned with the research objectives. Factor analysis was used to determine the underlying structure of the instrument, while Cronbach's Alpha was employed to measure the coefficient of internal consistency, which was found to be 0.78 (indicating good reliability). Descriptive statistics, including mean and standard deviation, were used to describe the data. Finally, the null hypotheses were tested using an independent t-test at a 0.05 level of significance to compare the performance or awareness levels between two independent groups.

RESULTS AND DISCUSSION

Table 1: Construct Validity of the Items of Meta-cognitive Awareness Inventory in Physics (MAIP) in Terms of their Factor Loadings

Factor 1		Factor 2		Factor 3		Factor 4		Factor 5	
Item	Loadings	Item	Loadings	Item	Loadings	Item	Loadings	Item	Loadings
0	.56	1	3	2	.	3	.	0	.60
8	0.43						.56		

			6		6								
			2		2								
		0		4		6			7		0	9	0.41
0	.65	4	.		.		.48			.47			
			6		5								
			4		0								
		0		5		44			3		0	1	0.49
1	.63	5	.		.		.47	1		.49	6		
			6		6								
			5		2								
		0		6		51			3		0	4	0.41
2	.55	6	.		.		.65	8		.50	9		
			5		4								
			7		2								
		0		8		54			5		0	5	0.49
3	.64	7	.		.		.44	2		.53	6		
			5		6								
			6		2								
		0		11		55			5		0	6	0.42
4	.64	8	.		.		.49	9		.46	5		
			4		4								
			3		2								
		0		29		58			6		0	7	0.50
5	.68	9	.		.		.58	3		.47	0		
			6		4								
			4		3								
		0		32		61			6		0		
6	.56	0	.		.		.45	6		.69			
			5		5								
			9		8								
		0		33		62			7		0		
7	.58	1	.		.		.46	3		.67			
			6		4								
			1		5								
		0		39		63			7		0		
8	.63	2	.		.		.44	4		.43			
			7		4								
			0		1								
		0		40		65							
9	.66	3	.		.		.52						
			6		4								
			7		2								
		0		46		68							
0	.67	4	.		.		.45						
			6		4								
			7		9								
		0		47		71							
1	.70	5	.		.		.50						
			6		4								
			5		1								
		0		53		72							

2	.66	6	.57	0	.73	54	75	.48	
3	.57	7	.50	0	.44	57		.54	
4	.71	8	.55	0	.64	60			
5	.72	9	.67	0	.68	61			
6	.69	0	.65	0	.45	62			
7	.45	5	.41	0	.42	64			
8	.69			0	.65	67			
9	.60			0	.69	68			
0	.50			0	.47	75			
1	.64			0	.45	76			
2	.46				.40				

Table 1 reveals the construct validity of the items of Meta-cognitive Awareness Inventory in Physics (MAIP) for senior secondary students in Benue State in terms of their factor loadings. The table shows that 43 items loaded above 0.40 on factor 1, 24 items loaded above 0.40 on factor 2, 15 items loaded above 0.40 on factor 3, 10 items loaded above 0.40 on factor 4, and seven items loaded above 0.40 on factor 5.

The analysis indicates that items 1, 2, 3, 4, 5, 7, 10, 12, 13, 14, 15, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 30, 34, 35, 36, 37, 41, 42, 43, 45, 48, 50, 51, 52, 53, 55, 56, 57, 58,

59, 60, 64, 66, 67, 70, 71, 72, 73, 74 and 76 loaded more than 0.4 on only a factor. The loading of the items on only one factor shows that the items are factorially simple or pure items. The table further reveals that items 6, 8, 9, 11, 16, 29, 31, 32, 33, 38, 39, 40, 44, 46, 47, 49, 54, 61, 62, 63, 65, 68, and 75 loaded more than 0.4 on two factors. The loading of these items on more than one factor shows that these items are factorially complex. Therefore, the construct validity of the items of the Meta-cognitive Awareness Inventory in Physics (MAIP) for secondary school students in Benue State in terms of their factor loadings is that, the MAIP has 52 factorially simple or pure items and 23 factorially complex items in terms of their factor loadings.

Table 2: Estimate of Internal Consistency of Components of Meta-cognitive Awareness Inventory in Physics (MAIP)

Cluster	Components of Meta-cognition	No of Items	Reliability Index
1	Declarative	15	0.92
2	Procedural	8	0.89
3	Conditional	6	0.87
4	Monitoring	8	0.91
5	Evaluation	11	0.93
6	Debugging	8	0.87
7	Planning	6	0.82
8	Information Management	13	0.91
Full length		75	0.98

Analysis of data in Table 2 shows the coefficient of internal consistency of the clusters of Meta-cognitive Awareness Inventory in Physics (MAIP) and the overall coefficient of internal consistency of the Meta-cognitive Awareness Inventory in Physics (MAIP). The table reveals that declarative knowledge with 15 items has coefficient of internal consistency of 0.92 while procedural knowledge with eight items has coefficient of internal consistency of 0.89, and conditional knowledge with six items has coefficient of internal consistency of 0.87. The table further reveals that, monitoring with eight items has coefficient of internal consistency of 0.91 while evaluation with 11 items has coefficient of internal consistency of 0.93 but debugging with eight items has coefficient of internal consistency of 0.87 and planning with six items has coefficient of internal consistency of 0.82, then information management with 13 items has coefficient of internal consistency of 0.91. Based on excellent reliability (0.90 and above), high reliability (0.70-0.90), moderate reliability (0.50-0.70) and low reliability (0.50 and below). The coefficients of internal consistency of the sub-scales show that, declarative knowledge, monitoring, evaluation and information management have excellent internal consistency while procedural knowledge, conditional knowledge, debugging and planning have high internal consistency. The coefficient of internal consistency of Meta-cognitive Awareness Inventory in Physics (MAIP) for secondary school students in Benue State is 0.98. This coefficient shows that the Meta-cognitive Awareness Inventory in Physics (MAIP) has excellent internal consistency hence reliable.

Table 3: Mean Meta-cognitive Awareness Ratings of Male and Female Students using Meta-cognitive Awareness Inventory in Physics (MAIP)

Students' Gender	N	Mean	Standard Deviation	Standard Error
Male	698	2.41	0.68	0.03
Female	684	2.34	0.65	0.02
Mean Difference		0.07	0.03	

The analysis of data in Table 3 shows the mean and standard deviation of meta-cognitive awareness of 698 male and 684 female students studying Physics in senior secondary schools

in Benue State. The table reveals that, the mean meta-cognitive awareness rating of male students is 2.41 with a standard deviation of 0.68. The table further indicates that, the mean meta-cognitive awareness rating of female students is 2.34 with a standard deviation of 0.65. These obtained mean and standard deviations show that, female students are more homogenous (that is, they clustered around the mean with lower standard deviation) in their meta-cognitive awareness rating than their male counterparts in senior secondary schools in Benue State. The difference in the mean meta-cognitive awareness rating of male and female students using Meta-cognitive Awareness Inventory in Physics (MAIP) for secondary schools in Benue State, Nigeria is 0.07 in favour of male students in Benue State. To ascertain if the difference in the mean meta-cognitive awareness of male and female students in senior secondary schools is statistically significant, the corresponding hypothesis is tested.

Table 4: t-test of Mean Meta-cognitive Awareness ratings of Male and Female Students using Meta-cognitive Awareness Inventory in Physics (MAIP)

Gender	N	Mean	Standard Deviation	t	df	Sig	Remark
Male	1380	2.41	0.68	1.977	1380	0.048	Sig
Female	1084	2.34	0.65				

N = Number of respondents, t = Critical value of t-test, df = Degree of freedom

The analysis of data in Table 4 shows that, the the probability associated with the critical value of t (1.977) at df = 1380 is 0.05, since the probability value of 0.048 is less than 0.05 level of significance if rounded up to two digits, the test statistic is significant and hence, the null hypothesis is rejected. Therefore, there is significant difference in the mean meta-cognitive awareness ratings of male and female students in favour of male students using Meta-cognitive Awareness Inventory in Physics (MAIP) for secondary schools in Benue State, Nigeria. This implies that male students have higher meta-cognitive awareness ratings than their female counterparts. Hence, gender is a factor in meta-cognitive awareness of students using Meta-cognitive Awareness Inventory in Physics (MAIP).

The study found that, the Meta-cognitive Awareness Inventory in Physics (MAIP) has excellent psychometric property of construct validity. Findings on a principal components analysis with varimax rotation conducted on the Meta-cognitive Awareness Inventory in Physics (MAIP) for senior secondary school students in Benue State revealed equivalence in the pattern of factor loading of the ratings of the Meta-cognitive Awareness Inventory in Physics (MAIP). A higher percentage of the items of Meta-cognitive Awareness Inventory in Physics (MAIP) are factorially simple or pure. Few items were cross loaded on more than one interpretable factor and were considered factorially complex.

Explicitly, the high number of factorially simple or pure items found in this study may be due to the high mean meta-cognitive awareness ratings found for students in urban areas and private senior secondary schools across the area of study. Furthermore, the complex items of Meta-cognitive Awareness Inventory in Physics (MAIP) in terms of their factor loadings may be the result of the interaction between the shifting conception of meta-cognition and external effects such as the students' culture, background and learning styles. The difference in conception could be a measurement artifact arising from biases that are typically found in self-reported inventory such as the Meta-cognitive Awareness Inventory in Physics (MAIP).

The finding agrees with that of Fung and Leung (2017) that, factor analysis with Oblimin rotation yielded four factors which were classified as prediction, planning, monitoring and evaluation according to the content of the items. The finding also agrees with that of Harrison and Vallin (2017) that, the 52 items function better as two theoretical dimensions, knowledge and regulation, than as a single dimension. Even though the two dimensions correlated strongly, the factor structure better explained the empirical data than did that of the

unidimensional model. It was also found that, this theoretical structure fit better than that based on Schraw and Dennison's exploratory factor analysis, which places into question scoring procedures based on that structure.

The finding concur with that of Sirajuddin et al., (2018) that, the result of empirical validation is 45 items are valid in topics of Newton's law, gravitational force, work and energy, momentum and impulse, and harmonic motion and I-KPS is valid instrument both theoretically and empirically. The finding also agrees with that of Arum et al., (2019) that, the assessment instrument is valid in the content validation and the empirical validation and able to measure Physics problem solving skills. The finding agrees with that of Panaoura and Philippou (2019) that, first order factor contained items for the knowledge of cognition and a different first order factor contained items for the regulation of cognition. The finding is consistent with that of Haeruddin et al., (2020) that, the Physics Meta-cognition Inventory (PMI) has good valid psychometric properties. Therefore, PMI can be used to measure the level of meta-cognition of students when solving physics problems. However, the finding disagrees with that of Teo and Lee (2012) that, the eight-factor hypothesized model that underlies the responses to the 52 items in the MAI did not fit adequately.

The finding in respect of the coefficient of internal consistency of Meta-cognitive Awareness Inventory in Physics (MAIP) for secondary school students in Benue State revealed that each cluster of the MAIP has high and excellent coefficient of internal consistency. The coefficient of internal consistency of Meta-cognitive Awareness Inventory in Physics (MAIP) for secondary school students in Benue State was 0.98. This coefficient shows that the Meta-cognitive Awareness Inventory in Physics (MAIP) has excellent internal consistency that is considered reliable.

The high coefficient of internal consistency found for Meta-cognitive Awareness Inventory in Physics (MAIP) for secondary school students in Benue State may be based on the fact that, the instrument measures the acquisition of domain-specific awareness within specific subject matter of instruction. The high coefficient of internal consistency found for the clusters of Meta-cognitive Awareness Inventory in Physics (MAIP) and the coefficient of internal consistency of the instrument shows the consistency of the ratings for different items for the same construct within the measured construct. The reliability results determine the extent to which individual difference in the ratings on the inventory are attributed to true differences in the constructs or the characteristics of students offering Physics as a school subject in the study area. That is whether the observed individual differences are simply a result of chance or biased errors. The finding revealed that, the Meta-cognitive Awareness Inventory in Physics (MAIP) has displayed high and excellent reliability which indicates minimum error of variance.

The findings also agree with that of Heli, et al (2017) that, the internal consistency of all the factors was found good and, moreover, the Alpha of the entire questionnaire was 0.90. The finding is consistent with that of *Rahmawati* et al., *(2018) that, the* value of the reliability coefficient (α) of 0.87 indicated that the instrument of Conception Test on Electrical and Magnetism topics was valid and sufficient to measure students' conception on electrical and magnetism topic. The finding is consistent with that of Sirajuddin et al., (2018) that, the reliability coefficient of Science Process Skills Instrument (I-KPS) is 0.935 and that the I-KPS is reliable instrument both theoretically and empirically. The finding agrees with that of Unlu and Dokme (2019) that, the measurement reliability of the sub-scale ranges from 0.87 to 0.72 and that the Cronbach's Alpha reliability coefficient for the whole scale was calculated as 0.92. The finding agrees with that of Panaoura and Philippou (2019) that, the inventory demonstrated an overall high reliability of Cronbachs' Alpha 0.83. The finding is consistent with that of Azza and Mundilarto (2020) *that, the reliability of the items of* Physics Cognitive Learning Achievement *was 0.89 for the ability ranging from -2 to 2 with standard error measurement 0.23, which means it was in a very high category.* The finding is consistent with that of Ike et al., (2020)

that, the result of this research obtained a reliable Concept Mastery Test that is enriched with all four types of representations.

Findings in respect of mean meta-cognitive awareness of male and female students using Meta-cognitive Awareness Inventory in Physics (MAIP) for secondary schools in Benue State revealed that there was significant difference in the mean meta-cognitive awareness in Physics of male and female students in favour of male students using Meta-cognitive Awareness Inventory in Physics (MAIP) for secondary schools in Benue State, Nigeria. This implies that, male and female students vary in their mean meta-cognitive awareness in Physics based on the Meta-cognitive Awareness Inventory in Physics (MAIP) ratings.

The significant difference found in the mean meta-cognitive awareness of male and female students in favour of male students based on Meta-cognitive Awareness Inventory in Physics (MAIP) ratings may be due to the fact that, male students are superior to female students in terms of physical physique, cognition, logical reasoning and academic achievement (Nworgu, et al., 2019). The allocation of more duties, responsibilities and roles to the male students in Physics class by their teacher might have enhanced their meta-cognitive awareness and may be responsible for the significant difference in the mean meta-cognitive awareness.

The finding agrees with that of Snehalatha (2017) that, testing the significance of difference in meta-cognitive awareness, the male students are found to be higher than their female counterparts. Similarly, the male higher secondary students are found to be higher than their female counterparts in the dimension meta-memory. The findings agrees with that of Nworgu, et al., (2018) that, there was significant difference between the meta-cognitive awareness of male and female science students of low cognitive ability levels. However, The finding disagrees with that of Aljaberi and Gheith (2015) that, Petra University students have a medium level of meta-cognitive thinking, and that the variables of sex had no effect on their level of meta-cognitive thinking. The finding disagrees with that of Jaleel and Premachandran (2016) that, there is no significant difference in the meta-cognitive awareness of secondary school students based on their gender and that, secondary school students are identically distributed among each group in the meta-cognitive awareness.

CONCLUSION

The Meta-cognitive Awareness Inventory in Physics (MAIP) for secondary school students in Benue State has excellent psychometric properties of construct validity, reliability and usability. The Meta-cognitive Awareness Inventory in Physics (MAIP) is effective in determining the level of meta-cognitive awareness in Physics of male and female students in senior secondary schools in Benue State, Nigeria.

AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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