Is the SAMR Model Valid and Reliable for Measuring the Use of ICT in Pedagogy? Answers from a Study of Teachers of Mathematical Disciplines in Universities in Uganda

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ABSTRACT

Puentedura's (2006) SAMR model of the use of ICT operationalises ICT as consisting of substitution (S), augmentation (A), modification (M) and redefinition (R) constructs. Accordingly, this study sought first, to establish the validity and reliability of each of the four constructs (S, A, M & R). Second, to test whether the four constructs were independent. Third, to re-examine whether the four-factor SAMR model of ICT was reasonable. A sample of 261 was chosen from among teachers of mathematical disciplines in four universities in Uganda who reacted to a self-administered questionnaire. The analysis involved using confirmatory factor analysis (CFA) and Cronbach alpha (first objective); Pearson's linear correlation (second objective); and exploratory factor analysis (EFA) (third objective). CFA suggested that while not all the items of each of S and A constructs were valid measures, all the items of each of M and R constructs were valid. The four constructs were highly inter-correlated. EFA revealed that the four-factor SAMR model of

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operationalising ICT was questionable. Hence a call was made to researchers to continue testing the SAMR model in different contexts with intent to refining it.

General terms: Academic Staff, Cronbach Alpha, Factor Analysis, Mathematical disciplines, Use of ICT in pedagogy

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1. INTRODUCTION

Lloyd (2005) defined ICT as "those technologies that are used for accessing, gathering, manipulating and presenting or communicating information" (p. 3). These technologies, she explained, include hardware such as computers and other devices; software applications; and connectivity such as access to the Internet. She then defined the use or integration of ICT in pedagogy (UIP) as "a change in pedagogical approach to make ICT less peripheral to schooling and more central to student learning" (p. 5). From its conception, UIP is of utmost importance. According to Noor-Ul-Amin (2013), UIP provides opportunities to the learner to access an abundance of information using multiple information resources and also to view information from multiple perspectives.

Given its importance, UIP has attracted several studies. But how is UIP measured in those studies? To that effect, several scholars (e.g. Jamieson-Proctor, Watson, Finger, Grimbeek & Burnett, 2006; Papanastasiou & Angeli, 2008; Peeraer & Petegem, 2012; Proctor, Watson & Finger, 2003; Puentedura, 2006) have made attempts to develop and/ or test instruments that measure UIP by teachers and students. Of particular interest in this study is the substitution, augmentation, modification and redefinition (SAMR) model (Puentedura, 2006). This study evaluated the validity and reliability of an instrument based on the SAMR model in the context of the teachers of mathematical disciplines in four universities in Uganda.

2. LITERATURE REVIEW

2.1 Instruments on the use of ICT in pedagogy than those based on SAMR

Jamieson-Proctor et al. (2006) developed an instrument that they termed the "Learning with ICTs: Measuring ICT Use in the Curriculum". Their instrument was an improvement of the "ICT Curriculum Integration Performance Measurement" instrument (Proctor et al., 2003), which had 137 self-rated items, scaled using the four-point Likert (as Never, Sometimes, Often & Very often). Using face validity that involved examining the items of the instrument for redundancy and ambiguity, Jamieson-Proctor et al. reduced the items to 45 in number. They then administered the refined instrument to 929 teachers in 38 state primary and secondary schools in Queensland, Australia. Using a series of validity and reliability analyses, they further reduced the instrument to 20 items, and termed it "Learning with ICTs: Measuring ICT use in the Curriculum".

Papanastasiou and Angeli (2008) constructed what they termed a "survey of factors affecting teachers teaching with technology (SFA-T^3)" (p. 70). Such factors included those related to (a) a teacher's knowledge of technology tools (14 items), and (b) a teacher's frequency of using technology for personal purposes (15 items). While they referred to their tool as being on "factors affecting teachers teaching with technology", in reality the tool had constructs – see those given above – dealing with teaching with technology itself. They sought to determine the reliability and validity of the instrument. Hence using Cronbach and factor analyses respectively, they found their instrument sound.

Peeraer and Petegem (2012) developed an instrument to measure the integration of ICT in education. Having carried out a literature search on the definitions of the integration of ICT in education, they used the item response modeling approach (Wilson, 2005 cited in Peeraer & Petegem, 2012, p. 1252) to develop a self-report instrument on teacher educators' use of ICT for teaching and support of students' learning. In the bid to test the validity and reliability of their 15-item instrument, Peeraer and Petegem (2012) collected data from 933 teacher educators working in five teacher education institutions in five different regions in the north and centre of Vietnam. Finally, using the Rasch model of measurement (Linacre, 2002 cited in Peeraer & Petegem, 2012), they concluded that their instrument could be used with confidence.

2.2 Instruments on the use of ICT in pedagogy based on SAMR

As part of his work with the Maine Learning Technologies Initiative, Puentedura (2006) developed the substitution, augmentation, modification and redefinition (SAMR) model of ICT which he intended to encourage educators to significantly enhance the quality of education provided via technology (Romrell, Kidder & Wood, 2014). According to Puentedura (2006 cited in Romrell et al., 2014), at the level of substitution, ICT acts as a substitute for another technology, but with no functional change. An example of this is when one uses a computer as a substitute for a type writer for purposes of producing documents but without any significant change to the function of a type writer. At the level of augmentation, ICT acts as a substitute for another technology, but with functional improvement. For example, one can use a computer as a substitute for a type writer but with significant functionality increase such as spell checking. At the modification level, ICT allows for activities to be redesigned. An example in the modification dimension is when ICT allows for the learning processes to integrate them with technology such as email and graphics packages. Lastly, at the redefinition level, ICT allows for the creation of new tasks that were previously inconceivable. According to Lubega et al. (2014), such tasks involve the use of visualization and simulation tools as part of the learning activities. According to Puentedura (2013, cited in Romrell, 2014, p. 5), "learning activities that fall within the substitution and augmentation [S & A] classification are said to enhance learning, while learning activities that fall within the modification and redefinition [M & R] classifications are said to transform learning".

In accordance with Green (2014) who contends that SAMR "is an extremely popular model" (p. 37), several researchers have used it to guide their studies on the use of ICT in pedagogy. For example, Azama (2015) examined the integration of ICT by a beginning Japanese class in a public high school in a rural town in California. He measured the integration of ICT using the SAMR model. In particular, he reported that "technology enhanced activities… [were] developed based on the SAMR model and students' learning… documented through formative assessments and personal reflections" (p. 21). In terms of results, Azama (2015) reported that,

although students' responses did not show any particular SAMR stage being more engaging than other stages, when students were asked to rate which technology tools they imagined they would use in the future, significantly more students chose redefinition tasks over the other stages of activities. Although students found some activities in the augmentation stage enjoyable, they perceived those activities… as [mere] "tools of learning". However, the activities in the modification and redefinition stage[s] were perceived as useful by students for everyday purposes (pp. 34 - 35).

Kihoza, Zlotnikova, Bada and Kalegele (2016) examined the technological knowledge, competencies, skills, attitude, beliefs and readiness to integrate classroom technology of teacher trainees and tutors. The trainees and tutors were from Morogoro Teacher Training College and Mzumbe University both of Morogoro Region in Tanzania. They used an instrument structured according to SAMR to collect data on the use of ICT in pedagogy from 206 respondents and used descriptive statistics to show that the majority of the respondents had low pedagogical ICT competencies. In particular they reported finding that, the "ICT competence level [that the] majority reported was [that of] beginners" (p. 116). That is, the majority of the respondents were at the substitution (S) level in SAMR terms. They went on to report that, in terms of the "augmentation [A] attributes [that] were used to assess tutors' and teacher trainees' readiness to integrate ICTs in classrooms", the majority of the tutors reported being well prepared and somewhat prepared. However for the teacher trainees, the majority reported either being poorly prepared or not prepared at all (p. 117). They recorded similar patterns for the use of ICT at the modification (M) and redefinition (R) levels.

Lubega et al. (2014) assessed the adoption of ICT in pedagogy by the academic staff and students of Makerere University in Uganda. Using an instrument that they had structured as per the SAMR model, they collected data from 600 respondents, which they analysed using descriptive statistics, notably percentages. Hence Lubega et al. found that non-use of a number of ICT tools in pedagogical processes in Makerere was highly prevalent. In particular, at the substitution (S) level in SAMR terms, they reported finding that, “a number of teaching activities... [were] yet to be computerized even at the basic substitution level” (p. 110). Then at the augmentation (A) level, they summarized their finding by noting that, “more pedagogical activities in and outside the classroom... [were] mainly ported onto substitution ICTs than augmentation ICTs” (p. 111). At the modification (M) stage, they reported that, “the most common modification ICT... [was] the Internet” (p. 112). Lastly with regard to the use of ICT at redefinition (R) level, they reported only a trace of activities at that level.

Speirs (2016) assessed mobile device skills and the integration of technology into the lives of pre-service teachers at the State University New York (SUNY) Plattsburgh and practicing teachers in New York State. Having structured his questionnaire using SAMR to categorise activities commonly completed with mobile devices, Speirs (2016) used a class of 10 psychometrics graduate students and their professor to ensure the face validity of the items. Then he collected data from 53 respondents. In terms of analysis, he reported that “total values for each SAMR level were calculated in accordance with the structure of the survey” (p. 15). Also, “scores for total integration level (IntTot)… were evaluated for normality” (p. 16). Hence in terms of findings, he reported that the “skewness for IntTot scores was highly… to the left, indicating that many participants indicated high level[s] of technology integration into their lives” (p. 18).

Apart from empirical studies using SAMR, even literature reviews (e.g. Green, 2014; Romrell et al., 2014) on the same are available. Green (2014) started generously by noting that “SAMR is an extremely popular model” (p. 37) because “SAMR is clean and simple, which means it can be easily adapted and interpreted in multiple ways” (p. 38). However she went on to question whether Ruben Puentedura who had a PhD in Chemistry and whose name features “on several institutional documents and news articles concerning his work in Physics, Chemistry and multimedia labs” (p.

38) could have originated the SAMR model independently. Green further asserted that, "Puentedura has not published any results of the decade of study he claims to have conducted" (p. 39) as he developed SAMR. She thus went on to insinuate that Puentedura may have plagiarized the idea of SAMR from Hughes (2005) whose article had identified three functions of technology as replacement (which SAMR calls substitution), amplification (which SAMR calls augmentation) and transformation (which terms SAMR reserves for both its modification and redefinition constructs together). Another shortcoming of SAMR, according to Green (2014) was that Ruben Puentedura who proposed it, had hardly used it in his empirical studies. In particular, Green (2014) contended that, "no peer reviewed papers on this model have been authored and published by Puentedura" (p. 38-39). That implied that it is others (e.g. Azama, 2015; Kihoza et al., 2016; Lubega et al., 2014; Speirs, 2016) who have empirically used SAMR and not its proponent, Puentedura, himself. Green (2014) however, made a general critique of all such studies lamenting that, "there is no record of research studies that could document the development and validation of SAMR" (p. 39). In other words, the studies that have used the SAMR model have used it at face value without checking its validity and reliability.

Romrell et al. (2014) devoted their energies to highlighting the SAMR model as a framework for evaluating mobile learning (mLearning). Having defined mLearning as "learning that is personalized, situated, and connected through the use of a mobile device" (p. 1), they went on to review recent literature on mLearning and to provide examples of activities from studies, that fell within each of the four classifications of the SAMR model. The classifications, as expected, were substitution, augmentation, modification and redefinition.

As suggested by the reviewed studies, as Green (2014) claimed, among the studies (e.g. Azama, 2015; Kihoza et al., 2016; Lubega et al., 2014; Speirs, 2016) that have used the SAMR model empirically, "there is no record of research studies that could document the development and validation of SAMR" (p. 39). Indeed, as we prepared this article, our efforts to come across one scholarly article of that kind was in vain. In other words, the studies that have used the SAMR model have used it at face value without checking its validity and reliability. On the basis of such gaps, this study came in handy to test the validity and reliability of the SAMR model using the teachers of mathematical disciplines in four universities in Uganda. In particular, the study sought; first, to establish the validity and reliability of each of the four constructs (S, A, M & R). The second objective of this study was to test whether the four constructs were independent. Third, the study was to re-examine whether the SAMR model of ICT as being made up of the four constructs (S, A, M & R) was reasonable.

3. METHODOLOGY

3.1 Instrument

Using the survey design, data were collected using Puentedura's (2006) SAMR measure of the use of ICT in pedagogy (UIP), which operationalises the use of ICT in pedagogy as having the substitution (S), augmentation (A), modification (M), and redefinition (R) constructs. This instrument was developed by Lubega et al. and hence sourced from Lubega et al. (2014, Tables III, IV, V & VIII). However, before collecting the data, preliminary validation of the instrument was carried out using face validity to see which items were applicable to teachers at university level. Hence, the items on S reduced from 13 to 12; those on A reduced from 16 to nine; those on M reduced from 10 to five; and lastly those on R reduced from six to five in number. In total there were 31 items measuring UIP. The items were scaled using the five-point Likert scale from a minimum of 1 for the worst case scenario (strongly disagree) to a maximum of 5, which was the best case scenario (Strongly agree).

3.2 Sample

The sample comprised 261 academic staff teaching mathematical disciplines in four universities in Uganda, namely Kyambogo (KyU), Makerere (Mak), Makerere University Business School (MUBS) and Mountains of the Moon (MMU). The term "mathematical disciplines" was taken to be broad and thus included a range of disciplines where mathematical skills are useful. Such disciplines included Science, Technology, Engineering and Mathematics (STEM) disciplines and their offshoots like Biomathematics, Finance, Management Science, Quantitative Data Management, and Software Engineering. As suggested in Table 1, a typical respondent was aged 30 but below 40 years (62.9%); a male (64.0%); belonging to the Makerere University Business

School, MUBS (36.0%); having served for below five years as a lecturer at university level (56.6%); holding a Masters degree (69.6%) as the highest qualification; and currently holding the academic rank of Lecturer (48.8%).

Table 1: Background Characteristics of the Respondents

Item	Categories	Frequency	Percent
Age group in years of the respondent	Up to 30	33	15.7
	30 but below 40	132	62.9
	40 and above	45	21.4
Gender of the respondent	Female	94	36.0
	Male	167	64.0
University to which the respondent belonged	Kyambogo	50	19.2
	Makerere	87	33.3
	Makerere University Business School	94	36.0
	Mountains of the Moon	30	11.5
Tenure in years of lecturing at university level of the respondent	Up to five	141	56.6
	Five but below 10	85	34.1
	10 and above	23	09.2
Highest academic qualification attained by the respondent	Bachelors degree	20	07.7
	Masters degree	181	69.6
	PhD degree	59	22.7
Academic rank of the respondent	Teaching Assistant	20	07.7
	Assistant Lecturer	68	26.2
	Lecturer	127	48.8
	Senior Lecturer	37	14.2
	Associate Professor	06	02.3
	Professor	02	0.8

3.3 Data Analysis

The validities of multi-item constructs of SAMR, namely S, A, M and R, were tested using confirmatory factor analysis (CFA), while their reliabilities were tested using the Cronbach alpha method. Pearson's linear correlation analysis was carried out to establish whether the constructs of SAMR were independent, while exploratory factor analysis (EFA) helped with the re-assessment of the structure of SAMR.

4. RESULTS

4.1 Validities and Reliabilities

The first objective of the study was to establish the validity and reliability of the measure for each of the four constructs of SAMR. This was achieved via confirmatory factor analysis (CFA) and Cronbach alpha on the items on each construct. The Kaiser rule or criterion (Kaiser, 1960 cited in Khan, 2006, p. 690; Yong & Pearce, 2013, p. 85) or the Kaiser-Guttman rule (cited in Schmidt, Baran, Thompson, Mishra, Koehler & Shin, 2009, p. 131) that stipulates that factors with eigenvalues greater than one be considered significant, was used in the study. For a given factor loading, 0.5 (Costello & Osborne, 2005) was used as the minimum. For reliability tests, a benchmark of $\alpha = 0.7$ (Tavakol & Dennick, 2011) for the Cronbach alpha was set. The results are as presented in the subsequent tables (Tables 2 through 5).

4.1.1 Use of Substitution ICTs

According to Table 2, confirmatory factor analysis (CFA) reduced the 12 items of the first construct (S) in SAMR to three factors. The respective factors had eigenvalues of 6.42, 1.54 and 1.16, meaning that the respective three factors accounted for 6.42/ 12 x 100 = 53.5%; 1.54/ 12 x 100 = 12.8%; and 1.16/ 12 x 100 = 09.7% of the total variance among the 12 items. The loadings of the respective items on a given factor are also given in Table 2 after a Varimax rotation, as recommended by Kline (1994, cited in Foster, 1998, p. 207). Considering loadings of at least 0.5 as being high, then Table 2 suggests that only seven items (S3 – S5, S7 – S10) loaded highly on the first and main factor. Five items (S1, S2, S4 – S6) loaded highly on the second factor; while two others (S11 & S12) loaded highly on the third and least among the significant factors. Given that "Kaiser's criterion will often yield too many factors [to be] retained" (Khan, 2006, p. 690), for the sake of parsimony, as advised by Khan (2006, pp. 690 - 691), only the five items (S3, S7 – S10) that loaded highly on only the first and main factor, were taken as the (most) valid items of S. Items S4 and S5 cross-loaded on the first two factors and hence were dropped for being complex (Yong & Pearce, 2013, p. 84). The reliability (Cronbach alpha, α) of the valid items (S3, S7 – S10) was 0.920, which being greater than 0.7, implied that the five items were reliable measures of S too.

Table 2: Loadings on Factors on the Use of Substitution ICTs (S)

		Loadings			
Items	Descriptions	Factor 1	Factor 2	Factor 3	α
S1	I use ICTs to prepare my lecture notes, assignments and examinations		0.910		0.920
S2	I use presentation software (e.g. PowerPoint) to deliver my lectures		0.709		
S3*	I upload my teaching and learning materials on electronic sites/ devices (e.g. MUELE) for students to access	0.711			
S4	When supporting my students, I communicate to them using e-mail	0.571	0.662		
S5	I refer my students to electronic databases for reference materials	0.569	0.634		
S6	When supporting my students, I communicate to them using my cell phone		0.570		
S7*	During my lectures, I use the smart boards/ interactive boards installed in the lecture rooms for writing	0.860			
S8*	I encourage students to submit their course work assignments through e-mail	0.800			
S9*	When communicating to my students, I use electronic notice boards	0.899			
S10*	When supporting my students, I communicate to them through social media (e.g. blogs, chat rooms, discussion boards, Facebook, Instagram and Twitter)	0.796			
S11	I record my lectures on CDs or other media and give them to my students			0.850	
S12	I take video/ audio recordings of myself while lecturing and use them in subsequent years to teach the same course to another cohort of students			0.908	
Eigenvalue		6.417	1.536	1.160	
% variation explained		53.5	12.8	09.7	

*Valid items of S

4.1.2 Use of Augmentation ICTs

According to Table 3, CFA reduced the nine items of the second construct (A) in SAMR to two factors. The respective factors had eigenvalues of 5.07 and 1.17, meaning that the respective two factors accounted for 56.3% and 13.0% of the total variance among the nine items. The loadings of the respective items on a given factor are also given in Table 3 after a Varimax rotation. Considering loadings of at least 0.5 as being high, then Table 3 suggests that only five items (A5 – A9) loaded highly on the first and main factor. The other four items (A1 - A4) loaded highly on the second and minor among the significant factors. As was the case for the construct S, and for the same reasons, only the five items (A5 – A9) that loaded highly on the first and main factor, were taken as the (most) valid items of A. Their reliability (Cronbach alpha, α) of 0.861 implied that the five items were also reliable measures of A.

Table 3: Loadings on Factors on the Use of Augmentation ICTs (A)

		Loadings		
Items	Descriptions	Factor 1	Factor 2	α
A1	I use search engines (e.g. Google) to look for content in my discipline		0.834	0.861
A2	I use editorial tools (e.g. spell checker) in my word processor to correct grammatical errors in any document I process		0.847	
A3	I use editorial tools (e.g. Thesaurus) in my word processor to get alternative words to use in my documents		0.717	
A4	I use online encyclopedias (e.g. Wikipedia) to make meaning of words or phrases that I do not understand		0.695	
A5*	I use digital libraries (e.g. MuLib and MakIR) as a source of useful content for my lectures	0.781		
A6*	I use the track changes tool in my word processor to review documents (e.g. student dissertations/ theses)	0.645		
A7*	I use internet group lists to contact my students in matters related to their academics	0.785		
A8*	I encourage my students to use Google docs to accomplish group course work assignments			
		0.795		
		0.811		
A9*	I use different videos to illustrate different case studies during my lectures	0.745		
Eigenvalue		5.069	1.167	
% variation explained		56.3	13.0	

*Valid items of A

4.1.3 Use of Modification ICTs

According to Table 4, CFA reduced the five items of the third construct (M) in SAMR to the ideal situation of one factor. The factor had an eigenvalue of 3.08, meaning that the factor accounted for 61.5% of the total variance among the five items. The loadings of the respective items on the factor are also given in Table 4. Considering loadings of at least 0.5 as being high, then Table 4 suggests that all the five items (M1 – M5) loaded highly on the factor. Hence all of them were valid items of M. Their reliability (Cronbach alpha, α) was 0.842, implying that the five items were also reliable measures of M.

Table 4: Loadings on the Factor on the Use of Modification ICTs (M)

Items *	Descriptions	Loadings	α
M1	I assign students topics to research about from the Internet	0.517	0.842
M2	I lecture modules in my discipline using e-learning platforms (e.g. MUELE)	0.892	
M3	I use content authoring software when preparing my lectures	0.882	
M4	I use online tools (e.g. RM Assessor) to assess my students	0.898	
M5	I use video conferencing or Skype to teach my students when I am not at the University	0.655	
Eigenvalue		3.075	
% variation explained		61.5	

* All items were valid for M

4.1.4 Use of Redefinition ICTs

According to Table 5, CFA reduced the five items of the fourth and last construct (R) in SAMR to the ideal situation of one factor. The factor had an eigenvalue of 3.46, meaning that the factor accounted for 69.2% of the total variance among the five items. The loadings of the respective items on the factor are also given in Table 5. Considering loadings of at least 0.5 as being high, then Table 5 suggests that all the five items (R1 – R5) loaded highly on the factor. Hence all of them were valid items of R. Their reliability (Cronbach alpha, α) was 0.888, implying that the five items were reliable measures of R too.

Table 5: Loadings on the Factor on the Use of Redefinition ICTs (R)

Items *	Descriptions	Loadings	α
R1	I use open education resources (e.g. massive open online courses, MOOCS) as my lecturing materials	0.851	0.888
R2	I use electronic games when lecturing	0.514	
R3	I use simulations (e.g. 2nd life) when lecturing	0.903	

R4	I use e-learning platforms (e.g. MUELE) to encourage group discussions among my students	0.900
R5	I use e-learning platforms (e.g.MUELE) to assess my students' learning	0.921
Eigenvalue		3.460
% variation explained		69.2

*All items were valid for R

4.2 Correlations among the SAMR Constructs

The second objective of the study was to test whether the four constructs in the SAMR model, namely substitution (S), augmentation (A), modification (M) and redefinition (R) were independent. Average indexes were computed for the valid items of the respective constructs from Tables 2 - 5. The indexes were then correlated using Pearson's linear correlation. Table 6 (correlation matrix) suggests that all the four constructs were significantly inter-related.

Table 6: Inter-correlations of the SAMR Constructs

	S	A	M	R
S				
A	0.667**			
M	0.783**	0.727**		
R	0.770**	0.703**	0.864**	

** Correlation is significant at the 0.01 level

4.3 Re-examining the Structure of SAMR

The third and last objective in the study was to re-examine whether the SAMR model of ICT (Puentedura, 2006) as being made up of the four constructs (S, A, M & R) was reasonable. Exploratory factor analysis (EFA) reduced the 31 items in the SAMR instrument (Tables 2 - 5) into as many factors. However, as suggested in Table 7, only the first six factors were significant since they had eigenvalues = 15.17, 2.40, 2.32, 1.25, 1.12 and 1.08 that exceeded 1.00. These factors explained 48.9%, 7.7%, 7.5%, 4.0%, 3.6% and 3.5% respectively of the joint variation in the 31 items. The items with high factor loadings (of at least 0.5) of the respective factors are also given in Table 7 after a Varimax rotation. The question is: Is the SAMR structure as suggested by

Puentedura (2006) discernible in Table 7? Table 7 suggests that only the first four of the factors were significant given that the sixth one had only two cross-loading and hence complex items. The fifth one had only two valid items and could be disregarded, in accordance with Yong and Pearce (2013) who observe that, "factors that have less than three variables… are… undesirable" (p. 86). Thus in agreement with the SAMR model, Table 7 suggested four factors from the 31 items on the use of ICT.

Apart from Factor 3 that was dominated by only one construct (A), none of the other three significant factors was dominated by items from only one construct of SAMR. In particular, Factor 1 had five valid items (S3, S7, S8, S9 & S10) on the use of substitution ICTs; one valid item (A7) on the use of augmentation ICTs; three valid items (M2 - M4) on the use of modification ICTs; and three valid items (R3 – R5) on the use of redefinition ICTs. Factor 2 had two valid items (S5 & S6) on the use of substitution ICTs; and three valid items (A5, A6 & A8) on the use of augmentation ICTs. Factor 4 had two valid items (S11 & S12) on the use of substitution ICTs; and one valid item (A9) on the use of augmentation ICTs. In summary, the SAMR structure as suggested by Puentedura (2006) could hardly be discerned in Table 7.

Table 7 Factors, their eigenvalues, % variance explained and their highly loading items

Factor	Eigenvalue	% variance	Highly loading items (loading in brackets)
1	15.17	48.9	S3 (0.689); *S4 (0.504); S7 (0.792); S8 (0.717); S9 (0.847); S10 (0.696); ** A4 (0.500); A7 (0.754); M2 (0.868); M3 (0.729); M4 (0.697); ***R1 (0.540); R3 (0.691); R4 (0.868); R5 (0.885)
2	2.40	7.7	*S4 (0.626); S5 (0.643); S6 (0.647); A5 (0.781); A6 (0.628); A8 (0.624)
3	2.32	7.5	A1 (0.751); A2 (0.762); A3 (0.692); ** A4 (0.609)
4	1.25	4.0	S11 (0.799); S12 (0.893); A9 (0.531); ****R2 (0.529)
5	1.12	3.6	S1 (0.762); S2 (0.771)
6	1.08	3.5	***R1 (0.600); ****R2 (0.583)

Footnote: Items prefixed with a similar symbol (*S4, **A4, ***R1 and ****R2) were cross-loading, and hence dropped for being complex

5. DISCUSSION

The first objective in the study was to establish the validity and reliability of each of the four constructs, namely substitution (S), augmentation (A), modification (M) and redefinition (R) in

Puentedura's (2006) SAMR model of ICT. Confirmatory factor analysis (CFA) showed that the items on construct S were categorisable into three factors (see Table 2, i.e. S3, S7 – S10 as the most important factor; S1 and S6 as another less significant factor; and S11 and S12 forming the third and least significant factor). This means that if for example all the items on S were to be an independent variable in a model, it would automatically mean that the dependent variable would be regressed on three different factors on S and not one as suggested by the SAMR model. If it was a question of looking for the valid items on construct S, then as we did in this paper (subsection 4.1.1), those factors (S3, S7 – S10) that loaded highly on only the first and main factor, were the most optimal set, given their high reliability (Cronbach alpha, α) of 0.898. Dropping the other seven items (S1, S2, S4 – S6, S11 & S12) in favour of only five is implying that the construct S of SAMR may be unnecessarily long.

CFA showed that the items on construct A were categorisable into two factors (see Table 3, i.e. A5 – A9 as the most important factor; and A1 – A4 forming a second but less important factor). This means that if for example all the items on A were to be an independent variable in a model, it would automatically mean that the dependent variable would be regressed on two different factors on A and not one as suggested by the SAMR model. If it was a question of looking for the valid items on construct A, then as we did in this paper (subsection 4.1.2), those factors (A5 – A9) that loaded highly on only the first and main factor, were the most optimal set, given their high reliability (Cronbach alpha, α) of 0.861. Dropping the other four items (A1 – A4) in favour of only five is implying that the construct A of SAMR may be unnecessarily long. CFA showed that the items on construct M could be reduced to one factor (see Table 4). This meant that all the five items on construct M that loaded highly on the one factor, were valid items of M. They were also reliable, given their high reliability (Cronbach alpha, α) of 0.842. That all the five items (M1 – M5) were valid and reliable, might be implying that the construct M of SAMR may be optimally long. CFA showed that the items on construct R could also be reduced to one factor (see Table 5). Also all the five items (R1 – R5) loaded highly on the factor, implying that they were valid ones. They were also reliable (their Cronbach alpha, $\alpha = 0.888$), suggesting that they were the ideal measure of R.

The second objective in the study was to test whether the four constructs of SAMR, namely S, A, M and R were independent. The results of correlation analysis (Table 6) suggested that all the four constructs were inter-related. This puts into question whether they are really measuring different things. That is food for thought for future researchers. It could also imply that when carrying out a study using the constructs of SAMR as explanatory variables, the researcher does not have to include all of them. The third and last objective of the study was to re-examine whether the four-factor SAMR model of ICT, that is, as made up of the four constructs (S, A, M & R) was reasonable. Exploratory factor analysis, EFA (Table 7) showed that the SAMR structure as suggested by Puentedura (2006) and operationalised by Lubega et al. (2014), could hardly be replicated using our data set. While our exploratory study using teachers of mathematical disciplines in four universities in Uganda cannot be used to dismiss Puentedura's (2006) suggestions and the operationalisation of Lubega et al. (2014), it still raises a lot of food for thought for future researchers. Is the four-factor SAMR model really reasonable? This question still begs for research in several contexts, and from researchers including Ruben Puentedura himself that Green (2014) accused of hardly having answered the question.

6. CONCLUSION

The use of ICT in pedagogy (UIP) provides opportunities to the learner to access an abundance of information using multiple information resources and also to view information from multiple perspectives. As such, UIP increases learner motivation and engagement by facilitating the acquisition of basic skills (Noor-Ul-Amin, 2013). Given the importance of UIP, in the study being concluded, an attempt was made to test the validity and reliability of one of the instruments that measure UIP by teachers and students. The instrument was the substitution (A), augmentation (A), modification (M) and redefinition (R) - SAMR model (Puentedura, 2006, as operationalized by Lubega et al., 2014). The context was that of the teachers of mathematical disciplines in four universities in Uganda. The study was among the very first to report findings on the validity and reliability of the SAMR model of ICT. CFA suggested that while some items of S and A respectively were not valid, all the items of each of M and R were valid. The four constructs were highly inter-related. Exploratory factor analysis (EFA) revealed that the four-factor SAMR model of operationalising ICT was questionable. Hence a call was made to researchers to continue testing the SAMR model in different contexts with intent to refining it. The study had limitations. Obviously, the sample scope was limited. More studies on SAMR could be carried out among other teachers in the four universities than those of mathematical disciplines. Studies could even be extended to other universities in Uganda and other countries.

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