International Journal of Education Sciences (IJES)
Received on 12. 06. 2014/09. 07. 2014
REF. NO. IJES-491
(Always refer our Reference No. for all correspondence)
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KEYWORDS Kolb's Learning Style Inventory. Reliability. Validity. Learning Styles.

ABSTRACT The purpose of this study was to investigate, from a South African perspective, the reliability and validity of the Kolb Learning Style Inventory (KLSI) 3.1 with mathematics students. The KLSI 3.1 was administered to (n=345) Mathematics I and II students at a university of technology in South Africa. Data was collected in two phases, during the preliminary data phase and the post-intervention data phase. Reliability and internal validity of KLSI 3.1 have been studied before; however, it has not been studied from a South African perspective yet. Findings in this study revealed that in both instances of the data collection the values of the alpha were found to be acceptable. The results also showed that the correlation coefficients of KLSI 3.1 for the preliminary data phase did not satisfy the prediction of the experiential learning theory. This study provided evidence that validity in the post-intervention phase applying the correlation coefficients as predicted by the theory was assured. Such knowledge may help to inform the selection and reliability of the instrument to accomplish the predictions of the theory. This is the first study in South Africa that provided evidence of the reliability and validity of the KLSI 3.1. This study suggested

reliability of the data collection, namely that the values of alpha were found to be acceptable. The internal validity of this instrument was also found to be acceptable. Barring for one instance in the preliminary data phase, all the correlation coefficients satisfied predictions from theory.

INTRODUCTION

The concept of learning styles has been used for an extensive range of student characteristics and differences (Felder and Brent 2005). Learning styles were derived from experiential learning theory (Kolb 1984; Kolb et al. 2000). Experiential learning theory defines learning as the process whereby knowledge is created through transformation of experience (Kolb and Kolb 2005). Knowledge, on the other hand, is described to result from the combination of grasping and transforming experience (Webber 2006). In literature, learning styles are described to involve the method in which students gather and process information that is guided by their characteristics, strengths and preferences (Warren 2004). In fact, it is opined that students invariably have different learning styles (Felder 1996). Regarding learning styles, it is argued that one learning style is neither preferable nor inferior to another, but is different, and differs in terms of characteristics, strengths and weaknesses (Felder and Brent 2005).

Over the years, from an experiential learning theory perspective, researchers have developed a number of instruments whose purpose was to determine students' learning styles (Felder and Brent 2005). Typical instruments include Honey and Mumford's (2006) Learning Style; the Merritt and Marshall (1984) Learning Style Questionnaire-Extended; the Boyatzis and Kolb (1995) Learning Style Profile; Mumford's (1987) Learning Diagnostic Questionnaire; and Boyatzis and Kolb's Executive Skills (Boyatzis and Kolb 1995; Henke 2001). Several studies focusing on establishing the reliability and validity of scores from Kolb's Learning Style Inventory (LSI) have been conducted in a number of countries. The countries include the United Kingdom (UK), Canada, Australia, Finland, Israel, Thailand, China, Melanesia, Spain and Malta (Kolb and Kolb 2005). In South Africa though, no study has either focused on the utility of the LSI or reported its psychometric properties yet. This article therefore, reports on the psychometric properties of the LSI version 3.1 (LSI 3.1) from a South African perspective. The LSI 3.1 was chosen here for two reasons. Firstly, because it is well represented in literature while it has been fairly used in other countries too. Secondly, in order to determine and categorize mathematics students' learning styles. To be able to

determine and categorize mathematics students' learning styles, it was important to ensure that any measures from the LSI 3.1 were reliable and valid. The purpose of this study was therefore to establish the reliability and validity of LSI 3.1 from the perspective of first year mathematics students from a South African university.

Learning Styles

Researchers (eg., Felder and Brent 2005; Giles et al. 2006) argue that characteristics of cognitive, affective and psychological behaviors that function as indicators of how learners perceive the learning environment, interact with and respond to, relate to learning styles. Felder (1996) is of the opinion that the manner in which students receive and process information is influenced by their preferences, characteristics and strengths. These are triggered by individual differences in learning styles (Warren 2004). In fact, Nolting (2009) points out that some students get more from verbal forms, such as written and spoken explanations, while others respond strongly to visual forms of information, such as diagrams, schematics and pictures. Some students function merely introspectively and individually, whereas others prefer to learn actively and interactively (Warren 2004). An important aspect here is that learning styles differ from student to student (Learning theories n.d.). It is crucial in the learning process to make students aware of their learning styles (Felder 1996). This enables students to learn better and become aware of their thinking processes (Felder 1996). In this regard, Hadden (2005) points out that, when lecturers prepare learning content or activities, learning styles should be taken into cognizance.

Learning styles were derived from experiential learning theory (Kolb 1984; Kolb et al. 2000). It is argued that experiential learning theory defines learning as the process whereby knowledge is created through transformation of experience (Learning theories n.d.). Regarding experiential learning, Kolb et al. (2000) and Smith (2001) provide information about the learning process on how we know people learn, grow and develop (Kolb et al. 2000).

Kolb's Learning Style Inventory

Literature shows that various appropriate measuring instruments of experiential learning theory had been developed (Kolb et al. 2000; Smith 2001; Felder and Brent 2005), such as the Learning Style Inventory (LSI), the Adaptive Style Inventory (ASI) and the Learning Style Profile (LSP) (Felder and Brent 2005). In order to reduce unauthentic common-method inconsistency among instruments, these instruments were theoretically adequate while

methodologically diverse (Kolb et al. 2000). Kolb and Kolb (2005: 9) point out that they developed the learning style inventory for two reasons:

- to serve as an educational tool to increase individuals' understanding of the process of learning from experience, and their unique individual approach to learning; and
- to provide a research tool for investigating experiential learning theory (ELT) and the characteristics of individual learning styles.

Over the last 35 years, five versions of the LSI have been published (Kolb and Kolb 2005). These authors point out that the original Learning Style Inventory (LSI 1) developed in 1969 was later published in 1971. Due to the low reliability coefficients and other concerns about the LSI 1, this led to a revision of the inventory in 1985, the LSI 2. The new version remained high in independent studies, while test–retest reliability remained low as a result of the internal reliability estimates of LSI 2 (Kolb and Kolb 2005). Furthermore, the LSI 2 is reported to have revealed a small decrease in internal reliability but a dramatic increase in test–retest reliability with the random scoring format (Kolb and Kolb 2005: 9). As a result, another version named the LSI 2a was published in 1993 (Kolb and Kolb 2005: 9). Six years later, the LSI version 3 was published. The randomized format of the LSI 3 in a revised self-scoring and interpretation booklet included a color-coded scoring sheet to simplify scoring. The LSI 3 continued to use the LSI 2 normative reference group until norms for the randomized version were created (Kolb and Kolb 2005: 10). In 2005, the LSI 3 was modified, and the LSI 3.1 was published (Kolb and Kolb 2005: 10). The reasons for the modification of LSI 3 were to include new norms based on a more diverse, larger and representative sample. In addition, the format, items, scoring and interpretative booklet remained similar while changes were in the norm charts used to convert raw LSI scores (Kolb and Kolb 2005: 10). The LSI 3.1 is currently the latest version of the original Learning Styles Inventory.

In order to determine an individual's learning style, the person responds to questions included in the questionnaire (Henke 2001). In the LSI 3.1, individuals are encouraged to choose the set of learning styles they would use in a specific learning situation (Kolb and Kolb 2005). This instrument identifies four learning styles that are related with the four characteristics of approaches to learning, which are: diverging, assimilating, converging and accommodating (Kolb et al. 2000; Webster 2002; Kolb and Kolb 2005). The instrument allows for the categorization of students into four groups based on their learning styles. The four groups are referred to as concrete experiences (CE), abstract conceptualization (AC), reflective observation (RO), and active experimentation (AE) (Kolb et al. 2000; Kolb and Kolb 2005).

Two dialectically related modes of grasping experience, namely concrete experience (CE) and abstract conceptualization (AC), and two dialectically related modes of transforming experience, namely reflective observation (RO) and active experimentation (AE) are described in literature (Felder 1996; Kolb et al. 2000; Webster 2002; Warren 2004; Nolting 2009; Learning theories n.d.). Literature defines four learning styles, i.e. diverging, assimilating, converging and accommodating as follows: concrete experience (CE) and reflective observation (RO) are described as diverging dominant styles (Kolb et al. 2000; Kolb and Kolb 2005). People following diverging dominant styles are best at viewing concrete situations from different perspectives and rely heavily upon brainstorming and generation of ideas (Kolb et al. 2000; Henke 2001, Smith 2001, Kolb and Kolb 2005). Assimilating dominant learning styles comprise abstract conceptualization (AC) and reflective observation (RO) (Kolb 1984; Kolb et al. 2000). People in this category are best at understanding a broad spectrum of information in a logical form (Kolb 1984; Kolb et al. 2000; Smith, 2001). These people can solve problems by inductive reasoning and their ability to create theoretical models (Kolb et al. 2000; Henke 2001, Smith 2001, Kolb and Kolb 2005). Abstract conceptualization (AC) and active experimentation (AE) meanwhile are converging dominant learning styles (Kolb 1984; Kolb et al. 2000). Individuals following the converging dominant learning style are reported to solve problems, make decisions and rely heavily upon hypothetical-deductive reasoning (Kolb et al. 2000; Henke 2001, Smith 2001, Kolb and Kolb 2005). Concrete experience (CE) and active experimentation (AE) are the accommodating dominant learning styles (Kolb 1984; Kolb et al. 2000). People with this learning style have the ability to learn from primary hands-on experience. They enjoy involving themselves in new and challenging experiences and solving problems (Kolb et al. 2000; Henke 2001, Smith 2001, Kolb and Kolb 2005).

Reliability and Validity of the Inventory

In reporting the reliability of scores from the LSI 3.1, Kolb and Kolb (2005) focused on the internal consistency in respect of Cronbach's alpha (1951) as well as on test–retest reliability. Kolb and Kolb (2005) illustrated internal consistency of scores through alpha values reported by different studies. The alpha values are illustrated in Table 1.

[Insert Table 1 about here]

In terms of test–retest reliability, Kolb and Kolb (2005) identify two studies that reported on this. These studies were conducted by Veres et al. (1991) as well as Ruble and Stout (1991). In both instances of reliability (internal consistency and test–retest reliability) determination,

Kolb and Kolb (2005) reported that the calculated values were acceptable. Regarding the validity of the LSI 3.1, studies evaluated by Kolb and Kolb (2005) revealed that correlation coefficients and factor analyses were the most computed methods. In the current study, reliability was computed through the determination of Cronbach's (1951) alpha.

Validity, on the other hand, was determined through computing correlation coefficients of the different subscales of the LSI 3.1 as opposed to computing factor analysis. The correlation coefficients were computed for two data collection phases. The basis for selecting the correlation method was the argument that "... with only four scale scores, factoring may be unnecessary because the factor pattern structure can be accurately estimated from an inspection of the correlation pattern among the four scales" (Loo 1999: 216). Regarding the correlation coefficients, it is pointed out that the theory of experiential learning proposes that the four primary modes of the learning cycle – CE, RO, AC and AE – are composed of two independent dialectic (bipolar) dimensions: a grasping dimension measured by the combination score AC–CE and a transformation dimension measured by the AE–RO combination score (Kolb and Kolb 2005: 21). Thus, the prediction is that:

1. AC–CE and AE–RO should be uncorrelated;
2. the CE and AC scales should not correlate with AE–RO;
3. the AE and RO scales should not correlate with AC–CE;
4. in addition, the dialectic poles of both combination dimensions should be negatively correlated, though not perfectly, since the dialectic relationship predicts the possibility of developmental integration of the opposite poles; and
5. finally, the cross-dimensional scales – CE/RO, AC/AE, CE/AE and AC/RO – should would not be correlated as highly as the within-dimension scales.

In establishing validity in this study, it was decided that the prediction presented here would have to be satisfied for it to be acceptable.

METHOD

Participants

Participants were 345 first year mathematics students at a university in South Africa. The first year mathematics syllabus covers exponents, functions, wave theory, radiant measure, trigonometry and hyperbolic functions. In this study, students are divided into three groups named MI – Group A, MI – Group B, and MI – Group C. The basis for the three groups is the qualifications students were pursuing. For an example, students in MI – Group A (n=105),

were pursuing an electrical engineering qualification. The second group [MI – Group B (n=49), were pursuing a chemistry qualification while the MI – Group C (n=191), were pursuing a surveying qualification. While all the students were in first year, they were be grouped differently. This is because they attended mathematics lectures at different times as they were registered for different courses. There were 167 (38.4%) females and 104 (23.9%) males, while 164 (37.7%) did not disclose their gender. Their ages ranged between 17 years and 44 years (M = 21.27, SD = 3.33). Of the total, 145 (33.3%) did not indicate their ages. There were 208 (47.8%) who were taking mathematics for the first time. On the other hand, 67 (15.4%) indicated that they had failed mathematics at least once.

Instrument and Procedure

The LSI 3.1 was used to collect data relating to students' learning styles (Kolb et al. 2000). Permission to use this questionnaire was obtained from the developers of the instrument. Also included in the instrument was a section requesting biographical data, such as age and gender. The LSI 3.1 is a 12-item inventory comprising four primary subscales that measure concrete experience (CE), reflective observation (RO), abstract conceptualization (AC) and active experimentation (AE). Scores from the subscales are combined to measure an individual's preference for abstractness over concreteness (AC–CE) and action over reflection (AE–RO) (Kolb & Kolb, 2005). The accommodating, diverging, converging and assimilating learning style types are created by dividing the AC–CE and AE–RO scores and plotting them on the learning style grid (Kolb and Kolb 2005).

The first subscale is accommodating. A typical example of an item from this subscale is "When I learn, I like doing things and when I learn, I like to watch and listen." The second subscale is the diverging learning style. This refers to students who are dominant in concrete experience (CE) and reflective observation (RO) A typical example from this subscale is "When I learn, I am open to experiences and I learn best when I rely on my observations." The third subscale is the converging learning style. A typical example from this subscale is "When I learn, I like ideas and theories and when I am learning I am an active person." The fourth subscale is the assimilating learning style. A typical example from this subscale is "I learn best from rational theory and I learn best when I listen and watch carefully."

In terms of the reported reliability of scores obtained from the LSI 3.1, Cronbach's (1951) alpha as a measure of the internal consistency of scores is reported to be .70 (Kolb and Kolb 2005). In fact, these authors indicate that they computed good internal consistency across a number of populations using the KLSI 3.1 (Kolb and Kolb 2005). With respect to the four

subscales, they reported α = .81 (CE), α =.78 (RO), α = .83 (AC), and α = .84 (AE) for scores from liberal arts college students. Similar alpha values were obtained with undergraduate psychology students. Further, values such as α = 0.80 (CE), α = 0.77 (RO), α = 0.70 (AC), and α = 0.58 (AE) were reported (Kolb and Kolb 2005).

Data in this study were collected in two phases that are named the preliminary data phase and the post-intervention data phase. In each phase, the students completed the LSI 3.1. All analyses were carried out using SPSS version 21. The reliability of scores from this instrument was determined by computing Cronbach's (1951) alpha. With regard to validity of scores from this instrument, Pearson's correlation coefficients were determined.

RESULTS

Biographical Information

The biographical information of the participants in all three study groups is shown in Table 2. In MI – Group A, the results reveal that 62 (59.1%) of the participants did not disclose information about their gender. Of the participants, 57 (54.3%) did not indicate their ages. Forty-one (39.0%) participants were registered for the very first time in the mathematics first-year course. Furthermore, seven participants indicated that they had failed the course at least once while the others (61%) did not disclose their registration status. In MI – Group B, there were 24 (49.0%) females and 22 (44.9%) males while 3 (6.1%) did not disclose this information. With respect to participants' ages, 93.9% ranged between 19 and 44 years (M = 23.8 years, SD = 4.8). Another three did not indicate their ages. The results show that 24 (49.0%) participants were registered for the very first time in this course. Of the participants, 12 (24.5%) indicated that they had failed the mathematics course at least once while (26.5%) did not disclose their registration status. In MI – Group C, there were 108 (56.5%) females and 45 (23.6%) males while 38 (19.9%) did not reveal this information. Their ages showed that 87.4% were between 18 and 35 years of age (M = 21.0 years, SD = 2.2) with 24 not indicating their ages. Of the participants, 126 (66.0%) were registered for the very first time in this mathematics course. Furthermore, 49 (25.6%) indicated that they had failed the course at least once while (8.4%) did not disclose their registration status.

[Insert Table 2 about here]

Scale Reliability

Here, the reliability of the scores from this instrument is reported in terms of the preliminary and the post-intervention phases. Table 3 shows that in both phases the alpha values ranged between 0.65 and 0.82 (Concrete Experience); 0.68 and 0.86 (Reflective Observation); 0.65 and 0.86 (Abstract Conceptualization); 0.68 and 0.83 (Active Experimentation)

[Insert Table 3 about here]

Scale Validity

In ensuring the validity of the LSI 3.1, the Pearson correlation coefficients were computed for both data phases. Tables 4 and 5 show Pearson's correlation coefficients for the four categories of the LSI 3.1 and the two independent dialectic dimensions, with respect to each phase. In respect of the *preliminary data* phase, it can be observed from Table 4 that the two bipolar dimensions [AC – CE and AE - RO] were not significantly associated to each other (r = .247). Similarly, CE had no association with the dialectic dimension AE – RO (r = .180). Also, AC had no association with this dimension. On the other hand, both AE and RO had no association with the dialectic dimension AC – CE. However, the cross dimensional scales of CE/RO (r = .640); AC/AE (r = .713); CE/AE (r = .513); and AC/RO (r = .600) were all associated.

[Insert Table 4 about here]

Similarly, Table 5 shows that the two dialectic dimensions [AC – CE and AE - RO] had no association to each other. Here CE and AC had no association with the dialectic dimension AE – RO. On the other hand, both AE and RO had no association with the dialectic dimension AC – CE. However, the cross dimensional scales of CE/RO (r = .589); AC/AE (r = .537); CE/AE (r = .478); and AC/RO (r = .543) were all correlated.

[Insert Table 5 about here]

DISCUSSION

In this study, the main purpose was to establish the reliability and validity of Kolb's Learning Style Inventory version 3.1. In terms of reliability of scores from the instrument, it was found that the alpha values ranged between .75 and .83 (preliminary data phase) as well as .65 and .82 (post-intervention data phase). Since the alpha values obtained in this study were comparable to those reported in literature (c.f. Ruble and Stout 1991; Veres et al. 1991;

Kayes 2005; Kolb and Kolb 2005), it was concluded that reliability was acceptable here. With respect to validity, it was similarly concluded to that validity was acceptable here. This was acceptable because in both data phases, all the correlation coefficients satisfied the predictions from literature (c.f. Kolb and Kolb 2005). In conclusion, as the preliminary results seem to complement those reported in literature is would be reasonable to accept the reliability and validity as reported here.

RECOMMENDATIONS

This article focused on the reliability and validity of scores from the KLSI 3.1, for students taking mathematics in a South African university. While the results are promising, it is recommended that further studies should be conducted on different samples within the South African context. Such studies will be useful in verifying the findings reported here. Importantly, though, this study adds to the body of knowledge that has addressed the issue of the reliability and validity of Kolb's Learning Style Inventory.

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Table 1: Internal consistency alphas from different studies using the KLSI 3.1*

Source	N	CE	RO	AC	AE	AC-CE	AE-RO
On-line sample	5 023	.77	.81	.84	.80	.82	.82
Kayes (2005)	221	.81	.78	.83	.84	.77	.84
Weirstra and DeJong (2002)	101	.81	.78	.83	.84	.83	.82
Veres et al. (1991)	711 initial	.56	.67	.71	.52	–	–
	1 042 repeated	.67	.67	.74	.58	–	–
Ruble & Stout (1991)	323 (1990)	.72	.75	.72	.73	–	–
	403 (1991)	.67	.78	.78	.78	–	–

* Adapted from Kolb and Kolb (2005)

Table 2:Biographical data of the three study groups

		MI – Group A (n=105)		MI – Group B (n=49)		MI – Group C (n=191)	
		N	%	N	%	N	%
Gender	Female	14	13.3	24	49.0	108	56.5
	Male	29	27.6	22	44.9	45	23.6
	Not disclosed	62	59.1	3	6.1	38	19.9
Age	17–19	29	27.6	1	2.0	35	18.3
	20–24	16	15.2	31	63.2	125	65.4
	25 years of age and older	3	2.9	14	28.6	7	3.6
	Not disclosed	57	54.3	3	6.1	24	12.6
Registration	1st time	41	39.0	24	49.0	126	66.0
	2nd time	5	4.8	8	16.3	29	15.2
	3rd time or more	2	2.0	4	8.2	20	10.4
	Not disclosed	57	54.2	13	26.5	16	8.4

Table 3: Cronbach alpha values in respect of each group, the LSI categories by preliminary and post-intervention data phases

Data phase	Group	Alpha value			
		CE	RO	AC	AE
Preliminary	MI – Group A	0.82	0.86	0.86	0.82
	MI – Group B	0.79	0.76	0.75	0.83
	MI – Group C	0.74	0.75	0.76	0.75
Post-intervention	MI – Group A	0.82	0.83	0.84	0.79
	MI – Group B	0.65	0.78	0.71	0.82
	MI – Group C	0.73	0.68	0.65	0.68

Table 4: Pearson's correlation coefficients for the four LSI 3.1 categories and the two independent dialectic dimensions (AC–CE and AE–RO) in respect of the preliminary data phase

		1	2	3	4	5	6
1	Concrete experiential (CE)	1					
2	Reflective observation (RO)	.640**	1				
3	Abstract conceptualization (AC)	.522**	.600**	1			
4	Active experimentation (AE)	.513**	.572**	.713**	1		
5	AC–CE	-.562**	-.106	.404**	.120	1	
6	AE–RO	-.180	-.517**	.069	.402**	.247	1

** $p < .05$

Table 5: Pearson's correlation coefficients for the four LSI 3.1 categories and the two independent dialectic dimensions (AC–CE and AE–RO) in respect of the post-intervention data phase

		1	2	3	4	5	6
1	Concrete experiential (CE)	1					
2	Reflective observation (RO)	.589**	1				
3	Abstract conceptualization (AC)	.419**	.543**	1			

4	Active experimentation (AE)	.478**	.458**	.537**	1		
5	AC–CE	-.569**	-.069	.503**	.025	1	
6	AE–RO	-.071	-.450**	.047	.584**	.104	1

** $p < .05$