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Satisfaction with asynchronous e-learning: An exploratory factor analysis of the Learner Satisfaction with Asynchronous e-Learning (LSAeL) instrument

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A R T I C L E I N F O

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Exploratory factor analysis
Learner satisfaction
Online learning
User experience

A B S T R A C T

Aim: To describe the development and psychometric testing of the Learner Satisfaction with Asynchronous e-Learning (LSAeL) instrument.
Background: Existing satisfaction with e-learning instruments may not accurately evaluate learner satisfaction with constructs associated with asynchronous e-learning.
Design: Methodological study.
Methods: Content, face and construct validity of the instrument were evaluated using a two-stage process. A five-member expert panel evaluated the instrument's content and face validity. A content validity index and a modified kappa co-efficient was used to calculate the content validity of individual test items and the global instrument and to adjust for chance agreement between raters. These data were then reviewed and individual items were removed, retained or refined accordingly. Using an empirically informed wholly asynchronous e-learning program 237 nursing students from a regional university in New South Wales, Australia completed the 35 item LSAeL instrument. An exploratory factor analysis (EFA) was then conducted to explore the dimensionality of the instrument.
Results: Exploratory factor analysis identified a seven-factor solution with 30 items, explaining an 86.1% of the total variance, was the best fit for the data.
Conclusion: The study demonstrates that the construct validity of the LSAeL instrument is acceptable. Instrument development is an iterative process and further testing with other cohorts and in other settings is required.

1. Introduction

E-learning can be broadly defined as any type of educational resource that is delivered in an electronic form (Clark and Mayer, 2011). With the evolution of technology and rapid authoring software solutions, e-learning has become more accessible than ever before, and its development is no longer reliant on engaging instructional design and e-learning experts. The proliferation of externally provided asynchronous e-learning programs and recent technological advances in the online learning sphere, presents an opportunity to develop and validate an instrument that measures user satisfaction specifically related to a) user experiences of wholly asynchronous e-learning programs and; b) factors that are influenced predominantly by e-learning instructional design quality.

2. Background

E-learning can be delivered in asynchronous or synchronous formats. Synchronous e-learning has functionality, such as discussion boards and web 2.0 applications, that afford interactivity between learners and/or educators, whereas asynchronous e-learning allows learning to occur at any time that is convenient to the learner and is not governed by time, place, educators or other learners. The distinction between synchronous and asynchronous delivery is integral to the context of this paper. The interactivity associated with synchronous e-learning facilitates knowledge generation (D'Souza et al., 2014) and is used mainly in formal educational contexts such as universities. However, the economy of formal education does not always allow for free access to such courses. This can be challenging for individuals seeking learning opportunities who choose not to enroll in a formal program of study or who wish to meet a specific learning need. In the formal education context however,

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asynchronous e-learning is often used for tutorial preparation and to access learning opportunities from external agencies or organizations. Alternatively, organizations who wish to deliver targeted education to upskill employees or deliver mandatory workplace education are more likely to use stand-alone asynchronous e-learning as a preferred delivery mode (Dečman, 2015). These learning opportunities are self-directed, do not use discussion boards or web 2.0 applications and do not require a person to facilitate learning, rather, the program is designed to act as personal tutor and to facilitate independent learning (Melhuish and Falloon, 2010). Asynchronous e-learning is convenient and supports a learner-centered approach that enables learners to balance personal, educational and work commitments.

Using the internet or local computer networks for education delivery is not without its limitations and e-learning developers need to be cognizant of the features that denote highly engaging quality learning opportunities. E-learning is not an educational panacea and careful consideration needs to be given to whether it is the 'best fit' for intended learning outcomes. Consequently, choosing e-learning for e-learning's sake or developing poorly designed programs will only lead to unmotivated and dissatisfied consumers who will learn little and be unlikely to engage further or adopt e-learning as a preferred learning mode (de Melo Pereira et al., 2015; Dečman, 2015).

2.1. Learner satisfaction measurement

The measurement of learner satisfaction is an important and relatively easy method of evaluating e-learning programs (Sun et al., 2008). Learner satisfaction is a multi-dimensional construct influenced by myriad factors, many of which are outside the control of educators and instructional designers. Broadly speaking, satisfaction is the positive psychological state derived from the learner's self-evaluation of their learning experience. In the case of e-learning, this evaluation is a cognitive process of comparing the learning experience with previous experiences or, in the absence of these, with the expectation of what the learning experience should be like. Historically, satisfaction with e-learning has been measured for quality of interface (including interactivity), system quality, reliability, support, speed of response (to technical issues), internet speeds and effectiveness and appropriateness of feedback (Chen et al., 2008; Lin et al., 2011; Sun et al., 2008; Wang, 2003). Other critical factors include learners' access to and confidence with information communication and technology (ICT), perceived ease of use and relevance to job role (Sun et al., 2008; Wang, 2003). In the context of stand-alone asynchronous e-learning modules, variables like ICT anxiety and internet speeds are beyond the control of the program and its developers. Consequently, they do not accurately represent user satisfaction with the actual e-learning program; rather, for the most part, they represent the user experience with engaging with ICT overall.

A literature search was conducted to identify validated instruments that measured user satisfaction with asynchronous e-learning. The databases of Medline, CINAHL, PsycINFO and Proquest were searched using the terms e-learning, instructional design, instrument and satisfaction for the period 2000 to September 2023. The search was supplemented by manually reviewing reference lists of relevant papers. A total of five relevant papers (de Melo Pereira et al., 2015; Palmer and Holt, 2009; Sun et al., 2008; Udo et al., 2011; Wang, 2003) were identified that reported psychometrically evaluated instruments that had been used to evaluate learner satisfaction with e-learning. However, no single paper identified a tool that would exclusively enable the measurement of satisfaction within the context of stand-alone asynchronous e-learning programs and variables that could be controlled by e-learning developers. For example, Wang (2003) measurement of Learner Satisfaction with Asynchronous e-Learning systems contained multiple items that assessed personalization of content and interaction with other learners and teachers, variables that are at odds with the definition of asynchronous e-learning. Similarly, Palmer and Holt (2009) measured participant perceived importance and satisfaction with items relating to student-student and teacher-student interactions. Sun et al. (2008) included items that measured computer related anxiety and technology related factors such as internet connection speeds; and the instrument by de Melo Pereira et al. (2015) contained items that measured participants' subsequent intention to use e-learning. While factors such as these influence user satisfaction, they are often beyond the control of educators and instructional designers who develop e-learning programs. In summary, these existing instruments lacked the specificity and sensitivity to evaluate the relevant elements of instructional design and they included items that measure factors that are beyond the control of the developer.

Instructional design (ID) is the systematic process of creating high quality, engaging and purposeful learning experiences that increase the efficiency of knowledge acquisition (Battou et al., 2017). It would be naïve to suggest that a single model or framework exists that should guide instructional design. Consequently, the focus of ID is the manner of learning rather than the process of teaching (Gagne et al., 2005). This focus targets intentional learning, whereby targeted learning outcomes inform the design and learning activities are used to support the learners' achievement of these outcomes. In contrast, incidental learning occurs in an indirect or unplanned manner which is often the case with poorly designed e-learning programs (Khuana et al., 2017; Merrill et al., 1996).

3. Methods

3.1. Aim/objective

The aim of this study was to develop and assess the face and content validity and psychometric properties of the Learner Satisfaction with Asynchronous e-Learning (LSAeL) instrument.

The development and testing of the LSAeL instrument occurred over two stages, in accordance with the process described by DeVellis (2012). Stage one used an expert panel and a face and content validity process to evaluate the draft instrument. Stage two explored the dimensionality of the instrument using exploratory factor analysis (EFA) on a purposive sample of second year undergraduate nursing students, who undertook an asynchronous e-learning module as part of a non-compulsory tutorial preparation activity. Both stages of the study were independently approved by the institutional Human Research Ethics Committee.

3.2. Stage 1: theoretical framework, item generation and measurement format

For the purpose of developing the LSAeL instrument, asynchronous e-learning was defined as any educational intervention that is mediated electronically via the internet or on a local computer or network which is devoid of any student-student or teacher-student interaction, whereby the program alone facilitates knowledge generation (Sinclair et al., 2016). Learner satisfaction was defined as the user's perceptions of satisfaction with instructional design features of the e-learning program (Kats, 2013). The instructional design principles described by Sinclair et al. (2017) and informed by Gagne et al. (2005) for the development of high-quality, high engagement asynchronous e-learning programs were used as the theoretical basis for the creation of the LSAe-L instrument (See Fig. 1). The instrument was designed from a pragmatic perspective that theorized that while there are many factors related to satisfaction with e-learning reported in the literature, many are beyond the control of the developer.

The first author developed items for each *a priori* domain of the instrument. Existing tools were used as stimulus in conjunction with the instruction design principles described by Sinclair et al. (2017) and informed by Gagne et al. (2005). No items were derived from existing instruments. The initial item pool comprised of 32 core items with eight of those items containing 18 sub-items, resulting in a total of 50 discrete items. A 5 point Likert type instrument format with anchors ranging

Domain 1: Gain attention
Domain 2: Describe the goal
Domain 3: Stimulate recall of prior knowledge
Domain 4: Present the material to be learned
Domain 5: Provide guidance for learning
Domain 6: Elicit performance "practice"
Domain 7: Provide informative feedback
Domain 8: Assess performance
Domain 9: Enhance retention and knowledge transfer

Fig. 1. *A priori* domains of instructional design principles (Gagne et al., 2005).

from strongly disagree to strongly agree was selected because it has been commonly used in satisfaction instrument measurements (de Melo Pereira et al., 2015; Sun et al., 2008; Wang, 2003) and is suitable for measuring perceptions (DeVellis, 2012). Positively and negatively worded items were included to preclude potential agreement bias. The second and third authors then reviewed and made recommendations about the refinement of items.

3.3. Expert panel review and process

To determine the suitability, clarity and relevance of the LSAeL instrument and its individual items, content validity was assessed using a triangulated approach described by Lynn (1986) and Polit and Beck (2006). A five member expert panel was engaged to evaluate the instrument's face and content validity (I-CV) and the instruments entire content validity (S-CV) (Lynn, 1986). The panel consisted of one academic with extensive experience in survey design, two independent e-learning instructional design experts and two e-learning content development experts from external organizations. Panel members were instructed to use a rating instrument to assess for content omission and overall comprehensiveness and to evaluate each item for repetition, relevance, clarity and ability to measure learner satisfaction within the context of instructional design (Lynn, 1986; Polit and Beck, 2006). Panel members were also asked to suggest alternate wordings if any item was deemed unclear or ambiguous.

A content validity index (CV-I) and a modified kappa co-efficient (Fig. 2) were then used to calculate the content validity of individual test items and the global instrument and to adjust for chance agreement between raters. Items were removed or refined based on feedback from the expert panel. The expert panel was reconvened to review and rate the next iteration of the instrument. At the conclusion of this process, the instrument contained 35 items. For a detailed account of the expert review process including data analysis and pre-post expert panel review scoring for CV-I and modified kappa please see online supplementary file 1.

$$\text{I-CV} = \frac{\text{Number of SME Scoring an item with 3 or 4}}{\text{Total number of SME}}$$

$$p_c = \left[\frac{[\,N!\,]}{[A!\,(N\text{-}A)!]}\right] \times 0.5^N \qquad k = \frac{\text{I-CV} - p_c}{1 - p_c}$$

Legend
I-CV = Item content validity
SME = Subject matter experts
p_c = probability of chance universal agreement
N = Number of SME
A = Number of 'relevant or clear and concise' 3-4 rated scores
k = Modified kappa coefficient

Fig. 2. Calculations used for determining I-CV and modified kappa (Fleiss et al., 2013; Polit et al., 2007) (adapted from Orts-Cortés et al., 2013).

3.4. Stage one: data analysis

The sub-scale content validity (SS-CV) scores were evaluated to determine the validity of each sub-scale with an SS-CV of $\geq$ 0.80 considered acceptable. The scale content validity (S-CV) was determined by universal agreement (S-CV/UA) by the expert panel. A modified kappa co-efficient was then calculated to evaluate for chance agreement between the expert panel and rated according to the four point instrument reported by Fleiss et al. (2013) as follows: Poor ($\leq$ 0.39), moderate (0.40–0.59), good (0.60–0.73) and excellent ($\geq$ 0.74). Potentially problematic items (PPI) were revised or discarded if the I-CV was $\leq$ 0.78 or if the kappa co-efficient was $\leq$ 0.59 (Fleiss et al., 2013; Lynn, 1986). Face validity was measured using the absolute approach described by Nevo (1985) whereby 100% agreement was required by experts for face validity to be satisfactory. The refined instrument was subsequently reviewed and rescored by the expert panel a second time.

3.5. Stage one: results

The expert panel unanimously agreed that the instrument accurately evaluated Learner Satisfaction with Asynchronous e-Learning programs instructional design elements with the original draft S-CV (relevance) being 0.975 (See online supplement file 1 for pre and post expert panel scoring). The minimum I-CV was 0.60 and the maximum, 1.00. The mean modified Kappa was 0.96. Two PPI were identified (i.e. modified Kappa $\leq$ 0.59), item 2 was removed from the instrument and item 3 was refined and re-evaluated by the panel. While the expert panel demonstrated strong agreement regarding item relevance, five PPI were identified as being poorly constructed in terms of clarity and conciseness.

The S-CV (clarity) of the LSAel overall was 0.92 with a minimum I-CV was 0.40 and maximum, 1.00. The mean modified kappa coefficient was 0.89 and 84.4% of items (n=27) were rated as excellent, 12.5% (n=4) were rated as weak, with the remaining item (#14) rated as poor for clarity. Item 14 was reworded based on the expert panel suggestions and the stem and its sub questions were removed and were reordered to become item 13 in the revised draft.

A follow up meeting with the expert panel resulted in the refinement of the remaining four PPI that were identified as having questionable relevance and/or clarity. The meeting resulted in the removal of one further item (#29) based on poor clarity whereby discussion could not achieve any resolution or alternative wording. The refined 30 item instrument was returned to the expert panel and 100% universal agreement was achieved (See online supplement file 1). The final items and sub items were then converted to discrete items (i.e. no stem with sub items) and re-ordered under the nine ID domains, resulting in a 35-item instrument (eg: Gain attention (Q1–4) contained two discrete items with two further stem items with seven associated sub-items; these were then converted to nine discrete items for the final instrument).

3.6. Stage 2: exploratory factor analysis

3.6.1. Setting, procedure and data collection

Stage two was conducted at a semi-metropolitan university in New South Wales, Australia. A purposive sample was drawn from a cohort of 622 undergraduate students enrolled in a second-year nursing course. Potential participants were recruited via advertisements made during lectures and posted on the course learning management system. The asynchronous e-learning program used to evaluate the instrument was a non-compulsory tutorial preparation activity on the topic of chronic kidney disease (Sinclair et al., 2017). After completing the program, students were given the option to anonymously evaluate it using the LSAeL instrument. Clicking on the link and completing the survey was taken as implied consent. The survey was hosted and delivered using Questionmark Perception (Questionmark, Trumbull, Connecticut, USA), a standards-based, assessment creation, delivery and reporting application. Data were exported and analysed using SAS Version 9.42 (SAS Institute Inc., Cary, NC, USA).

3.7. Data analysis

Items were checked for normality and excessive missing data. The Kaiser-Meyer-Olkin (KMO) Test for Measuring of Sampling Adequacy (MSA) and Bartlett's test to determine whether the sample was adequate for factor analysis. Internal domain consistency was assessed using Cronbach Alpha with an $\alpha > 0.70$ considered satisfactory (Cronbach, 1951). The dimensionality of the LSAeL instrument was examined through an exploratory factor analysis (EFA). As a result of the skewness of each item, factor analysis using a Pearson Correlation matrix was not suitable, consequently a polychoric correlation was used to verify correlation between items in each domain. The Kaiser-Guttman criterion (Kaiser, 1991) (i.e. eigenvalue > 1.0) and Horn's parallel level test (Glorfeld, 1995) were used to determine the number of factors retained; the solutions were then scrutinized for plausibility. Principal axis extraction was then used with an oblique (promax) rotation to confirm the number of factors. Final factor solutions were interpreted with threshold minimum factor loadings of 0.4 (Tabachnick and Fidell, 2013). If items did not load, content interpretation was undertaken with consideration of the item's *a priori* domain used to assign item placement to the factor which theoretically best reflected its conceptual meaning, or it was removed from the final solution.

4. Results

Of the 622 students enrolled in the course, 255 accessed and completed the e-learning module (response rate 38.1%). Of these, 237 completed the LSAeL instrument (response rate 93%). The subject to item ratio in terms of sample size was 6.97:1. The sample consisted of 213 females (consistent with the demographic of nursing) and 22 males, two participants identified as transgender/intersex. Participants had an average age ($\pm$ SD) of 29.8 ($\pm$ 9.16) (range 18–52) and seven participants identified as having English as their second language.

4.1. Item level analysis

Table 1 reports the summary of item response distribution (n (%), mean, SD), skewness, kurtosis, standard error and the number of missing values for each item. The response range for all items was 1–5 and mean scores ranged between 3.28 and 4.53. This demonstrated some skewness in responses, with most participants strongly agreeing to each item, except for item 23. Item 23 was a negatively worded validation item, which may explain its inconsistent distribution. As a result, it was removed from the instrument and not included in further analyses.

4.2. Data suitability for exploratory factor analysis

The KMO test for MSA was 0.9672 and Bartlett's Test of Sphericity was significant ($\chi^2 = 9866.27$. df $=561$, $p < 0.0001$) indicating that the data and sample size was adequate for factor analysis. Principal axis extraction with oblique (promax) rotation was used to identify the factors underling the LSAeL instrument.

Table 1
Summary of Item Response Distribution (n (%), mean, SD), number of missing values, standard deviation (SD), kurtosis, standard error (SE) and skewness.

	Category										
Item	Strongly agree	Agree	Unsure	Disagree	Strongly disagree	Missing	Mean	SD	Kurtosis	SE	Skewness
1	105 (44.3%)	110 (46.4%)	20 (8.4%)		2 (0.8%)		4.33	0.70	2.87	0.05	-1.16
2	121 (51.1%)	104 (43.9%)	10 (4.2%)		2 (0.8%)		4.44	0.66	4.80	0.04	-1.49
3	122 (51.5%)	97 (40.9%)	16 (6.8%)		2 (0.8%)		4.42	0.69	3.62	0.05	-1.40
4	140 (59.1%)	86 (36.3%)	9 (3.8%)		2 (0.8%)		4.53	0.65	5.78	0.04	-1.79
5	110 (46.4%)	109 (46.0%)	16 (6.8%)		2 (0.8%)		4.37	0.69	3.49	0.04	-1.27
6	106 (44.7%)	105 (44.3%)	21 (8.9%)	3 (1.3%)	2 (0.8%)		4.31	0.75	2.46	0.05	-1.23
7	102 (43.0%)	103 (43.5%)	28 (11.8%)	2 (0.8%)	2 (0.8%)		4.27	0.77	1.79	0.05	-1.07
8	125 (52.7%)	84 (35.4%)	25 (10.5%)	1 (0.4%)	2 (0.8%)		4.39	0.76	2.28	0.05	-1.31
9	116 (48.9%)	97 (40.9%)	20 (8.4%)	2 (0.8%)	2 (0.8%)		4.36	0.74	2.73	0.05	-1.32
10	97 (40.9%)	111 (46.8%)	20 (8.4%)	4 (1.7%)	2 (0.8%)	3 (1.3%)	4.27	0.76	2.48	0.05	-1.21
11	111 (46.8%)	107 (45.1%)	13 (5.5%)		2 (0.8%)	4 (1.7%)	4.39	0.67	4.05	0.04	-1.35
12	107 (45.1%)	111 (46.8%)	11 (4.6%)	2 (0.8%)	2 (0.8%)	4 (1.7%)	4.37	0.70	4.11	0.05	-1.42
13	115 (48.5%)	106 (44.7%)	10 (4.2%)		2 (0.8%)	4 (1.7%)	4.42	0.66	4.73	0.04	-1.45
14	111 (46.8%)	103 (43.5%)	14 (5.9%)	2 (0.8%)	3 (1.3%)	4 (1.7%)	4.36	0.75	4.22	0.05	-1.57
15	99 (41.8%)	110 (46.4%)	19 (8.0%)	1 (0.4%)	2 (0.8%)	6 (2.5%)	4.31	0.71	2.92	0.05	-1.19
16	109 (46.0%)	102 (43.0%)	16 (6.8%)	2 (0.8%)	2 (0.8%)	6 (2.5%)	4.36	0.73	3.25	0.05	-1.36
17	113 (47.7%)	97 (40.9%)	18 (7.6%)	1 (0.4%)	2 (0.8%)	6 (2.5%)	4.38	0.72	3.09	0.05	-1.34
18	111 (46.8%)	95 (40.1%)	23 (9.7%)		2 (0.8%)	6 (2.5%)	4.35	0.73	2.46	0.05	-1.20
19	126 (53.2%)	92 (38.8%)	10 (4.2%)	1 (0.4%)	2 (0.8%)	6 (2.5%)	4.47	0.68	4.87	0.04	-1.65
20	114 (48.1%)	97 (40.9%)	16 (6.8%)	2 (0.8%)	2 (0.8%)	6 (2.5%)	4.38	0.73	3.30	0.05	-1.41
21	99 (41.8%)	113 (47.7%)	16 (6.8%)	1 (0.4%)	2 (0.8%)	6 (2.5%)	4.32	0.70	3.37	0.05	-1.24
22	111 (46.8%)	98 (41.4%)	16 (6.8%)	4 (1.7%)	2 (0.8%)	6 (2.5%)	4.35	0.76	2.98	0.05	-1.41
23	47 (19.8%)	37 (15.6%)	19 (8.0%)	60 (25.3%)	68 (28.7%)	6 (2.5%)	3.28	1.53	-1.43	0.10	-0.33
24	108 (45.6%)	106 (44.7%)	13 (5.5%)	2 (0.8%)	2 (0.8%)	6 (2.5%)	4.37	0.71	3.75	0.05	-1.40
25	94 (39.7%)	101 (42.6%)	29 (12.2%)	5 (2.1%)	2 (0.8%)	6 (2.5%)	4.21	0.81	1.45	0.05	-1.05
26	83 (35.0%)	114 (48.1%)	27 (11.4%)	4 (1.7%)	2 (0.8%)	7 (3.0%)	4.18	0.77	1.84	0.05	-1.02
27	93 (39.2%)	115 (48.5%)	16 (6.8%)	4 (1.7%)	2 (0.8%)	7 (3.0%)	4.27	0.74	2.99	0.05	-1.27
28	87 (36.7%)	119 (50.2%)	17 (7.2%)	5 (2.1%)	2 (0.8%)	7 (3.0%)	4.23	0.75	2.77	0.05	-1.23
29	105 (44.3%)	110 (46.4%)	13 (5.5%)		2 (0.8%)	7 (3.0%)	4.37	0.67	4.02	0.04	-1.31
30	118 (49.8%)	92 (38.8%)	16 (6.8%)	2 (0.8%)	2 (0.8%)	7 (3.0%)	4.40	0.73	3.35	0.05	-1.46
31	117 (49.4%)	100 (42.2%)	11 (4.6%)		2 (0.8%)	7 (3.0%)	4.43	0.67	4.58	0.04	-1.48
32	105 (44.3%)	60 (25.3%)	61 (25.7%)	2 (0.8%)	2 (0.8%)	7 (3.0%)	4.15	0.90	-0.35	0.06	-0.65
33	78 (32.9%)	126 (53.2%)	22 (9.3%)	3 (1.3%)	2 (0.8%)	6 (2.5%)	4.19	0.73	2.61	0.05	-1.06
34	100 (42.2%)	110 (46.4%)	18 (7.6%)	1 (0.4%)	2 (0.8%)	6 (2.5%)	4.32	0.71	3.06	0.05	-1.21
35	101 (42.6%)	106 (44.7%)	19 (8.0%)	3 (1.3%)	2 (0.8%)	6 (2.5%)	4.30	0.75	2.68	0.05	-1.25

4.3. LSAel instrument: exploratory factor analysis

The EFA generated eight eigenvalues greater than one (See Table 2), Horn's parallel level analyses generally agreed with the Kaiser's eigenvalue findings and are not included in the results of this paper. Subsequently, seven to nine factor solutions were generated and explored (See - Online supplementary file 2). The nine-factor solution demonstrated three cases of cross loading and was discarded. There were no cross loadings in the seven or eight factor solutions. After detailed examination of specific items and factor loadings and identifying that items 19 and 24 were solitary items in the eight-factor solution, the seven-factor solution was identified as the best plausible fit with the data accounting for 86.1% of the total variance. Items 10, 19, 21 and 33 had factor loadings < 0.4 and were removed, item 32 loaded weakly (0.42) into factor five and the decision was made to refine the item in future instrument iterations as there was scope to improve the clarity of its wording.

4.4. Internal domain reliability

Cronbach's alpha was calculated for each *a priori* domain and is presented in Table 3 along with the correlation of each item with the domain total, followed by the correlation as that item was deleted from the domain. Alphas ranged between 0.898 – 0.958 for each domain suggesting high internal consistency and that all items in each domain were measuring the same underlying construct. Only the removal of Item 10 would improve the internal consistency of domain 2, although it still had a good correlation with the total. The *a priori* domains 3, 5, 8 and 9 contained two or less items, consequently their tests were limited, suggesting that additional items should be generated for future versions or that the domain be removed (Raubenheimer, 2004).

All 30 items retained had loadings > 0.4, each factor was explored and mapped with consideration of the *a priori* domain of instructional design outlined in Fig. 1. Factor loadings for each item are presented in Table 4 along with their corresponding sub-scales labeled as:

Sub-scale 1 (Factor 6): Gain attention (3 items). This sub-scale evaluated the learner's perception of whether the program's introductory features captured their attention and provided a sound rationale for the program and how it was relevant to them. Factor loadings ranged between 0.70 and 1.00.

Sub-scale 2 (Factor 3): Identify goals and logical progression of content (6 items). This sub-scale assessed whether the modules/program provided clear learning outcomes and whether the resources and content facilitated the achievement of the learning objectives. Factors loaded between 0.45 and 1.00 with the top loading item being *"The layout of the module/s were user friendly."*.

Sub-scale 3 (Factor 2): Resources and strategies to enhance content delivery (5 items). These items sought to identify learners' perspectives about the way the program connected prior knowledge with new content, particularly through the use of multimedia. Items loaded between 0.64 and 1.00 with the strongest loadings relating to the use of video, animation and graphic usage to enhance content delivery. It also measured whether the resources and strategies used facilitated knowledge generation while avoiding memory overload.

Table 2
Kaiser Eigenvalues.

Number of factors	Eigenvalue	Proportion of variance explained %	Cumulative variance explained %
1	10.07738	29.64	29.64
2	5.401377	15.89	45.53
3	4.934798	14.51	60.04
4	3.794286	11.16	71.20
5	2.088137	6.14	77.34
6	1.710923	5.03	82.37
7	1.263826	3.72	86.09
8	1.158886	3.41	89.50
9	0.893104	2.63	92.13

Table 3
Internal consistency; *Alpha and corrected item-total correlation not reported due to number of items being < 3.

Domain/ items	Alpha	r
Domain 1	0.958	
Q1	0.955	0.794
Q2	0.955	0.804
Q3	0.957	0.747
Q4	0.953	0.847
Q5	0.951	0.886
Q6	0.952	0.864
Q7	0.952	0.857
Q8	0.952	0.854
Q9	0.954	0.809
Domain 2	0.937	
Q10	0.943	0.724
Q11	0.914	0.880
Q12	0.920	0.841
Q13	0.910	0.905
Q14	0.924	0.824
Domain 3*	…	
Q15	…	…
Domain 4	0.952	
Q16	0.943	0.856
Q17	0.940	0.898
Q18	0.941	0.882
Q19	0.946	0.827
Q20	0.943	0.854
Q21	0.947	0.805
Q22	0.953	0.742
Domain 5*	…	
Q23-Q25	…	…
Domain 6	0.898	
Q26	0.839	0.816
Q27	0.803	0.858
Q28	0.915	0.726
Domain 7	0.906	
Q29	0.887	0.785
Q30	0.883	0.795
Q31	0.824	0.862
Domain 8*	…	
Q32-Q33	…	…
Domain 9*	…	
Q34-Q35	…	…

Sub-scale 4 (Factor 1): Maintain attention (6 items). These items measured whether the methods used to present content engaged participants, maintained their interest, motivation, attention and consequently their capacity to actively learn. Factors loaded between 0.52 and 1.00 with the strongest loading item being *"The module/s posed questions that required me to think carefully"*.

Sub-scale 5 (Factor 7): Elicit performance 'practice' (2 items). This sub-scale evaluated the learner's perception of whether the program used assessment techniques that enabled them to apply newly acquired knowledge during the program. This sub-scale consisted of two items which loaded at 0.73 and 1.00 and will need to be developed and refined further in the future to ensure it is a stable factor. Raubenheimer (2004) suggested that this should be seen as an exception and a minimum of three items should load significantly into a scale to ensure its stability.

Sub-scale 6 (Factor 5): Provide informative feedback and consolidate learning (5 items). These items evaluated the degree of satisfaction users have with the amount, timing and quality of feedback delivered by the program and its impact on consolidating their learning. Factor loadings ranged between 0.42 and 1.00 with the strongest loading item being *"…provided results and feedback at an appropriate time."*.

Sub-scale 7 (Factor 4): Flexible navigation and knowledge transfer (3 items). This sub-scale, with factor loadings ranging between 0.46 and 1.00, evaluated whether the user was provided with sufficient resources and means to enable transfer and application of new knowledge to their workplace. These items also rated the user's perception of whether the

Table 4
LSAeL Instrument questions, subscales (SS) and factor loadings. Factor loadings calculated using principal axis extraction with promax rotation. Factor items retained are in bold font, with items < 0.4 in normal font.

Item	Question	EFA Sub-scale title	F1 (SS4)	F2 (SS3)	F3 (SS2)	F4 (SS7)	F5 (SS6)	F6 (SS1)	F7 (SS5)
4	4. The module/s provided useful content	Maintain attention	**0.52**	0.00	0.00	0.03	0.03	0.02	-0.04
5	5. The module/s provided interesting content	Maintain attention	**0.87**	0.02	0.00	0.00	0.01	0.00	0.00
6	6. The module/s provided engaging content	Maintain attention	**0.87**	0.00	0.00	0.00	0.00	-0.01	0.01
7	7. The module/s motivated me to learn	Maintain attention	**0.86**	0.00	0.00	0.00	-0.01	0.00	0.01
8	8. The module/s posed questions that required me to think carefully	Maintain attention	**1.00**	0.00	0.00	0.00	0.00	0.00	0.00
9	9. The module/s used multimedia that maintained my interest	Maintain attention	**0.55**	0.00	0.06	-0.01	-0.05	0.01	-0.01
15	15. The module/s enabled me to use my existing knowledge and experience as a foundation for new learning	Resources and strategies to enhance content delivery	0.00	**0.64**	0.01	0.3	0.00	0.00	0.00
16	16. The module/s utilized audio elements effectively	Resources and strategies to enhance content delivery	0.00	**0.68**	0.02	0.00	0.00	0.21	0.00
17	17. The module/s utilized video elements effectively	Resources and strategies to enhance content delivery	0.00	**1.00**	0.01	0.01	-0.01	0.04	0.00
18	18. The module/s utilized animations and graphics effectively	Resources and strategies to enhance content delivery	0.03	**0.99**	0.01	0.00	0.00	0.00	0.02
20	20. The module/s presented the right amount of information for the topic	Resources and strategies to enhance content delivery	0.02	**0.61**	0.04	0.03	0.07	-0.01	0.00
11	11. The module/s provided clear learning objectives	Identify goals and logical progression of content	0.00	0.14	**0.50**	0.13	0.00	0.04	0.00
12	12. I understood what I needed to do to complete the module	Identify goals and logical progression of content	0.00	0.1	**0.94**	0.01	0.00	-0.01	0.00
13	13. The content of the module aligned with the learning objectives	Identify goals and logical progression of content	0.00	0.06	**0.55**	0.17	-0.01	0.03	0.00
14	14. The resources available to me in the module assisted me to achieve the learning objectives	Identify goals and logical progression of content	0.00	0.03	**0.78**	0.12	-0.01	0.00	0.01
22	22. The layout of the module/s was user-friendly	Identify goals and logical progression of content	0.01	0.00	**1.00**	0.00	0.02	-0.07	0.00
28	28. The module/s provided questions that were easy to understand	Identify goals and logical progression of content	0	0.07	**0.45**	0	0.1	-0.01	0.08
25	25. The introductory/help pages gave me clear instructions about how to progress through the module/s	Flexible navigation and knowledge transfer	-0.2	0.00	0.00	**0.46**	0	0.00	0.06
34	34. I will be able to apply what I have learned from this module/s to my clinical practice	Flexible navigation and knowledge transfer	0.01	0.04	0.01	**0.81**	-0.04	0.00	0.00
35	35. The module/s enabled me to review additional content if or when I needed to.	Flexible navigation and knowledge transfer	0.00	0.00	0.04	**1.00**	-0.01	0.00	0.00
24	24. The 'pop-up' boxes helped me recall important information	Provide informative feedback and consolidate learning	-0.01	0.05	0.00	0.06	**0.68**	0.00	0.00
29	29. The module/s provided feedback that was beneficial to my learning	Provide informative feedback and consolidate learning	0.00	0.17	0.00	0.00	**0.45**	0.02	0.08
30	30. The module/s provided feedback that showed me where or why my response was incorrect (if applicable)	Provide informative feedback and consolidate learning	0.00	-0.00	0.00	-0.06	**0.78**	0.00	0.00
31	31. The module/s provided me with results and feedback at an appropriate time	Provide informative feedback and consolidate learning	0.00	0.00	0.00	-0.02	**1.00**	0.00	0.00
32	32. The module/s made it easy for me to evaluate my learning performance	Provide informative feedback and consolidate learning	0.00	0.00	0.00	-0.14	**0.42**	0.00	0.12
1	1. The introductory video/s captured my attention	Gain attention	0.02	0.00	-0.02	-0.06	0.00	**0.73**	0.00
2	2. The introductory video/s provided a sound rationale for the module	Gain attention	0.00	0.01	0.00	0.00	0.00	**0.93**	-0.03
3	3. The introductory video/s explained how the learning objectives were relevant to my practice	Gain attention	-0.01	0.00	0.00	0.01	0.00	**1.00**	0.00
26	26. The module/s offered a variety of ways to assess my learning	Elicit performance "practice"	0.00	0.01	0.00	0.00	0.00	0.00	**1.00**
27	27. The module/s provided questions that adequately assessed my learning	Elicit performance "practice"	0.00	0.02	0.00	0.00	0.03	-0.02	**0.73**
33	33. On completion of the module/s I was confident I had achieved the learning objectives	< 0.4 Remove on the basis of subjectivity and that assessment assesses this construct	0.00	0.18	0.06	0.36	0.00	-0.04	0.04
10	10. The time required to complete the module was reasonable given the content covered	< 0.4 Remove on the basis that this is a subjective criteria and potentially influenced to factors outside the IDs control	0.00	0.31	0.09	0.00	-0.22	-0.06	-0.01
19	19. The module/s provided information that was relevant to my study (practice)	< 0.4 Remove on the basis that this is a subjective criteria and potentially influenced to factors outside the ID control	0.02	0.22	0.08	0.33	0.02	0.00	-0.01
21	21. The content was delivered at an appropriate level for me	< 0.4 Remove on the basis that this is a subjective criteria and potentially influenced to factors outside the ID control	0.01	0.25	0.18	0.00	0.02	-0.2	0.01

program sufficiently provided guidance on how to use and progress through the program and navigate associated functionality successfully.

The internal domain reliability was reassessed for each sub-scale and corresponding items for the final seven factor solution with Cronbach alphas and item-total correlations and are reported in Table 5 and ordered to represent the logical flow of asynchronous e-learning design.

5. Discussion

This paper has reported the development and psychometric testing of the Learner Satisfaction with Asynchronous e-Learning (LSAeL) instrument. Many items in existing instruments measure latent variables that are out of the control of developers of asynchronous e-learning programs. Consequently, the LSAeL instrument was developed to provide a tool that measured satisfaction related to variables that are under the control of the developers of wholly asynchronous e-learning programs.

The engagement of the expert panel resulted in the removal of 15 items on the basis that the learner was not in a position to reliably answer items about accuracy, quality and evidence levels of content. The decision to remove these items strengthened the ability of the instrument to evaluate measures pertaining to ID particularly given that some of the existing e-learning satisfaction instruments have items that measure other constructs. To illustrate item 14 underwent significant revision in the LSAeL instrument even though existing instruments include items such as “The web site provides accurate information” or “The website provides high quality information” (Udo et al., 2011) or in the case of Wang (2003), “The e-learning system provides up-to-date content” or “The e-learning system provides sufficient content”. It is unrealistic for the learner to be able to assess whether this was the case given that they would have undertaken the program to learn. They did not undertake the program from the position of an expert who would reasonably be considered as a person able to assess this construct.

When exploring the nature of the factor loading for the eight-factor solution in comparison to the *a priori* domains, several items loaded in a manner that did not fit the theoretical assumptions. On content interpretation of the seven-factor solution, *a priori* aligned items were a better fit, consequently the seven-factor solution was retained. The seven-factor solution accounted for 86.1% of the variability in the inter-correlation matrix which is well above the accepted minimum of 50% in health-care psychometrics (Pett et al., 2003). Four of the seven factors contained at least three items that loaded 0.5 or greater, suggesting that these four may be stable factors (Fabrigar et al., 1999). No item cross-loaded on other factors. Four items (10, 19, 21, & 31) failed to load on any factor using the threshold criterion of > 0.4. After content interpretation and consideration of the weak loading, these items were removed from the instrument on the basis that they evaluated subjective criteria and were potentially influenced by factors outside the developers’ control. For example, item ten: ‘The time required to complete the module was reasonable given the content covered’ – This item would be influenced by the learner’s perception of what a reasonable amount of time constituted and would be influenced by factors beyond the developer’s control.

Cronbach’s alpha for seven sub-scales ranged from 0.868 to 0.957 and corrected item-total correlations ranged from 0.699 to 0.922. The factors did not align directly with the *a priori* domains predicted prior to analysis. The inconsistencies may derive from methodological discrepancies, artefacts in the data or invalid question formation in the development phase of the instrument. The latter is more plausible given that four items did not load on any of the seven factors and were discarded on the basis that they were subjective in nature and were potentially influenced by factors outside developers’ control. Another possible reason is that Gagne’s principles of instructional design, despite being foundational practices were developed in the 1960 s and pre-dated online learning. The revised instrument contains 30 items and will require additional refinement and consideration to rigorously evaluate all constructs.

Table 5
Internal consistency of seven factor solution *Alpha not reported due to number of items being < 3.

Subscale/ items	Alpha	r
Gain attention	0.920	.
Item 1	0.918	0.800
Item 2	0.847	0.888
Item 3	0.891	0.832
Identify goals and logical progression of content	0.947	.
Item 11	0.935	0.859
Item 12	0.935	0.863
Item 13	0.932	0.895
Item 14	0.937	0.844
Item 22	0.944	0.788
Item 28	0.942	0.800
Resources and strategies to enhance content delivery	0.953	.
Item 15	0.951	0.810
Item 16	0.938	0.888
Item 17	0.932	0.922
Item 18	0.935	0.905
Item 20	0.950	0.820
Maintain attention	0.957	.
Item 4	0.953	0.823
Item 5	0.946	0.891
Item 6	0.943	0.912
Item 7	0.947	0.882
Item 8	0.946	0.886
Item 9	0.956	0.801
Elicit performance 'practice'	0.915	.
Item 26*	.	.
Item 27*	.	.
Provide informative feedback and consolidate learning	0.920	.
Item 24	0.910	0.753
Item 29	0.898	0.824
Item 30	0.901	0.801
Item 31	0.891	0.866
Item 32	0.913	0.776
Flexible navigation and knowledge transfer	0.868	.
Item 25	0.866	0.753
Item 34	0.815	0.751
Item 35	0.763	0.805

5.1. Limitations, implications for future research

This study and the revised LSAeL instrument has both strengths and limitations. This study design could not identify whether items had been inadvertently omitted that address the entire construct related to wholly asynchronous e-learning instructional design. We attempted to overcome this limitation by engaging with an expert panel to refine and improve items to accurately reflect the domains represented. However, the expert panel review process is subjective in nature and potentially biased by personal opinion and experience. This study attempted to control for this by providing a clear explanation of the construct being assessed by the panel. Integrating a triangulated data analytical approach enabled us to overcome previously identified limitations (Polit and Beck, 2006) of using the CV-I approach exclusively, by also using the modified kappa statistic to adjust for chance agreement within the panel. In doing so, item structure was refined to improve item fit at both a global and sub-instrument level after the first review from the expert panel. The expert panel raised concerns about instrument length and the potential for response burden. Survey length has been reported to affect response rates of participants in previous studies with web-based surveys likely to be answered quickly and longer surveys being more likely to lead to user disengagement (Galesic and Bosnjak, 2009; Morgado et al., 2018). Face validity could have been assessed using 10–20 students to review the instrument, we decided against this due to the experience of the SME panel and the extensive feedback provided.

In stage two, the sample was drawn from a single cohort of undergraduate students enrolled at the same university. These students were enrolled across three campuses and represented a typical undergraduate cohort. Criteria regarding ideal sample size recommendations to avoid sampling error vary greatly (Pett et al., 2003). Some (Pett et al., 2003) suggest that a subject to item ratio of 5:1 is considered satisfactory whereas others recommend higher ratios of 10:1 (Costello and Osborne, 2005). The ratio in this present study was almost 7:1 and prior to analysis the KMO test for MSA and Bartlett's Test of Sphericity indicated that the data and sample size for this study was adequate for factor analysis.

Despite anonymous self-report style instruments lessening social desirability bias, they are subject to possible bias such as item misinterpretation or subjectivity in interpretation of anchor meaning. Recall bias is a further potential issue particularly if participant responses were inaccurate or incomplete regarding their experiences due to hasty completion or poor recollection of the learning event.

The development and robust psychometric testing of new instruments and instruments is an extensive and prolonged process. Some of these limitations provide the opportunity to further validate the instrument to inform its use in other cohorts, languages and asynchronous e-learning programs. As the instrument is further refined, consideration must be given to the construction of new items, while being mindful of response burden, to ensure that there are a minimum of three items per sub-scale to successfully identify the sub-scale during psychometric testing (Raubenheimer, 2004). This will improve the likelihood that items will replicate and significantly load on each factor. If further testing is conducted, confirmatory factor analysis should be undertaken to evaluate the relationship between the manifest variables and their underlying constructs and test whether the instrument performs similarly in other populations of interest.

6. Conclusion

This paper has demonstrated the LSAeL instrument to be both valid and internally reliable. The final EFA resulted in a refined 30 item instrument with a seven-factor structure, which explained 86.1% of the total variance which is well above the threshold of 60% accepted for psychometric testing in the social sciences (Hair et al., 2014). EFA by its very nature is exploratory, it does not use inferential statistical methods and exists to explore a data set (Costello and Osborne, 2005). This process has enabled close consideration of the LSAeL instrument and enabled the research team to refine the instrument further and identify domains that require the addition of further items.

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CRediT authorship contribution statement

Christopher J. Oldmeadow: Formal analysis, Validation, Writing – original draft. **Ashley Kable:** Formal analysis, Investigation, Methodology, Supervision, Writing – review & editing. **Peter M. Sinclair:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Validation, Writing – original draft, Writing – review & editing. **Amanda Wilson:** Writing - review and editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.nepr.2024.103897.

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