VALIDITY AND RELIABILITY OF SMART SCIENCE LEARNING EXPERIENCE INVENTORY (SSLEI)

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The Smart Science Learning Experience Inventory (SSLEI) was developed by the authors to assess Malaysian students' perceptions of their science learning experience as indicated in the Conceptual Blueprint for Malaysian Smart Schools. The instrument was psychometrically evaluated using 764 15-year-old students from two Smart schools and two Mainstream schools in Malaysia. The initial instrument with a Cronbach's alpha measuring at 0.89 consisted of 11 pre-determined subscales. However, the alphas for the 11 pre-determined subscales were generally marginal to inadequate, casting doubts on original subscale concepts. The 30-item SSLEI was then psychometrically refined through factor analysis. The revised post-hoc subscales consisted of parsimonious range of eight coherent groups: (1) Information and Communication Technology, (2) Supported Learning, (3) Science Process Skills, (4) Constructivist Practice, (5) Self-Determined Learning, (6) Learning Preference, (7) Active Thinking, and (8) Values Inculcation. Although 6 items were removed from the original SSLEI to form a coherent eight subscales in the Revised SSLEI for reasons discussed in the article, these items were retained in the original SSLEI for overall measure of smart science learning experience by virtue of the high alpha that indicated its full-scale high internal consistency.

INTRODUCTION

A significant transformation of the Malaysian educational system occurred in 1999 — the birth of Smart Schools Initiative. The Smart Schools Initiative is one of the seven flagship applications that are part of Malaysia's Multimedia Super Corridor (MSC) project. The Government of Malaysia seeks to capitalise on the presence of leading-edge technologies and the rapid development of the MSC's infrastructure to jump-start deployment of enabling technology to schools. Hence, the formation of a group of 90 pilot Smart Schools in 1999 that serve as the nucleus for the eventual nation-wide deployment of Smart School teaching concepts and materials, skills, and technologies (Smart School Project Team, 1997a). By 2010, the term 'Smart' is expected to be redundant when all schools, be they primary or secondary, would have been transformed to that of Smart Schools (Smart School Project Team, 1997b).

The conceptualised document entitled "The Malaysian Smart School: A Conceptual Blueprint" (Smart School Project Team, 1997a) explains that the Malaysian Smart School Concept is derived from best practices from around the world, as well as from the best home-grown practices of teachers and educators in Malaysia. In essence, the Malaysian Smart School is defined as:

> *…a learning institution that has been systematically reinvented in terms of teaching-learning practices and school management in order to prepare children for the Information Age (ibid., p.10).*

SMART SCIENCE TEACHING

This section seeks to bring to the fore, several distinctive indicators which are perceived to constitute the "reinvention in terms of teaching and learning" (ibid., p.10). These indicators emerge mainly from the policy documents, particularly the Conceptual Blueprint for Malaysian Smart Schools and the smart school edition science syllabuses. It has been persuasively argued that, "The journey of the Smart School project might otherwise be a long and gradual one, but we can now use technology to take us there quickly and efficiently" (ibid., p.37). The corollary that stems from such argument is that science teaching and student learning can be made more efficient and enabling with the use of technology.

Next, there is a strong advocacy for explicit teaching of thinking skills. This seems to find its roots in Perkins' (1995) notion of "metacurriculum", which in turn, is adapted from other leading theorists in the area of thinking (i.e., Costa, 1991; Paul, 1990). Additionally, Smart School pedagogy is to be 'student-centred' with the following characteristics (Smart School Project Team, 1997a, p.39): (1) appropriate mix of learning strategies to ensure mastery of basic competencies and promotion of holistic development, (2) allowance for individual differences in learning styles to boost performance, and (3) classroom atmosphere compatible with different teaching-learning strategies. The element of mastery learning in the Smart School resembles Perkins' (1995) idea of "Theory One and Beyond" which promotes, amongst others, thoughtful practice and informative feedback.

There are three further key teaching and learning processes of Smart Schools, namely self-accessed, self-paced, and self-directed learning. In self-accessed learning, students learn how to access and use relevant learning materials. In self-directed learning, students are given the responsibility for directing, managing and planning their own learning Self-paced learning means that a student learns at his/her own pace, with enough challenging materials to help him/her achieve a certain competency level. It is envisaged that the use of technology will facilitate self-accessed, self-paced, and self-directed learning (CDC, 1999). Hence, when a student's role is switched from relatively dependent and passive towards a self-accessed, self-paced, and self-directed, the teacher's role undergoes, in tandem, an evolution from 'sage on the stage' to 'guide on the side.'

Besides, it has been advocated that the planning for teaching and learning should take the constructivist elements into consideration. Therefore, "teacher takes into consideration students' existing knowledge" is an important feature of a constructivist teaching because meaningful learning occurs when students "link existing idea with new idea to restructure their idea" (CDC, 1999, p.12).

In the science curriculum for Smart schools, "the mastery of scientific skills needed for experimenting and understanding of nature" (CDC, 1999, p.7) has been given due emphasis. 12 science process skills that "enable students to question a certain phenomenon and to find the answer in a systematic fashion" (ibid.) have been explicitly identified and defined in the syllabus. However, teachers are expected to imbue these science process skills, not in isolation and context-free environment, but within a science context in an integrated manner.

On inculcation of values, 16 values are outlined, namely, "compassion, self-reliance, respect, love, freedom, courage, physical and mental cleanliness, co-operation, diligence, moderation, gratitude, rationality, public spiritedness, humility, honesty, and justice" (Smart School Project Team, 1997a, p.32). At operational levels, it has been recommended that these "noble" values be inculcated during the teaching and learning either "casually or systematically" (CDC, 1999, p.11).

The discussion in the preceding paragraphs sets a framework from which students' smart science learning experience could be gauged, particularly in terms of their exposure to a range of science teaching approaches as advocated in the policy documents. In essence, 11 smart science teaching elements have been identified, namely the use of ICT, self-directed learning, self-paced learning, self-accessed learning, mastery learning, constructivist practice, multiple intelligences and learning styles, student-centred learning, thinking skills and metacognition, science process skills, and values inculcation.

PURPOSE OF THE STUDY

The research on learning environments in science indicates that the learning environment is associated, amongst others, with student cohesiveness and satisfaction (Haertel, Walberg, & Haertel, 1981), and achievement (Fraser, 1986; Fraser, Walberg, Welch, & Hattie, 1987). However, the instrumentation used does not seem to be a good fit with the Malaysian smart school guiding principles for the teaching of science. Furthermore, Aldridge and Fraser (1997) caution the use of questionnaires framed in a Western context in a different culture. They foresee the inadequacy of the interpretation of data, which measures a Western idea of what constitutes a positive learning environment, due to non-consideration of socio-cultural factors that influence the classroom from which the data are gathered. Given the limitations of the existing instruments, the purpose of this study was to develop a valid and reliable instrument to measure students' science learning experience in the Malaysian context in general, and one that parallels the Malaysian smart science teaching concept, in particular.

METHOD

Item Generation

The 30-item Smart Science Learning Experience Inventory (SSLEI) (see Appendix 1) was developed using literature review and documents consultation, particularly the Smart School Blueprint (Smart School Project Team, 1997a) and the smart school edition Form 3 Science Syllabus (CDC, 1999). Firstly, 11 smart teaching elements that procure information about students' experience in theoretical as well as practical science classes were identified. These elements have been discussed in the previous section.

Then, the indicators that reflect each smart teaching element were delineated. An example of a smart teaching element is *constructivist practice.* For the case of constructivist practice, three indicators (or items) were generated as shown in Table 1. Table 2 shows the categorisation of 30 items (see Appendix 1) into 11 smart science teaching elements. For each item, a 6-point Likert scale (i.e., 0=Non Existence; 1= Very Little; 2= Little; 3=Moderate; 4=Much; and 5=Very Much) was used. From this set of six scaled statements, respondents were asked to choose the one which best described their science learning experience. The items were scrutinised by two experienced science teachers from the Smart as well as the Mainstream schools to establish their clarity and appropriateness.

Table 1
Items for Constructivist Practice

Items	Statements
1	Teacher shows interest in my views about the topic that I am about to learn.
2	Teacher creates opportunities for me to test my views/ideas/predictions.
3	Teacher provides learning activities that help develop, modify or change my earlier views/ideas.

Table 2
Items in Smart Science Teaching Elements

Smart Science Teaching Elements	Items
Constructivist Practice	1, 2, and 3
Multiple Intelligences and Learning Styles	4, 5, and 6
Self-Directed Learning	7, and 8
Self-Paced Learning	9, and 10
Self-Accessed Learning	11, and 12
Mastery Learning	13, 14, and 15
Student-Centred Learning	16, 17, and 18
Thinking Skills and Metacognition	19, 20, and 21
Science Process Skills	22, 23, and 24
Values	25, and 26
Information and Communication Technology	27, 28, 29, and 30

Subjects and Procedures

The SSLEI was administered to 764 15-year-old students from two Smart Schools (n=383) and two Mainstream Schools (n=381) in Malaysia. This involved a purposive sampling on the basis of their typicality. The judgement made in the selection process was, in part, informed through a consultation with two officers from the Ministry of Education who played a key role in monitoring schools throughout Malaysia.

In each school, the administration of the SSLEI was done simultaneously for all the classes. A teacher's guide was prepared for the use of the respective class teachers. In the guide, teachers were asked to inform students that the questionnaire was not meant to be a test and hence, there was no right or wrong answer for each item. Instead, students were encouraged to express their views that best represented their science learning experience.

Data Analysis Procedures

Statistical procedures were used to establish the reliability and construct validity of the SSLEI. Alpha coefficients (Cronbach, 1951) were computed to evaluate the internal consistency of the SSLEI as a whole, and the internal consistency of the pre-determined subscales (i.e., each of the 11 pre-determined smart teaching elements). Exploratory factor analysis was used to examine whether, on the basis of students' responses to the 30 items in the SSLEI, a smaller number of factors could be identified. This 'inductive approach to scaling' (De Vaus, 2001, p.257) clusters items that 'go together,' reflecting the sets of items students responded in a consistent way.

RESULTS

Scale and Item Analyses

On a possible minimum score of 0 and a maximum score of 150, a mean score of 79.9 and individual scores ranging from 3 to 144 were generated. These results indicate that the SSLEI displays adequate sensitivity since the scores of 764 students in the sample covered more than ninth-tenths (94%) of the potential range of the scale.

For test-retest reliability of the SSLEI, it was not feasible to carry out the test twice. However, the overall internal reliability, established using Cronbach's coefficient alpha, was measured at 0.89, which can be claimed as a high value and indicating that the items have high internal consistency. Interestingly, as shown in Table 3, deleting any of the 30 items does not increase the reliability of SSLEI. This indicates that all the items contribute to this reliability and none should be dropped from the overall measure of students' smart science learning experience.

Table 3
Scale Testing Coefficients

Item	Means	SD	Corrected Item-total Correlations	Alpha if Item Deleted
1	2.98	1.23	0.39	0.89
2	2.90	1.18	0.49	0.89
3	3.17	1.23	0.48	0.89
4	3.13	1.27	0.43	0.89
5	3.20	1.23	0.46	0.89
6	3.49	1.24	0.30	0.89
7	2.74	1.39	0.47	0.89
8	2.19	1.42	0.41	0.89
9	2.62	1.46	0.47	0.89
10	3.43	1.33	0.50	0.89
11	3.74	1.34	0.41	0.89
12	2.46	1.79	0.49	0.89
13	3.35	1.28	0.50	0.89
14	2.91	1.14	0.56	0.89
15	1.34	1.45	0.33	0.89
16	2.83	1.52	0.53	0.89
17	2.81	1.33	0.53	0.89
18	2.68	1.42	0.34	0.89
19	2.37	1.55	0.33	0.89
20	3.07	1.25	0.41	0.89
21	2.73	1.24	0.50	0.89
22	3.41	1.34	0.47	0.89
23	2.81	1.37	0.51	0.89
24	2.65	1.46	0.46	0.89
25	3.07	1.31	0.46	0.89
26	2.61	1.41	0.45	0.89
27	1.71	1.64	0.43	0.89
28	1.29	1.56	0.47	0.89
29	1.08	1.41	0.40	0.89
30	1.10	1.56	0.34	0.89

Alpha for scale = 0.89

Also shown in Table 3 are the corrected item-total correlations (r), which range from 0.30 to 0.56 inclusive. Since all the r-values exceed the threshold of 0.3 recommended by De Vaus (2001), this signifies that the 30 items seem to belong to, and form part of the scale for SSLEI. Additionally, items with r-values of 0.3 and above are considered to discriminate well (e.g., discriminating between students who reported less favourably and those who reported positively on their smart science learning experience) and this is reinforced by sufficient variability shown with standard deviations ranged from 1.14 to 1.79, with a pooled SD of 20.51.

Construct validity "evaluates a measure by how well the measure conforms with theoretical expectations" (De Vaus, 2001, p.56). In this case, two to four items (or, indicators) were generated for each of the 11 pre-determined smart learning elements (or, constructs, or subscales). On internal consistency reliability, Gay and Airasian (2000) advocate that, in addition to the reliability of the total scale, subscale reliabilities should be evaluated and reported. They also note that it is extremely difficult to state appropriate reliability coefficients for different types of scales because reliability is "dependent on the group being tested" and that when scales are developed in new areas, "reliability often is low initially" (ibid., p. 177). De Vaus (2001), however, argues that, "as a rule of thumb alpha should be at least 0.7 before we say the scale is reliable" (p. 256). As reported earlier, the overall internal reliability of the SSLEI was high with alpha measuring at 0.89. The internal reliability for each subscale, on the other hand, seems to be marginal to inadequate (i.e., 0.40 – 0.69) except for the subscale on *information and communication technology*, which was measured at 0.81 (see Table 4).

Table 4
Construct Reliability of SSLEI

Construct	Items	Corrected item-total correlation
Constructivist Practice	1	0.62
	2	0.66
	3	0.62
		= 0.62
Multiple Intelligences & Learning Styles	4	0.62
	5	0.65
	6	0.44
		= 0.52
Self-Directed Learning	7	0.69
	8	0.70
		= 0.56
Self-Paced Learning	9	0.66
	10	0.61
		= 0.45
Self-Accessed Learning	11	0.62
	12	0.74
		= 0.51
Mastery Learning	13	0.56
	14	0.64
	15	0.48
		= 0.48
Student-Centred Learning	16	0.62
	17	0.62
	18	0.55
		= 0.57
Thinking Skills and Metacognition	19	0.50
	20	0.48
	21	0.53
		= 0.40
Science Process Skills	22	0.66
	23	0.69
	24	0.69
		= 0.69
Values	25	0.65
	26	0.68
		= 0.50
Information and Communication Technology	27	0.67
	28	0.76
	29	0.78
	30	0.73
		= 0.81

Alpha for scale = 0.89

Item-item correlations were computed and the results indicated that 423 out of 435 correlations were significantly positively correlated at less than the 0.05 significance level. This suggests that the items are related and that "they may constitute one or more factors" (Bryman & Cramer, 1998, p.279). Given these results, an exploratory factor analysis is useful to examine whether, on the basis of students' responses to the 30 items in the SSLEI, a smaller number of factors (or, subscales) could be identified and higher subscale internal reliabilities could be achieved. Such inductive approach to scaling aggregates items that cohere, reflecting the sets of items students responded in a consistent way (De Vaus, 2001).

FACTOR ANALYSES

When subjected to principal components factor analysis, factors and their corresponding eigenvalues and percentages of variance accounted for, are yielded and summarised in Table 5. An eigenvalue is a "measure that attaches to factors and indicates the amount of variance in the pool of original variables that the factor explains…[and] to be retained, factors must have an eigenvalue greater than 1" (De Vaus, 2001, p.261). This criterion — retaining only factors with eigenvalues greater than 1 — was first proposed by Kaiser (1960). Using this criterion, a six-factor solution emerges. Looking at the factor loadings in Table 6, Factor 1 attracts substantial loadings from all the items, in contrast to the other five factors. This is expected because these factors are extracted successively and will account less and less variance overall. However, "the initial extraction of factors does not make it clear which variables [or, items] most 'belong' to each factor" (De Vaus, 2001, p.263); hence a factor rotation is needed.

Table 5
Communalities, Eigenvalues and Per Cent of Explained Variance in the Unrotated Solution

		Extraction Sums of Squared Loadings		
Component	Communality	Eigenvalue	% of Variance	Cumulative %
1	.454	7.54	25.16	25.16
2	.550	2.49	8.31	33.47
3	.416	1.43	4.78	38.25
4	.651	1.21	4.06	42.31
5	.593	1.09	3.63	45.94
6	.349	1.07	3.57	49.51
7	.503	.99	3.31	52.82
8	.483	.90	3.00	55.82
9	.430	.88	2.93	58.75
10	.451	.86	2.87	61.62
11	.571	.84	2.80	64.42
12	.588	.76	2.54	66.96
13	.477	.75	2.51	69.47
14	.487	.73	2.44	71.91
15	.317	.71	2.36	74.27
16	.451	.69	2.31	76.58
17	.501	.67	2.24	78.82
18	.497	.62	2.08	80.90
19	.369	.61	2.05	82.95
20	.365	.58	1.94	84.89
21	.371	.54	1.81	86.70
22	.580	.53	1.78	88.48
23	.558	.53	1.76	90.24
24	.570	.50	1.67	91.91
25	.310	.47	1.56	93.47
26	.380	.45	1.50	94.97
27	.588	.41	1.38	96.35
28	.641	.40	1.31	97.66
29	.694	.38	1.28	98.94
30	.657	.33	1.06	100.00

Extraction Method: Principal Component Analysis.

Table 6
Unrotated Factor Matrix [a]

	Factor					
Item	1	2	3	4	5	6
14	**.632**	-.225	.055	-.158	-.041	-.088
17	**.596**	-.061	-.001	.058	.254	.273
16	**.581**	-.013	**-.309**	-.090	.025	.095
23	**.578**	-.087	**-.302**	**.310**	-.167	-.022
10	**.575**	-.284	-.096	-.093	.085	-.122
13	**.573**	-.234	-.116	-.158	.086	-.221
21	**.559**	-.039	.032	.203	.108	-.051
2	**.551**	-.087	**.340**	.022	.155	**.313**
3	**.550**	-.205	.120	-.149	.015	.184
7	**.534**	-.119	**.318**	.166	.104	-.252
22	**.534**	-.176	**-.317**	.224	**-.336**	.008
5	**.532**	-.182	.159	**-.309**	**-.360**	.163
12	**.527**	.190	**-.350**	**-.342**	.179	-.053
9	**.526**	-.039	-.288	.049	-.153	-.208
25	**.523**	-.143	-.009	.079	-.097	.013
24	**.515**	-.016	**-.342**	**.370**	-.203	.093
26	**.496**	.041	-.127	**.320**	-.090	-.078
4	**.492**	-.114	.106	-.284	**-.465**	.294
11	**.487**	-.295	-.117	**-.336**	.142	-.288
20	**.470**	-.073	.114	.246	.213	-.140
8	**.467**	-.009	**.425**	.208	-.054	-.195
6	**.364**	-.273	-.082	-.183	.250	-.199
29	**.398**	**.727**	.010	-.056	-.027	-.058
30	**.348**	**.713**	.111	.026	-.041	-.114
28	**.473**	**.637**	.041	-.070	-.003	-.074
27	**.442**	**.546**	-.157	-.262	.019	.038
15	**.355**	**.370**	.082	.020	-.093	-.196
1	**.451**	-.065	**.463**	.052	.073	.155
18	**.383**	.028	-.137	.182	**.444**	**.316**
19	**.357**	.212	-.015	.065	.126	**.420**

Extraction Methods: Principal Component Analysis.
[a]. 6 components extracted

Factor rotation is important as it results "in factors on which only some variables load and in variables that load on only one factor" (ibid., p.263). This gives a clear pattern of loadings (i.e., the factors are more clearly marked by high loadings for some variables and low loadings for others), lending itself to easier interpretation. Given that there are a number of rotational strategies, *varimax* rotation is chosen because it produces "factors that are unrelated to or independent of one another" (Bryman & Cramer, 1998, p. 284) and hence, "are easy to interpret" (Brace, Kemp, & Snelgar, 2003, p. 304).

The results of rotated six-factor loadings are shown in Table 7. Despite adopting the Kaiser criterion, not all items seem to fall into coherent groups. Some have multiple loadings (i.e., items 1, 3, 12, 14, 16, 18, and 21) while others such as item 15 has much lower loading as compared to the rest of the items that loaded onto the same factor. Furthermore, the residual correlation matrix, computed between observed and reproduced correlations and indicates "partial correlations between pairs of variables [or items] with effects of factors removed" (Tabachnick & Fidell, 1996, p. 672), shows 137 residuals (or 31.0%) with absolute values greater than 0.05. This suggests the presence of another factor or factors.

Table 7
Rotated Factor Matrix [a]

Item	Factor					
	1	2	3	4	5	6
29	**.818**	-.029	.076	.084	.025	.105
30	**.778**	-.104	.053	.186	-.018	.051
28	**.776**	.053	.084	.154	.059	.132
27	**.696**	.192	.069	-.101	.141	.179
15	**.489**	.047	.127	.234	.041	-.052
11	.014	**.729**	.100	.109	.132	-.015
13	.058	**.592**	.224	.221	.144	.058
6	-.060	**.558**	.035	.157	.011	.093
12	**.433**	**.555**	.141	-.143	.089	.210
10	-.014	**.531**	.258	.232	.173	.136
14	.068	**.462**	.208	**.313**	**.343**	.099
16	.231	**.388**	**.369**	-.038	.189	.272
24	.110	.066	**.715**	.065	.079	.178
22	.019	.183	**.696**	.076	.235	.018
23	.095	.198	**.681**	.151	.083	.127
26	.178	.101	**.510**	.256	.028	.111
25	.049	.223	**.343**	.256	.236	.138
8	.158	.035	.125	**.651**	.129	.021
7	.079	.248	.139	**.637**	.050	.085
9	.177	.174	.178	**.521**	.251	-.051
1	.071	.077	-.097	**.475**	**.345**	.299
20	.066	.221	.218	**.455**	-.093	.221
21	.132	.226	**.316**	**.374**	.032	.248
4	.101	.099	.200	.059	**.764**	.061
5	.072	.227	.140	.169	**.698**	.036
3	.079	**.302**	.116	.236	**.407**	**.300**
18	.064	.157	.172	.059	-.123	**.648**
17	.095	.257	.210	.215	.161	**.557**
19	.237	-.056	.134	.066	.156	**.517**
2	.050	.101	.026	**.411**	**.335**	**.505**

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
[a.] Rotation converged in 7 iterations.

Therefore, it seems desirable to compare several analyses, each time specifying a different number of factors as suggested by Tabachnick and Fidell (1996). When four-, five-, seven-, eight-, nine- and 10-factor models were explored, the adequacy and plausibility of extraction favoured the 10-factor model. It has the least number of residuals with absolute values exceeding 0.05 as compared to other models, suggesting a good analysis. Additionally, after the removal of 'noisy' items, the remaining items loaded persuasively into 8 coherent factors, which taken together, accounted for 61.62% of the total variance explained. Table 8 shows the results of 10-factor model loadings.

Table 8
Rotated Factor Matrix [a]

Item	Factor									
	1	2	3	4	5	6	7	8	9	10
Q29	**.816**	-.011	.095	.076	.091	.002	.038	.033	-.033	-.088
Q30	**.793**	-.098	.056	.054	.174	.001	-.014	.037	-.052	.078
Q28	**.782**	.049	.050	.070	.126	.085	.089	.106	-.013	.078
Q27	**.708**	.186	.050	.057	-.122	.141	.136	.081	.031	-.057
Q11	-.005	**.742**	.052	.067	.073	.076	.019	.095	.168	-.024
Q10	-.049	**.642**	.194	.151	.211	.082	.151	.121	-.077	-.009
Q13	.073	**.608**	.195	.162	.117	.108	.005	.096	.086	.223
Q12	**.439**	**.539**	.210	.045	-.105	.084	.190	-.171	.127	.007
Q14	.038	**.535**	.127	.234	.251	.247	.082	.216	-.004	-.047
Q24	.098	.062	**.750**	.040	.120	.082	.164	.083	.032	-.053
Q23	.109	.182	**.736**	.151	.103	.051	.024	.098	.086	.083
Q22	.002	.276	**.626**	.037	.055	.199	-.002	.276	-.117	.002
Q16	.218	**.352**	**.373**	.005	.055	.237	**.341**	-.025	.125	-.039
Q1	.094	.136	-.084	**.703**	.159	.090	-.015	.246	-.058	-.039
Q2	.082	.089	.159	**.696**	.202	.148	.209	-.054	.037	.025
Q3	.059	.236	.198	**.545**	.000	.283	.040	.060	.182	.117

Q21	.175	.171	**.357**	**.379**	.178	-.046	.060	.155	.145	.195
Q8	.098	.078	.157	.207	**.743**	.061	.041	-.055	-.004	-.103
Q9	.135	.214	.044	-.011	**.606**	**.316**	.092	.166	-.040	.113
Q7	.075	.170	.121	.216	**.599**	.055	.091	.104	.214	.159
Q4	.099	.105	.169	.157	.084	**.797**	.041	.036	-.017	.024
Q5	.061	.210	.070	.171	.169	**.715**	.048	.140	.079	-.019
Q18	.080	.061	.040	.022	.064	-.001	**.795**	.227	.088	.093
Q17	.122	.181	.247	.298	.175	.178	**.510**	-.041	.117	.143
Q19	.188	.134	.137	.261	.045	.003	**.464**	-.012	**-.383**	**-.311**
Q25	.068	.209	.145	.259	.077	.166	.065	**.673**	.090	.005
Q26	.185	.083	.277	.006	.129	.042	.168	**.665**	.044	.072
Q6	-.039	.229	.089	.132	.106	.055	.127	.097	**.802**	-.098
Q20	.137	.237	.136	.188	.257	-.035	.132	.164	-.113	**.662**
Q15	**.405**	.123	.116	.074	**.326**	-.097	-.026	.141	.005	**-.500**

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
[a.] Rotation converged in 8 iterations.

The first group of four items seems to be factorially distinct, all with loadings greater than 0.71 on Factor 1, and less than 0.30 on Factors 2-10 (Table 8). These items are fully derived from *information and communication technology* (ICT) in the original SSLEI. Fully representing the original subscale, this group of items (items 27-30) retains its labelling as Information and Communication Technology (ICT).

The second set of items consists of five items with factor loadings between 0.53 and 0.74. The distinctiveness of this group is marred by item 12, which has double loading. Inspection of the wording of item 12: "Teacher provides me the opportunities to look up on my own, the explanation/meaning of science concepts from sources such as internet, CD-ROMs, or reference book" shows that it alludes to ICT and hence also loads weakly on ICT-related Factor 1. By removing item 12, the other four items load distinctively on Factor 2. This consists of item 10 from *self-paced learning*, item 11 from *self-accessed learning*, and items 13-14 from *mastery learning*. They seem to form an amalgamation that portrays the active and supportive role of the science teacher in ensuring progressive understanding of scientific concepts among students. Taken together, this group aggregates itself as Factor 2 that defines the notion of Supported Learning.

The third factor is most strongly associated with three items (items 22–24) with factor loadings between 0.62 and 0.75, cohering into a group that fully encompasses the subscale of *science process skills* in the original SSLEI. A further item (item 16) displays weaker triple loading and hence, its removal. Therefore, Factor 3, consisting of the original three-item subscale, remains strongly suggestive of Science Process Skills.

The fourth factor, again most strongly associated with three items (items 1, 2 and 3), which fully drawn from original SSLEI subscale of *constructivist practice*, bring to the fore, a conceptual change scenario where students' pre-instructional views are uncovered, tested and modified accordingly with the outcome expectation that students' construct an understanding of scientific concepts that mirrors the school science view. A further item (item 21) displays double loading on this and the previous factor, and hence its exclusion. Taken together, this group of items, which forms Factor 4, retains the original subscale of Constructivist Practice.

A related set of three items loads rather heavily on Factor 5, with factor loadings of 0.60, 0.61, and 0.74 (Table 8). Items 7 and 8 are drawn from the *self-directed learning* while item 9 comes from the *self-paced learning* of the subscales in the original SSLEI. Considering that the factor loading of 0.32 for item 9 is relatively weak as compared to its much dominant loading of 0.61 on Factor 5, it results in a decision to retain this item. Taken together, these three items reflect the self-determination of a student in learning the things that s/he wants to, interests in, and decides upon within his/her current learning ability. Therefore, Factor 5 is best labelled as Self-Determined Learning.

The sixth set of items consists of two items that come from the *multiple intelligences and learning styles* subscale of the original SSLEI. The factor loadings are relatively high with 0.80 and 0.72 for items 4 and 5 respectively. Collectively, these two items recognise that students differ in many ways and that the provision of appropriate learning experiences for all students is crucial to making a difference in students' learning. The assumption underlying the use of a range of learning styles and activities to cater for students' learning preference is that "no pupils are continually disadvantaged by the continuous use of teaching approaches that do not suit them" (Keogh & Naylor, 2002, p. 271). Therefore, Factor 6 is best labelled as Learning Preference.

The seventh set of items comprises items 17, 18 and 19 with corresponding factor loadings of 0.51, 0.80 and 0.46. Although item 19 has triple loading (i.e., 0.46, -0.38, and -0.31), the two other 'phantom factors' on which this item loads weakly are non-existence in the final post-hoc revised subscales. The two negative loadings simply mean that the item is related to the 'phantom factors' in opposite direction. Therefore, a decision is made to retain item 19 within this seventh group of items. These three items come from two different pre-determined subscales of the original SSLEI, namely *student-centred learning* (items 17 and 18), and *thinking skills and metacognition* (item 19). When taken together, however, all these items reflect the central notion of active thinking where students explain, justify, and discuss using words, graphics and symbols within the context of student-student and student-teacher interactions. This supports Factor 7 as one concerned with Active Thinking.

The eighth set, consisting of two items, forms a distinctive and coherent group, or rather pair, with equally high factor loading of 0.67. They are fully drawn from the pre-determined subscale of *values* in the original SSLEI. Maintaining this pair as a persuasive case for a clear Factor 8, it invokes the notion of Values Inculcation.

The putative factors representing the ninth and tenth groups are considered phantom as each of the factors contains only one high loading item and does not present a clear and persuasive factor. Hence, the exploratory factor analysis reveals eight coherent groups that are psychometrically sound. The revised SSLEI, showing the items for each of the eight subscales, factor loadings and subscale reliability coefficients is given in Appendix 2.

DISCUSSION

The original 30-item SSLEI is maintained for the overall measure of students' smart science learning experience simply because of the high Cronbach's alpha yielded (= 0.89). However, the 11 pre-determined subscales, purported to measure the theoretical smart teaching elements, were not wholly supported by statistical analysis, casting doubts on the original subscale concepts. This could be explained by the incongruence between respondents' (or students') understanding and the wording of items used to portray the theoretical framework of smart science learning experience. By revising the subscales by means of exploratory factor analysis, eight coherent factors emerged. These factors explain, reflect and represent the way in which 764 15-year-old students collectively perceive their science learning experience, responding to items originally conceived to represent the theoretical demand of science learning experience. This line of argument is consistent with the findings of Aldridge and Fraser (1997) who acknowledge the occurrence of different interpretation to some of their questionnaire items from the way intended.

Nunnally (1967) recommends the threshold of 0.60 for the alpha reliability coefficient as being acceptable for research purposes. The post-hoc subscale reliabilities (see Appendix 2) indicate that all the subscales have the adequate internal consistency except for two subscales, namely, Active Thinking and Values Inculcation, each yields an alpha of 0.48 and 0.50 respectively. Therefore, results for the subscale of Active Thinking in the revised SSLEI need to be interpreted with caution. The alpha coefficient of 0.50 for the Values Inculcation subscale, however, is deemed adequate as the subscale consists of only 2 items.

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APPENDIX 1:

Smart Science Learning Experience Inventory (SSLEI)

Instructions

The meaning of the scale 0, 1, 2, 3 ,4 and 5 is shown below

0	1	2	3	4	5
Non Existence	Very Little	Little	Moderate	Much	Very Much

Using the scale of 0 to 5, indicate by checking (√) in the appropriate column, the extent to which you feel you have the following experiences in the learning of science in Forms 1-3.

1. Teacher shows interest in my views about the topic that I am about to learn.
2. Teacher creates opportunities for me to test my views/ideas/ predictions.
3. Teacher provides learning activities that help develop, modify or change my earlier views/ideas.
4. Teacher uses learning activities and materials that suit/match my preferred way of learning.
5. Teacher teaches in ways that fit the way I learn best.
6. Teacher explains using other methods/ways if I could not understand.
7. Teacher supports the learning of things that I want to learn or am interested in.
8. Teacher allows me to decide on what I want to learn or explore.
9. Teacher allows me to learn the topics according to my current learning ability.
10. Teacher supports me to achieve the targeted levels of learning competency.

11. Teacher encourages me to access and use learning materials from a variety of sources apart from the school textbook.
12. Teacher provides me the opportunities to look up on my own, the explanation/meaning of science concepts from sources such as Internet, CD-ROMs, or reference books.
13. Teacher ensures that I know the relatively basic/simple science knowledge/ideas before teaching me the more difficult ideas or topics.
14. Teacher ensures that I receive adequate feedback on my achievement at each level of learning.
15. Teacher provides remediation for science concepts that I failed to understand.
16. Teacher puts me in learning groups for discussion and problem solving activities.
17. Teacher encourages me to explain and justify my results or views.
18. Teacher places importance on student talk/discussion rather than spending most of the time explaining and giving the correct answer to the class.
19. Teacher encourages me to use graphic organisers like radiant maps, concepts maps, Venn diagrams to organise key ideas.
20. Teacher gives time and opportunity for me to reflect upon what I have learnt or studied.

21. Teacher provides me opportunities to solve problems in novel situations.
22. Teacher highlights science process skills during the practical work in the laboratory.
23. Teacher encourages me to hypothesise and predict in the laboratory.
24. Teacher allows me to decide on planning, carrying out, and reporting my experiment.
25. Teacher mentions the moral values related to theoretical and/or practical work in science.
26. Teacher encourages me to evaluate the good and bad of certain products of science.
27. Teacher explains certain science ideas by using models/animations from CD-ROMs.
28. Teacher provides opportunities to use a computer interface to measure in the science laboratory.
29. Teacher encourages me to gather, calculate and graph my data using a spreadsheet such as Microsoft Excel.
30. Teacher allows me to submit the report of our practical work using word processor such as Microsoft Word

APPENDIX 2:

Subscale Items with Varimax Rotation Factor Loadings and Reliability Coefficients for the Revised Smart Science Learning Experience Inventory (SSLEI) (N=764)

Subscale/Item		Factor Loadings	Alpha Coefficient
1.	Information and Communication Technology		
27	Teacher explains certain science ideas by using models/ animations from CD-ROMs.	**.71**	
28	Teacher provides opportunities to use a computer interface to measure in the science laboratory.	**.78**	
29	Teacher encourages me to gather, calculate and graph my data using a spreadsheet such as Microsoft Excel.	**.82**	
30	Teacher allows me to submit the report of our practical work using word processor such as Microsoft Word.	**.79**	
			0.81
2.	**Supportive Learning**		
10	Teacher supports me to achieve the targeted levels of learning competency	**.64**	

11	Teacher encourages me to access and use learning materials from a variety of sources apart from the school textbook	**.74**	
13	Teacher ensures that I know the relatively basic/simple science knowledge/ideas before teaching me the more difficult ideas or topics	**.61**	
14	Teacher ensures that I receive adequate feedback on my achievement at each level of learning.	**.54**	
			0.73
3.	**Science Process Skills**		
22	Teacher highlights science process skills during the practical work in the laboratory.	**.63**	
23	Teacher encourages me to hypothesise and predict in the laboratory	**.74**	
24	Teacher allows me to decide on planning, carrying out, and reporting my experiment.	**.75**	
			0.69

4.	**Constructivist Teaching**		
1	Teacher shows interest in my views about the topic that I am about to learn.	**.70**	
2	Teacher creates opportunities for me to test my views/ideas/ predictions.	**.70**	
3	Teacher provides learning activities that help develop, modify or change my earlier views/ideas	**.55**	
			0.62
5.	**Self-Determined Learning**		
7	Teacher supports the learning of things that I want to learn or am interested in.	**.60**	
8	Teacher allows me to decide on what I want to learn or explore.	**.74**	
9	Teacher allows me to learn the topics according to my current learning ability.	**.61**	
			0.64

6.	**Learning Preference**		
4	Teacher uses learning activities and materials that suit/match my preferred way of learning.	**.76**	
5	Teacher teaches in ways that fit the way I learn best.	**.70**	
			0.64
7.	**Active Thinking**		
17	Teacher encourages me to explain and justify my results or views.	**.51**	
18	Teacher places importance on student talk/discussion rather than spending most of the time explaining and giving the correct answer to the class.	**.80**	
19	Teacher encourages me to use graphic organisers like radiant maps, concepts maps, Venn diagrams to organise key ideas.	**.46**	
			0.48
8.	**Values Inculcation**		
25	Teacher mentions the moral values related to theoretical and/or practical work in science	**.67**	
26	Teacher encourages me to evaluate the good and bad of certain products of science	**.67**	
			0.50