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In-Depth Analysis of the Arabic Version of the Felder-Silverman Index of Learning Styles

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Abstract The aim of this paper is to compare learning style characteristics from two very different linguistic and cultural groups to see how homogeneous they are.. The paper analyses the learning styles of a large sample of Arabic learners using the first validated Arabic version of the Felder-Silverman learning style model (FSLSM), and compares these with samples from English learners in previous studies, notably a study from Graf et al. The analysis takes the form of linear discriminant analysis, cross validated by frequencies and correlation analysis to identify representative characteristics of each learning style dimension and to determine how representative these characteristics are within the different samples. To ensure robust methodological support, the paper applies the methods used by Graf et al., therefore providing a direct comparison between the English and Arabic groups of learners from the two studies. Our results show differences between representative characteristics for the different learning cohorts, which could indicate that culture and learning environment have an influence on learning style preferences.

Keywords: *learning styles, Felder-Silverman learning style model, discriminant analysis, Arabic cohort*

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1. Introduction

As Reigeluth (1996) [1] has observed, in the context of education, "one size does not fit all". Research indicates that the characteristics of learners differ [2] and intimates that these variations manifest themselves with regard to learning, processing information, representation of knowledge and the forms of educational resources that are preferred. As Rasmussen (1998) [3] has noted, a student's learning style may be diagnosed, and certain learners progress better utilising modes of instruction tailored to their individual needs. These needs may be met via employment of instruction enriched with technology; flexible and organic systems of education have the potential to generate an environment in which individual needs are satisfied. However, these adaptive learning supports are dominated by English-language examples based on English versions of psychometric learning style instruments.

The most appropriate psychometric instrument found to support adaptive learning systems is the Felder-Silverman learning style model (FSLSM) [4,5], as it has been success-fully implemented in previous works when individually adapting the electronic learning material [6,7,8,9]. From a system design perspective, it is also practical, enabling a number of learning dimensions to be represented and implemented; and the corresponding results are easy to interpret [8]. Bajraktarevic et al., (2003) [10], for example, confirmed the benefits of providing adaptivity in a study showing that students taking an online course that matched their preferred learning style (sequential or global) achieved significantly better results than those who took a course that did not match their preferred learning style.

Notwithstanding, it did not appear that any robust Arabic variant existed, though a literal translation example was acquired by contacting Professor Felder. The literal translation proved to be inadequate in accurately capturing the psychometric attributes within the instrument. In the following stage, a more accurate Arabic version was produced, which involved obtaining permission and advice from the authors of the FSLSM with regard to carrying out a thorough verification of the instrument in Arabic [11]. This verification consisted of an iterative process involving blind forward and backward translation and the participation of a bilingual psychologist and education and linguistics experts. The validated Arabic FSLSM instrument was then applied to a sample of 1,024 female students in the faculties of Arts and Humanities and Economics and Administration at King Abdul-Aziz University in Saudi Arabia [12] as part of the process of developing an Arabic adaptive learning system (in this case to support the teaching of statistics to undergraduate students).

The development of adaptive systems often draws upon learning style models; however, the majority of adaptive systems incorporate only some aspects of these traditional learning style models rather than all proposed characteristics of the model. This is motivated by the restriction of most adaptive systems to specific functions and a specific course structure [13], but also for practical reasons (e.g. some learning style char-acteristics may not have sensible alternative presentations for the learning material). When conducting investigations into learning styles, it is therefore important to consider which characteristics of the learning style model are supported by the system. The development of an efficient adaptive learning system is likely to be aided by understanding the dominant learning characteristics and preferences of the target cohort of learners [14].

There is clearly a question about the level of homogeneity among learning style characteristics across different cultures and learning environments. There may be subtle differences embedded in the different language constructs, all of which may influence the representative characteristics and preferences of different learning cohorts, and consequently the design of efficient adaptive learning support. What is needed is a robust comparison of learning style characteristics between different groups of learners from different educational, cultural and linguistic environments. For this research, we compared the work of Graf et al. (2007) [14], which was based on English-speaking samples (from New Zealand and Austria) and a learning environment using an English version of the FSLSM, with the results of our own sample from within an Arabic learning environment. In order to ensure that the comparison was robust, we followed the same methods adopted by Graf et al. (2007) [14], thereby making direct comparison possible.

The primary approach of the method developed by Graf et al. is to develop a graded characterisation within the four dimensions of the FSLSM and to use tools such as linear discriminant analysis to examine the representativeness within these dimensions of each characteristic of the sample responses. The results of the study will then be used to guide the design of an improved adaptation process.

The structure of this paper roughly follows that of Graf et al.'s research (2007) [14], as follows: first there will be a discussion of the Felder-Silverman learning style theory. The paper then discusses the development of the Arabic adapted learning system, which raised questions about the homogeneousness of learning style characteristics and provided stimulus for the research. Next, the paper discusses the methods and the different stages of the process, including methods used to identify the semantic grouping and classification of characteristics within the instrument. The paper then discusses the results of applying these classifications to the responses, including applying linear discriminant analysis, and the cross-validation methods used. Next, the paper compares these results with those of Graf et al. before providing further discussion about the implications of the results, limitations of the work and areas for further study.

1.1. Felder-Silverman Learning Style Theory

There are a number of theories regarding individual learning styles, including those of Pask (1976) [15], Honey and Mumford (1986) [2], Kolb (1984)[16] and Felder and Silverman (1988) [17]. Most descriptions of individual learning styles categorise people into only a limited number of groups. However, the FSLSM goes further: this system differentiates preferences on four dimensional levels, thus allowing adaptive education systems to create learning systems that are more tailored towards learners' preferences. Felder notes that students with pronounced preferences in their learning styles may encounter hardships in perceiving information delivered via methods not congruent with these preferences [17,18].

The FSLSM [17] identifies four dimensions in which to categorise the learning styles of individuals; these can be observed independently and illustrate the ways in which individuals prefer to process (active/reflective), perceive (sensing/intuitive), receive (verbal/visual), and understand (sequential/global) information. The first table describes, in brief, the contextual preferences of typical learners from each of the four dimensions of the Felder-Silverman model.

Table 1. Felder's learning dimensions [6]

Description	Dimension		Description
Learn by working in groups and handling things.	Active	Reflective	Learn better when they can think and reflect about the information presented to them. Work better alone or with one other person at most.
Prefer to deal with facts, raw data and experiments; patient with details, but don't like complications.	Sensing	Intuitive	Prefer to deal with principles and theories, are easily bored when presented with details and tend to accept complications.
Easily remember what they see: images, diagrams, timetables, films, etc.	Visual	Verbal	Remember what they've heard, read or said.
Follow a linear reasoning process when solving problems and can work with a specific material once they've understood it partially or superficially.	Sequential	Global	Take large intuitive leaps with the information; may have difficulty when explaining how they got to a certain result; require an integral vision.

1.2. Development of an Arabic Adaptive Learning System Based on the FSLSI

Several educational systems have been developed that adapt to learning styles, including the system of Carver et al. (1999a) [6], the Arthur system [19], MASPLANG [20], INSPIRE [21], TANGOW [8], and the AHA! system created by Cristea and de Bra (2006). Many researchers currently agree on the importance of modelling and using learning styles. However, there is little agreement on which aspects of learning styles are worth modelling and what can be done differently for users with different styles [22].

The first such adaptive system produced in Arabic was the Teacher Assisting and Subject Adaptive Material (TASAM) system [4,12]. The TASAM system used Felder and Silverman's learning style theory to determine an individual's preferred learning style and then presented learners with material based on their learning style preferences within the four dimensions of sensing-

intuitive, visual-verbal, active-reflective and sequential-global [17,23].

The TASAM system used an adaptive teaching taxonomy that integrated learning styles with teaching strategies to select learning materials to be presented to individual learners via electronic media. This taxonomy was constructed based on an evaluation of the Soloman-Felder learning style theory and builds on previous work, such as that of Franzoni et al. (2008) [24], which employed an expert panel using the Delphi method. The TASAM system was initially applied to a statistics course aimed at first-level undergraduates across two faculties at the King Abdul-Aziz University in Saudi Arabia [4,12].

The subject of statistics was chosen for several reasons. Firstly, expert-refined and validated learning materials were available, which were kindly provided by evaluation of a teacher. Secondly, it was a relatively straightforward task to redesign statistics-related materials for a computer-based environment. Thirdly, statistics was considered to be a timely and desirable learning objective for potential participants. Finally, statistics is an abstract topic, which presented opportunities to develop different representations for the same concept by employing different representational forms within electronic media. The statistics course using the TASAM system ran between 2010 and 2011.

The adaptation model in TASAM specified the way in which the presentation of content should be adapted based on learning styles. It was implemented as a set of classically structured 'if condition, then action' style rules. These rules form the connection between the domain model and the learner model in order to update the learner model and provide appropriate learning materials. Following Kinshuk and Lin (2003) [25], moderate and strong preferences were grouped together to enable 16 combinations of learning style dimensions from which representational templates were generated (see Table 2). While working on the development of the Arabic adaptive learning system based on learning style instruments developed for English-based learning environments, questions emerged about the homogeneousness of learning style characteristics across language, environment and culture. This provided the stimulus for the current research.

Table 2. 16 combinations of learning style dimensions

Combinations of learning style dimensions
active/sensing/visual/sequential
active/sensing/visual/global
active/sensing/verbal/sequential
active/sensing/verbal/global
active/intuitive/visual/sequential
active/intuitive/visual/global
active/intuitive/verbal/sequential
active/intuitive/verbal/global
reflective/sensing/visual/sequential
reflective/sensing/visual/global
reflective/sensing/verbal/sequential
reflective/sensing/verbal/global
reflective/intuitive/visual/sequential
reflective/intuitive/visual/global
reflective/intuitive/verbal/sequential
reflective/intuitive/verbal/global

2. Methodology

The method consisted of following the approach used by Graf et al. (2007) [14], which involved the selection of a relevant sample to test the learning style instrument, followed by the use of a variety of tools to ascertain and analyse the learning style characteristics and representativeness of the sample responses.

2.1. Participants

The Arabic version of the ILS questionnaire was applied to a selection of 1,024 female bachelor's degree students from two faculties at the King Abdul-Aziz University in Saudi Arabia: namely, the Arts and Humanities faculty (consisting of two different departments: Arabic Psychology and Mass Communication) and the Economics and Administration faculty (consisting of five departments: Public Administration, Accounting, Economics, Political Science, Law and Business Administration).

Table 3. Semantic Groups Associated with the Arabic Index of Learning Styles (ILS) Questions, Grouped Manually

Style	Semantic group	Arabic ILS questions	Style	Semantic group	Arabic ILS questions
		(Answer a)			(Answer b)
Active	Trying something out	1, 17, 25, 29	**Reflective**	Think about material	1, 5, 17, 25, 29
	Socially oriented	5, 9, 13, 21, 33, 37, 41		Impersonally oriented	9, 13, 21, 33, 41, 37
Sensing	Existing ways	2, 26, 30, 34	**Intuitive**	Innovative or creative	2, 14, 22, 26, 30, 34
	Concrete material	6, 10, 14, 18, 38		Abstract material	10, 38
	Careful with details	22, 42		Not careful with details	42
				Dealing with theory	6, 18
Visual	Pictures	3, 7, 11, 15, 19, 23, 27, 31, 35, 39, 43	**Verbal**	Spoken words	3, 15, 19, 27, 35
				Written words	7, 11, 23, 31, 39
				Difficulty with visual style	43
Sequential	Detail oriented	4, 28, 40, 44	**Global**	Overall picture	4, 8, 20, 16, 28, 40
	Sequential progress	12, 20, 24, 32		Non-sequential progress	24, 32
	From parts to the whole	8, 16		Relations	36
	Focusing on subjects	36		Thinking about results	12, 44

2.2. Manual Grouping of Questions

Continuing with the method used by Graf et al. (2007) [14], there then followed a manual grouping of questions within the ILS according to the similarity of semantics. Table 3 shows the semantic groups identified for each learning style as well as the questions belonging to each of these groups. A question may appear twice in Table 3 if the answer to this question points to two different semantic groups. The original work of Graf et al. (2007) [14] in the previous version have been identified the semantic groups according to English ILS question . in our study we identified the semantic groups according to the Arabic ILS questions.

The semantic groups of Table 3 have been identified manually by three experts psychologists from department of Psychology at the King Abdul-Aziz University in Saudi Arabia as following:

1- Identified the Arabic ILS questions in the same category for each learning style , such as the questions (1, 17, 25, 29) Identified in the same learning style so these questions are posted in the semantic group (Trying something out).

2.3. Classification of Learner Preferences

Learners' preferences were classified by analysing the distribution of preferences for each dimension within the Arabic Index of Learning Styles (ILS) questionnaire, resulting in Table 4, which categorises learners' preferences as strong/moderate (values from 5 to 11) or balanced (values from +3 to -3).

Table 4. Strength of Preferences (distinguishing between strong/moderate and balanced preferences) in the Data from the Arabic Index of Learning Styles Questionnaire

Str./mod.ACT	Balanced	Str./mod. Ref	Str./ mod. Sen	Balanced	Str./mod. Int	Str./mod. Vis	Balanced	Str./mod.Ver	Str./mod.Seq	Balanced	Str./mod.Glo
26%	64%	10%	20%	62%	18%	60%	37%	3%	24%	66%	10%

2.4. Semantic Grouping by Linear Discriminant Analysis

The next stage in Graf et al.'s (2007) [14] method was to use the classifications provided in Table 3 to determine the most representative groups for each learning style and to find the most representative semantic groups for each dimension. This activity was based on linear discriminant analysis.

Fisher's linear discriminant analysis, a common multivariate technique used for linear dimension reduction, was performed to identify the most characteristic semantic groups within each dimension (Duda et al., 2000) [26]. The following details of applying the linear discriminant analysis are drawn from the work of Graf et al. (2007) [14].

Let A be the 1024 x 88 matrix containing in rows individuals and in columns the ai , i=1,…,88. The matrix A has rank at most 44 by construction, since two columns are constrained to sum up to 1 in rows [14].

The answers provided to the Arabic ILS questionnaire were then subjected to Fisher's linear discriminant analysis (LDA) in terms of matrix A .

This technique is a commonly employed multivariate method of reducing dimensions and can be used to identify the optimal linear direction of separation. This is calculated using a typically one-dimensional vector of coefficient w that highlights the separation between groups. Using this vector, the highest absolute values of coefficients are indicative of the most significant discrimination variables. Thus, this study used LDA to identify significant discriminating variables within each FSLSM dimension of the ILS system based on the responses given by participants. In effect, X being an m-by-n matrix, let $w`m_i^{(1)}$ and $w`m_i^{(2)}$, i =1,…, n be the d-dimensional sample means of the projected points according to the classes of individuals, and ($1/m$) ($s_1^2 + s_2^2$) an estimate of the whole variance of the pooled data, where

$$SC^2 = \sum_{x \in C_i} w`x_i - w`m_i^{(c)} \quad (1)$$

and c € C = { 1,...,k } indicates the class; LDA aimed at finding a vector w that maximises the criterion function

$$J(w) = \frac{\left| w`m_i^{(1)} - w`m_i^{(2)} \right|^2}{s1^2 + s2^2} \quad (2)$$

As a means of determining the significance of each semantic class within each dimension, the coefficients of w in terms of each possible answer were analysed according to a mock index that listed the importance of each group based on dimension; this was determined by identifying the average of absolute coefficient values as listed in Table 3. The findings are listed in Table 5.

2.5. Cross-Validation

The next step was to cross-validate the results. To this end, both Pearson's correlation and frequency analysis were used. Let Q be the 1024 x 44 matrix containing in rows individuals and in columns the answer to each of the Arabic Index of Learning Styles (ILS) questions. For each question q_i , Q = 44, two numerical variables, namely the two answers to each question, $a1$ = 1 if q_i = 1 (otherwise 0) and $a2$ = 1 if q_i = -1 (otherwise 0) were obtained (Graf et al., 2007). Table 6 summarises the results of the frequency analysis.

3. Results

3.1. Classification of Learner Preferences

Firstly, the distribution of preferences for each dimension was examined. The results showed that 61% of the students had an 'active' learning preference, 56% had a 'sensing' preference, 88% had a 'visual' preference, and 62% displayed a 'sequential' preference.

Table 4 contains a more in-depth breakdown, categorising learners' preferences as strong/moderate (values from 5 to 11 in the data from the Arabic Index of Learning Styles questionnaire) or balanced (values from +3 to -3 in the data from the Arabic Index of Learning Styles questionnaire).

3.2. Linear Discriminant Analysis

The linear discriminant analysis identified four clusters. The attributes of each of these clusters are presented in Table 5.

Significant elements in the clusters are represented by the figures in bold.

Table 5. Relevance of Semantic Groups in Learning Style Dimensions in the Data from the Arabic Index of Learning Styles Questionnaire (values > 0.5 are highlighted)

ILS	Semantic Groups	Cluster 4	Cluster 3	Cluster 2	Cluster 1
		ACT/REF	SENS/INT	VIS/VERB	SEQ/GLO
Active	Try something out	**0.523**	0.402	**0.541**	0.346
	Socially oriented	**0.694**	**0.502**	**0.659**	**0.58**
Reflective	Think about material	0.444	**0.541**	0.435	**0.609**
	Impersonally oriented	0.305	**0.53**	0.342	0.419
Sensing	Existing ways	**0.79**	**0.811**	**0.561**	0.379
	Concrete material	0.32	**0.513**	**0.752**	0.27
	Careful with details	**0.527**	**0.521**	0.4	0.215
Intuitive	Innovative or creative	0.34	0.308	**0.514**	**0.729**
	Abstract material	**0.799**	**0.583**	0.246	**0.748**
	Not careful with details	0.362	0.469	0.339	**0.539**
	Dealing with theory	**0.725**	0.463	0.223	**0.729**
Visual	Pictures	**0.79**	**0.544**	**0.817**	**0.68**
Verbal	Spoken words	0.186	0.343	0.153	0.268
	Written words	0.251	**0.607**	0.227	0.394
	Difficulty with visual style	0.122	0.271	0.117	0.214
Sequential	Detail oriented	0.428	0.485	0.407	0.302
	Sequential progress	**0.74**	**0.673**	**0.713**	**0.52**
	From parts to the whole	**0.714**	**0.594**	**0.652**	**0.547**
	Focusing on the subjects	**0.611**	**0.671**	0.476	0.338
Global	Overall picture	0.474	0.474	**0.53**	**0.595**
	Non-sequential progress	0.304	0.419	0.331	**0.588**
	Relations/connections	0.389	0.33	**0.524**	**0.662**
	Thinking about results	0.225	0.25	0.187	0.434

The clusters show interesting profiles for different groups of learners. For instance, since a high value indicates a strong impact of the semantic group for the respective learning style, it can be seen that for an active learning style the preference for social orientation (e.g., for discussing and explaining learning materials to others or for working in groups) has more impact than the preference for trying something out (e.g., "Let's try it out and see how it works").

Active learners tend to like group work, and as a further impact relating to preferences tend to be patient with details and good at memorising facts, more comfortable with abstractions, better at remembering what they see (pictures, diagrams), and tend to gain understanding in linear steps, with each step following logically from the previous one. Further study is required, as the FSLSM does not describe these relationships.

Each group in the sensing/intuitive dimension shows a predilection for the 'sensing' learning characteristics, notably in terms of fondness for existing ways (e.g., enjoying courses that have connections to the real world and disliking innovation). A fondness for abstract material (e.g., for finding interpretations or theories that link facts) is most common among intuitive learners.

Additional study is required, as the FSLSM does not account for these connections – for instance, there is an extra influence in the observations pertaining to the sensing/intuitive dimension in terms of a preference for learning by working in groups and handling things; periodically reviewing what has been read and thinking of possible questions and applications; remembering what has been seen, such as pictures and diagrams; getting the most out of written and spoken explanations; and gaining understanding in linear, logical steps.

Only a picture preference (e.g., remembering what is seen, such as pictures and diagrams) semantic group exists within the visual learning style – also very common – but in the verbal learning style, no common semantic can be identified.

In terms of the sequential/global dimension, highly pertinent factors for these learning styles include relations/connections, overall pictures, and non-sequential progress (e.g., skimming through an entire chapter to get an overview before starting to study specific information and relating the subject to information already known in

order to see the bigger picture). For 'global' individuals, the most relevant preference is that for relations and connections to other areas; for sequential learners, the ability to infer the whole solution from parts and make sequential progress (e.g., outlining course lecture material in a logical order) are the most relevant.

3.3. Cross-Validation

3.3.1. Empirical Frequency Analysis

The empirical frequency analysis aspect of the cross-validation process examined how participants favouring a particular learning style responded to specific questions. In terms of the active/reflective dimension, for example, a question was deemed representative if an 'active' student responded to it with more clarity more frequently than a 'reflective' participant. Therefore, to validate the representative nature of queries in the active/reflective dimension, a comparison was made between the number of 'active' participants who responded with active preferences and the number of 'reflective' participants who responded with active preferences.

The representative nature of a question for the active/reflective dimension is signalled by the discrepancies in these percentages. Similar calculations were therefore carried out for the other dimensions. A divergence of 30%+ was noted in 7 questions in the active/reflective dimension, 6 in the sensing/intuitive, 11 in the visual/verbal and 8 in the sequential/global. Table 6 shows the 5 questions with the greatest representativeness (in order of rank).

To interpret the table, in relation to the active/reflective dimension, for instance, evidently the primary and tertiary questions in terms of relevance concern preferences among learners for trying things out and thinking about the learned material, whereas the secondary, fourth and fifth most relevant questions concern social orientation, inquiring as to whether learners are extroverted and social within their class groups and enjoy team exercises. The Index of Learning Styles Questionnaire (available at www.engr.ncsu.edu/learningstyles/ilsweb.html) was used.

Table 6. The Five Most Representative Questions for Each Dimension of the Arabic Index of Learning Styles (ILS) Questionnaire According to Frequency Analysis

	Rank	Question No	Question
Active/Reflective	1	17	When I start a homework problem, I am more likely to (a) start working on the solution immediately (b) try to fully understand the problem first.
	2	37	I am more likely to be considered (a) outgoing (b) reserved.
	3	29	I more easily remember (a) something I have done (b) something I have thought a lot about.
	4	9	In a study group working on difficult material, I am more likely to (a) jump in and contribute ideas (b) sit back and listen.
	5	5	When I am learning something new, it helps me to (a) talk about it (b) think about it.
Sensing/Intuitive	1	26	When I am reading for enjoyment, I like writers to (a) clearly say what they mean (b) say things in creative, interesting ways.
	2	34	I consider it higher praise to call someone (a) sensible (b) imaginative.
	3	2	I would rather be considered (a) realistic (b) innovative.
	4	10	I find it easier (a) to learn facts (b) to learn concepts.
	5	6	If I were a teacher, I would rather teach a course (a) that deals with facts and real life situations (b) that deals with ideas and theories.
Visual/Verbal	1	15	I like teachers (a) who put a lot of diagrams on the board (b) who spend a lot of time explaining.
	2	43	I tend to picture places I have been (a) easily and fairly accurately (b) with difficulty and without much detail.
	3	19	I remember best (a) what I see (b) what I hear.
	4	39	For entertainment, I would rather (a) watch television (b) read a book.
	5	35	When I meet people at a party, I am more likely to remember (a) what they looked like (b) what they said about themselves.
Sequential/Global	1	12	When I solve math problems (a) I usually work my way to the solutions one step at a time (b) I often just see the solutions but then have to struggle to figure out the steps to get to them
	2	28	When considering a body of information, I am more likely to (a) focus on details and miss the big picture (b) try to understand the big picture before getting into the details.
	3	16	When I'm analysing a story or a novel (a) I think of the incidents and try to put them together to figure out the themes (b) I just know what the themes are when I finish reading and then I have to go back and find the incidents that demonstrate them.
	4	20	It is more important to me that an instructor (a) lays out the material in clear sequential steps (b) gives me an overall picture and relates the material to other subjects.
	5	44	When solving problems in a group, I would be more likely to (a) think of the steps in the solution process (b) think of possible consequences or applications of the solution in a wide range of areas.

3.3.2. Correlation Analysis

Correlations were calculated spanning the total positive responses to each of the 88 responses generated by the ILS questionnaire (with 2 possibilities for each question), and the information was converted from a binary scale into a numerical equivalent in order to apply Pearson's correlation coefficient.

Numerous augmented (higher than 0.7) values were observed, and the p values related to these values were minimal ($p < 0.05$), which is important. Significance was noted for questions belonging to the range of semantic

groups linked with the active/reflective, sensing/ intuitive and sequential/global dimensions and questions that were cross-correlative among those groups, as well as for questions pertaining to the semantic groups related to the visual/verbal dimension (pictures/spoken and written words).

4. Further Comparison Between the Two Studies: Preferences in Saudi Arabian Sample and Preferences in New Zealand and Austrian Samples

The study conducted by Graf et al. (2007) [14] is based on a 207-member sample group from Massey University in New Zealand and the University of Technology in Vienna. The members of this sample group had achieved varying levels of education and were drawn from the departments of Web Engineering, Information Management and Information Systems. The sample groups consequently display significant differences, which allows for comparison in order to explore the homogeneity of learning style characteristics.

4.1. Classification of Learner Preferences

Looking at the overview of similar studies provided by Felder and Spurlin in 2005, the results of the present study are largely coherent; there are a number of minute divergences in the sensing/intuitive dimension because a fractionally greater number of intuitive subjects participated in this study. As well, in comparison with the overview of similar studies provided by Graf et al. in 2007, some differences can be seen in the sequential/global dimension where more sequential learners have participated in the Manual Grouping of Questions.

The comparison between the semantic groups associated with the Arabic Index of Learning Styles (ILS) questions and the English Index of Learning Styles (ILS) questions as follows:

- results concerning the active/reflective, sensing, and visual/verbal dimensions are generally the same as the results generated by Graf et al. (2007) [14].
- results concerning the intuitive, sequential/global and verbal dimensions show some differences when compared to the results generated by Graf et al. (2007) [14].

4.2. Analysis of Semantic Groups of the Learning Style Dimensions Using Linear Discriminant Analysis

Most participants in Saudi Arabia expressed a preference for socially inclined within the active dimension, which was the least represented attribute in the reflective dimension. However, in New Zealand and Austria, the majority of participants expressed a preference for trying something out in the active dimension and impersonal orientation within the reflective dimension. Existing ways was the most representative element of the sensing/intuitive dimension in Saudi Arabia, whereas in the other two countries, it was concrete material in the sensing dimension, while abstract materials was most prominent in the intuitive dimension in the case of all three nations. In the visual/verbal dimension, the majority of Saudi Arabian students preferred pictures only, whereas for the other two nations, the preference was for written and spoken words as well as pictures; however, in the sequential/global dimension, students in all three countries expressed a preference for from parts to the whole and relations/connections (see Table 7).

Table 7. Comparison of Preferences and Semantic Groups Between Saudi Arabia and New Zealand/Austria

Dimension	Most representative preferences and semantic groups in Saudi Arabia (this study)	Most representative preferences and semantic groups in New Zealand and Austria (Graf *et al.* study)
Active	Socially oriented	Trying something out
Reflective	Non-most representative preferences	Impersonally oriented
Sensing	Existing ways	Concrete material
Verbal	Non-most representative preferences	Written and spoken words

Different representative characteristics were found in the English-speaking and Arabic-speaking samples, with the primary differences based in the active, reflective, sensing, and verbal dimensions. Thus, the representative characteristics of learning style preferences do not seem to be homogeneous across the English-speaking and Arabic-speaking learner sample groups.

5. Discussion

In the classification of learner preferences, the results of this study generally correlate with the overview provided by Felder and Spurlin in 2005 of similar studies; there are a number of minute divergences in the sens-ing/intuitive dimension because there were a fractionally greater number of intuitive subjects in this sample group. Also, in comparison with the results generated by Graf et al. (2007) [14], variations were detected in the sequential/global dimension, as more learners of this style formed part of the sample group. In addition, based on the preference data, the results generated by our study are largely complementary to those found by Graf et al. (2007) [14]. This information can be seen in Table 4.

Following analysis of the clusters, the most common aspects of learning styles were identified using discriminant analysis. Table 3 outlines these results. According to these findings, most participants from the Saudi Arabian sample expressed a preference for socially oriented within the active dimension, which was the least represented attribute in the reflective dimension. In comparison, in New Zealand and Austria, most participants showed a preference for trying something out within the active dimension and impersonal orientation within the reflective dimension. Existing ways was the most representative element of the sensing/intuitive dimension in Saudi Arabia, whereas in the other two countries, it was concrete material in the sensing

dimension, while abstract materials was most prominent in the intuitive dimension in the case of all three nations. In the visual/verbal dimension, the majority of Saudi Arabian students preferred pictures only, whereas in the other two nations, the preference was for written and spoken words as well as pictures; however, in the sequential/global dimension, students in all three countries showed a preference for from parts to the whole and relations/connections (see Table 5).

Given that many adaptive learning systems are centred on only a limited number of learning style elements as opposed to the entirety of suggested characteristics, it is important to identify which features of learning styles should be supported by such a system. LDA appears to be a suitable means of identifying representative characteristics, and it also appears that it may be used to produce indications of greater accuracy pertaining to the significance of each characteristic. The LDA tool may be used to determine which learning style characteristics should be used in an adaptive learning system for a particular cohort of learners.

Key findings from this study seem to indicate that representative characteristics of learning style preferences are not homogeneous across English-speaking and Arabic-speaking learner sample groups. There is a clear requirement for further research exploring representative characteristics of learning style preferences for other groups of learners, including how much these characteristics vary between groups and how adaptive learning systems should be designed to address the needs of specific groups.

The results of this study will be used to further develop learning environment to guide the design of an improved adaptation algorithm, as follows:

1- Reduce the 16 combinations of learning style dimensions to 4 combinations of learning styles, as the most representative preferences and semantic groups in Saudi Arabia were in the dimensions of active, sensing/intuitive, visual and sequential/global. We were able to reduce the combinations of learning styles from 16 to 4 (A/S/V/S, A/S/V/G, A/I/V/S, and A/I/V/G).

2- In creating adaptations of our system, utilise questions based on the preference for socially oriented in the active dimension, such as questions 5, 9, 13, 21, 33, 37 and 41, thus reducing the questions concerning the active dimension from 11 to 7.

3- In the sensing/intuitive dimension, utilise questions based on the preference for discussion of existing ways (such as questions 2, 30 and 34) for the sensing dimension or questions based on abstract material for the intuitive dimension (such as questions 10 and 38), thus reducing 'sensing' questions from 11 to 3 and 'intuitive' questions from 11 to 2.

4- Only the visual employ questions grounded in visual preference, such as questions regarding discussion of pictures (i.e. questions 3, 7, 11, 15, 19, 23, 27, 31, 35, 39, and 43).

5- For the sequential dimension, utilise questions based on the preference for from parts to the whole (8, 16) and questions based on the relations/connections preference (36) for the global dimension, thus reducing 'sequential' questions from 11 to 2 and 'global' questions from 11 to 1.

6- We adapted our system to be based on 26 of the FSILS questions of instead of all 44, thus making the enrolment and learning style capture process easier for users and making the corresponding adaptation more efficient.

6. Study Limitations and Areas for Future Research

There are clearly limitations to this study. Firstly, the sample used, though relatively large (1,024), was biased as all participants were drawn from one university in Saudi Arabia and all were female undergraduates. Similarly, the samples from Graf el al.'s study (2007) used for comparison had their own biases. However, the samples used for comparison could be classified as distinct groups based on language, learning environment and culture, and thus provide a valid base for exploring the homogeneousness of learning style characteristics. Further studies involving learners from different cultural groups with a more balanced mix of gender, language, and culture would clearly add to this area of research and help map the variations of learning style characteristics. Such work would contribute to the development of a comprehensive overview of the attributes of learning style preferences that could inform the development of adaptive learning support systems.

There may also be biases within the learning styles instrument and the analysis tools used. For instance, using a different learning styles model may produce different results; the same applies to the analysis tools used as well as the overall method. There is clearly an opportunity for further research in exploring relevant learning style characteristics using other learning style instruments or other tools of analysis.

We have identified possible cultural, linguistic and educational environment influences on learning style preferences. There may also be other influences on learning styles, such as performance, student characteristics or cognitive traits. It is obvious that further research is required to investigate these differences. In addition, the formulation of learning style characteristics can be used to quickly identify the learning styles of individuals who are studying online, i.e. by reducing the number of FSILS questions from 44 to 26 to identify learning style preferences. However, though this reduction may have benefits in terms of efficiency and ease of use, it may actually miss some subtle attributes of learning style preferences.

There are further avenues for research in applying the Arabic version of the Felder-Soloman ILS instrument, as well as other learning style instruments, to different groups in Arabic-speaking learning environments, and more generally for investigating the homogeneity of learning styles among different groups of people around the world.

7. Conclusion

This paper has added to the debate about the homogeneity of learning styles among groups of people around the world with differences in language, learning environment and culture. Our study identifies different learning style characteristics than those identified by a previous study, namely that of Graf et al. (2007), which used a significantly different cohort of learners. This paper followed as closely as possible the method suggested by

Graf et al. to ensure the most robust possible comparison. The method involved using a range of statistical tools, such as linear discriminant analysis and various methods of frequency analysis and correlation analysis, to cross-validate the data and identify significant clusters of learning style characteristics represented in the sample. This paper has consequently provided support for a more in-depth evaluation of learning styles, such as the method suggested by Graf et al., which could provide a better understanding of learning styles and aid the development of appropriate adaptive learning systems.

This paper has shown how identifying learning style characteristics for a cohort of learners (with their own specific linguistic, educational and cultural attributes) may be used to inform the development and application of adaptive learning systems. Furthermore, this analysis may be used to identify the learning style attributes that would be most beneficial in informing the development of adaptive systems by identifying which learning style attributes are most relevant for a particular cohort of learners.

The results show differences in representative characteristics between different learning cohorts, which indicate possible cultural and learning environment influences on learning style preferences. Semantic groups in Saudi Arabia are generally similar to semantic groups in New Zealand and Austria in terms of the intuitive, visual, sequential and global dimensions. However, differences between semantic groups can be seen in the sensing, active/reflective and verbal dimensions. The representative characteristics of learning style preferences do not seem to be homogeneous between English-speaking and Arabic-speaking samples of learners.

These results offer a more accurate representation of learning styles among different groups of learners, which increases the potential to create learning environments that can be adapted to the individual needs of students. As well, the detailed examination of the characteristics of learning styles could enhance teaching methods, therefore creating a learning environment that is more efficacious and tailored.

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