VALIDATING THE HEIRARCHY
OF THE iSTARTSMART® ACADEMIC CONTENT

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Abstract

The purpose of this analysis was to investigate the validity of skill groupings in an instructional technology learning system designed for use by children in early childhood education classrooms. A Principal Component Analysis was performed to measure the fit of 18 skill games to their 5 assigned groupings in the system, covering a range of academic school readiness literacy and math skills. Using data from the developer's online reporting system; achievement in those 18 skills was analyzed from a selected group of 274 preschool children from the United States with a high degree of game-play. These outcomes were loaded onto factors selected using an eigenvalue evaluation in an effort to determine the validity of the system's representation of those groupings as they exist in the broader educational context. Results indicate a robust fit between system hierarchy and pedagogical hierarchy, with strong initial loadings along the existing hierarchy, minimal deviation, and weak subsequent loadings. These results suggest that the existing system hierarchy is a good match for the pedagogy which it purports to represent, and in this manner is appropriate for its intended purpose. This lays the groundwork for a future Confirmatory Factor Analysis, and modifications to the system to create an even better fit between the learning system and pedagogy. (Contains 2 tables).

Introduction

The use of instructional technology has grown in prevalence in early childhood classrooms, particularly in recent years (e.g., Simon, Nemeth, & McManis, 2013; Blackwell, Lauricella, & Wartella, 2014). Such technology has shown promise for improving academic school readiness in young children if designed around appropriate content (e.g., Guernsey, Levine, Chiong, & Severns, 2012; Clements & Sarama, 2003).

The set of foundational literacy and math skills necessary for children to be successful once they enter formal schooling is supported by a large body of evidence (e.g., National Early Literacy Panel, 2008; National Research Council Committee on Early Childhood Mathematics, 2009). For foundational literacy skills, the National Early Literacy Panel has identified alphabet knowledge, phonological awareness, phonological memory, rapid automatic naming of letters/digits and writing/writing name as the early literacy skills most important for school readiness, as these most strongly and consistently predict the subsequent conventional literacy skills of reading and writing. For foundational math skills, the National Research Council Committee on Early Childhood Mathematics identified number, including whole number, operations and relations, as well as geometry, spatial thinking and measurement as the most important skill areas in which young children should be able to show competency.

It is therefore appropriate for developers of instructional technology learning systems designed for preschool children to include such content, as well as ensure that its delivery to young users occurs in a meaningful way.

Study Context

The iStartSmart® by Hatch (iSS) is a touch-based, computer-assisted learning system designed for preschoolers. The system presents a set of school readiness skills in the form of child-directed games. As part of the built-in hierarchy, the system groups game-play opportunities of these readiness skills into “Skill Levels”; tutorial (mechanics instruction), emerging, developing, developed and completed (maintenance). These levels are rolled up into “Skills” covering the content, which are organized further by grouping them into “Skill Families”, aligned to existing findings widely accepted within the field of early literacy and math (e.g., National Early Literacy Panel, 2008; National Research Council Committee on Early Childhood Mathematics, 2009).

When a child plays on the system, the skills within each family are presented on a continuum of complexity. There are five Skill Families covering 18 individual skills. Grouped under Phonological Awareness are sentence segmenting, initial sounds, blending compound words, segmenting compound words and onset rime; Alphabet Knowledge is solely represented by letter recognition; Language Development holding language vocabulary (with a focus on position vocabulary), spatial skills and measurement; Logic and Reasoning having the skills of common shapes, sorting and patterning; and Numeric Operations covering counting foundations, numeral recognition, sequence counting, objects in a set, addition and subtraction.

While the grouping of these activities is well supported in other contexts, there remains a question as to the validity of the hierarchy as it is presented in the specific implementation within the iSS system. We were therefore interested in applying a statistical examination of the grouping of the skills into families to validate the pedagogical underpinnings of the organization and delivery of that content to children during game-play. We considered the following hypothesis:

> The iStartSmart Family groupings will maintain the original hierarchy of academic school readiness skills.

Methods

Sample

In order to ensure adequate power to reliably classify the skills into families, the sample included the 274 preschool children having maintained at least a developing level in the system across the 18 skills from the 2012-13 school year. These data were retrieved from the developer's database underpinning its reporting system, which holds a record of game-play information over the entire school year period. Permission for use of this dataset for data analysis with the purpose of understanding and improving the system fell under a signed EULA (End User License Agreement) and therefore was exempt from IRB approval.

Analysis

For this study, a Principal Component Analysis (PCA) was the methodology selected. Particular consideration was given to the decision to use a principal component approach instead of a confirmatory factor analysis approach. While the skill family groupings had a reasonably strong basis in established pedagogy, the lack of existing quantitative analysis of those groupings implied that an exploratory approach would be most appropriate.

While the system interface may discriminate between levels of mechanical aptitude and technological familiarity, mechanical tasks in the system are limited in their complexity and breadth (e.g., tapping icons), and therefore the impact of the variance related to these has a low likelihood of being correlated with individual factors. While the academic content being presented differs substantially between Skill Families, the same limited set of straightforward mechanical tasks is repeated throughout all Skills and Skill Families. Technological familiarity as an influence is precluded by the nature of the sample; the children selected for inclusion in the analysis each logged considerable individually tracked progress with the system and as such would have experiential knowledge of the games, as well as the built-in instruction designed for children who might have limited access to technology outside of the classroom.

While it may be reasonable to consider the existing hierarchy as a priori factors, the lack of any direct quantitative evidence to that effect, in combination with the high likelihood that the variance associated with those factors is shared across all of the factors, made it desirable for the statistical method to assign all of the variance of the included factors for exploratory purposes. A PCA by its nature imposes those constraints (Suhr, 2005).

A PCA generated a set of factors grouping the skills and then loading them onto each included factor, producing weights quantitatively estimating correlations between factors and variables. Weights can range in absolute value from 0 to 1, with higher weights indicating that the skill is more closely affiliated with that factor. The most commonly accepted way to measure the strength of a factor is by evaluating the eigenvalue of that factor. Although there are a variety of methods for deciding which factors are strong enough to keep in a final model, one commonly accepted method is to keep all factors with an eigenvalue greater than 1 (Kaiser, 1991); which was the method employed in this study. Those factors are then retained in the final model to which a rotation is applied; and the degree to which a skill can be ascribed to the fundamental characteristic represented by that factor can be estimated.

Results

From this analysis, the six components with an eigenvalue greater than 1 were retained in the final set. As shown in Table 1, the initial eigenvalues showed that the first factor accounted for 20.9% of the total variance, the second factor 13.5%, the third 9.5%, the fourth 9.0%, the fifth 6.5% and the sixth 5.5%; for a total of 65.1%. Because of the starkness of difference in the fundamental skills measured by each family, an orthogonal rotation was applied to the factor loadings. The rotation chosen was a Varimax rotation with Kaiser normalization (SPSS version 21). With consideration to the eigenvalue inspection, this rotated PCA yielded the six uncorrelated factor solution presented in Table 2.

Table 1. Eigenvalues for all components and kept components from iStartSmart skills using principal component analysis (*N*=274).

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.769	20.940	20.940	3.769	20.940	20.940
2	2.440	13.558	34.498	2.440	13.558	34.498
3	1.711	9.503	44.001	1.711	9.503	44.001
4	1.626	9.033	53.034	1.626	9.033	53.034
5	1.160	6.446	59.480	1.160	6.446	59.480
6	1.010	5.612	65.092	1.010	5.612	65.092
7	.875	4.860	69.952			
8	.714	3.967	73.920			
9	.670	3.722	77.641			
10	.594	3.301	80.943			
11	.587	3.263	84.205			
12	.555	3.085	87.291			
13	.477	2.649	89.940			
14	.453	2.517	92.457			
15	.424	2.356	94.813			
16	.387	2.149	96.962			
17	.343	1.907	98.869			
18	.204	1.131	100.000			

Extraction Method: Principal Component Analysis.

Table 2. Factor loadings from iStartSmart skills using principal component analysis with varimax rotation.

Rotated Component Matrix							
		Component					
Skill	Skill Family	1	2	3	4	5	6
Sentence Segmenting	Phonological Awareness	.524					
Initial Sounds	Phonological Awareness	.697					
Blending Compound Words	Phonological Awareness	.797					
Segmenting Compound Words	Phonological Awareness	.859					
Onset Rime	Phonological Awareness	.825					
Counting Foundations	Numeric Operations					.904	
Numeral Recognition	Numeric Operations					.608	
Sequence Counting	Numeric Operations		.636				
Objects in a Set	Numeric Operations		.806				
Addition	Numeric Operations		.788				
Subtraction	Numeric Operations		.659				
Language Vocabulary	Language Development			.782			
Spatial Skills	Language Development			.791			
Measurement	Language Development			.836			
Letter Recognition	Alphabet Knowledge						.787
Common Shapes	Logic and Reasoning				.764		
Sorting	Logic and Reasoning				.805		
Patterning	Logic and Reasoning				.668		
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.							
a. Rotation converged in 6 iterations. Values under .4 suppressed							

Discussion

The loading of the factors matched the learning system's current organization well, with four of the six components mapping directly onto the existing skill families. All of the skills grouped in the system under Phonological Awareness, Language Development, Logic and Reasoning, and Alphabet Knowledge loaded onto single factors; factors 1, 3, 4 and 6, respectively.

While the loadings for the skills in the Numeric Operations family split onto two factors (Factors 2 and 5), the nature of that split fits well with that of the inputs. Counting Foundations and Numeral Recognition both loaded onto a single factor (Factor 5), and both of those skills are recognition skills. The skills that loaded onto Factor 2 were Sequence Counting, Objects in a Set, Addition and Subtraction; each requiring the application of a recognized object to an operational task. In conjunction with the game design differences that split neatly along those lines (the skills loading onto factor 5 being prerequisites to those loading onto factor 2), while the skills would ideally load onto a single factor, indicating a single fundamental driver to line up with the system's grouping, there is a reasonable enough fit to justify placing these under the Numeric Operations family in the system to remain within the bounds of sound pedagogical theory. Given that these skills are all presenting mathematical concepts, these two factors fit well within the family for presentation purposes to early learners.

Additionally, the strength of the loadings was high, with no skill having a highest loading under .52, with all but one of the 18 meeting the convention of loadings of over .6 for high; and with none falling below the .4 guideline for low loading (Hair, Black, Babin, Anderson, & Tatham, 2006). Furthermore, subsequent loadings were weak, giving additional credence to the fit of the skills to their families. While this analysis suggests a good fit between the system and its pedagogical underpinnings, there do remain concerns regarding the limitations that arise around sample size. With a variable to factor ratio of 3:1, a larger dataset would have been ideal; especially given the exploratory nature of the present work.

Conclusions

The loading of the factors fits well with the pedagogical understanding of academic skill acquisition and its hierarchy. The differences between the theoretical and the computational skill loadings are reasonably explained by existing pedagogical theory. There is then a strong likelihood that there exists adequate evidence to support our hypothesis that the iStartSmart Family groupings would maintain the original hierarchy of academic school readiness skills. These results strongly suggest the manner in which the literacy and math content is organized and presented within the system has both a pedagogically and psychometrically sound basis. This lends support for the use of the system as an appropriate choice of instructional technology for promoting academic school readiness.

Future Directions

The results, when considered in light of the limitations of the analyses, suggest value in performing a confirmatory factor analysis in the future with a larger dataset. As the iSS learning system sees a more widespread deployment, there should be a considerably larger set of data to work with in future analyses. It might also be of interest to test in a limited setting what effects splitting the Numeric Operations skills into distinct families might have on the factor loading as well as on level achieved by children. If that were to show a positive effect on level achieved, that could drive change in the future development of the system.

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