The International Workshop on
Technology-Enhanced Collaborative Learning
(TECL 2017)
in conjunction with CRIWG/CollabTech 2017

Saskatoon, Canada

Preface

The aim of this work is to provide a forum where international participants can share knowledge on the latest developments in technology-enhanced collaborative learning environments as well as map out directions for future developments and research collaborations.

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Date: August 10, 2017

Venue: Oak Room of the ParkTown Hotel, Saskatoon, Canada.

A Visual and Interactive Recommender System for Scientific Papers

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Abstract. In this paper, we present a visual and interactive Recommender System for scientific papers. It allows users to control the contextual elements, for instance researchers and papers, that will be used as content to generate the recommendations and setting up the parameters weights of the system, such as, users, items, novelty and popularity. To demonstrate our proposal, we present an example of how users can configure the Recommender System to receive recommendations. Our main contributions for the field are: (i) a new interaction method to capture user preferences; and (ii) a new user interface for Recommender Systems.

Keywords: Recommender Systems, Interaction, Visualization, User Control.

1 Introduction

In recent years, research related to Recommendation Systems(RS) has gone beyond ensuring accuracy and also has focused on analyzing human factors captured through user's interaction with the RS. A strategy to support transparency and controllability of the recommendation process is to combine interactive visualization techniques with recommendation techniques [3]. For example, Knijnenburg et al. [5] allow users to order the recommendation list according to different attributes in a RS of best practices for energy efficiency. Some approaches allow their users to modify the content that will be used by the RS [1, 4]. Another line of work, using hybrid models, allows their users to modify the weights assigned to each recommender via sliders, e.g., [7, 2]. Yin et al. [8] present a learning environment that contains an academic search engine. Using the tool, students can perform trend analyses, automatically extract outlines from the literature, and analyze documents as a time-series.

In a previous work [6], we defined a Bayesian user-controllable model and applied it in the scientific paper recommendation. Our proposal is based on the concept of context, Context-Aware RS make use of contextual information with the aim of improving the recommendation. In this paper, we present a visual and interactive interface where users can control the contextual elements (researchers and papers) that will be used as content to generate the recommendations. Furthermore, users can setting up the parameters weights of the RS, such as, users, items, novelty and popularity. In summary, we achieve the following contributions for the field: (i) a new interaction method to capture user preferences; and (ii) a new user interface for RS.

2 The Recommender System

The RS is based on Bayesian Networks (BN), wherein for each available paper for recommendation is created one BN that calculates its prediction for the given context. This prediction is obtained by the value of the variable *Prediction* of the BN, and it is influenced by four variables of the context. *Users* – this variable concerns the researchers who are saved in the system, the user can define which researchers she wants to include into the context. Thus, to calculate the prediction of the items, the RS will give more importance to the items similar to those included researchers. *Items* – this attribute represents the items that the user can insert into the context, thus the RS will search for similar articles to compose the recommendation list. *Novelty* – this variable is related to how much novelty a paper has, e.g., we consider that survey papers have a low level of novelty. Likewise, newer papers receive a higher value than the new older papers. *Popularity* – this attribute is defined by how popular a paper is, we consider that the more citations the article has, the more popular it will be and increase the chance of it being recommended. All BN nodes have two states, $True$ and $False$, the BN has four types of node: **Prediction node** – in the BN, only the node *Prediction* is such, it represents the predictive value of an item to a user in a given context. In other words, the higher the value of $P(Prediction)$ greater will be the predicted value of the item to the user. **Parameter nodes** – this type of node represents the parameters used in the RS, the nodes of this type are parents of the node *Prediction*. We define four parameters, $Users$, $Items$, $Popularity$ and $Novelty$, so we create a node with the same name for each parameter. Each node of this type has two parents, one representing a user preference and another representing an item feature. **User preference nodes** – this type of node represents the weight given by the user to a specific parameter, i.e., it serves as an interface between the user and the model. There are four nodes of this type, *UserUsers*, *UserPopularity*, *UserNovelty* and *UserItems*. **Item feature nodes** – such node represents a paper feature. There are four nodes of this type, one for each parameter, *ItemUsers*, *ItemPopularity*, *ItemNovelty* and *ItemItems*. The complete description of the model, i.e., details about BN structure and weights, can be found in [6].

The system provides the following features to users: (i) create context; (ii) configure context; (iii) share context; (iv) save context; (v) delete context; (vi) copy context; (vii) search researchers; (viii) search papers; and (ix) give feedback about recommendations. Figure 1 presents the context configuration screen, the red numbers in the screen indicate: (1) Context's title, every context is created with the default title *Context without title*, but user can change it. (2) Options buttons, save, share, copy and delete context. (3) Parameters configuration, where users can change context configuration through sliders. There is one slider for each variable of the context, $Users$, *Items*, *Popularity* and $Novelty$, with specific color and icon. The sliders values are integers from 5 to 100, with 50 as default, these values are divided by 100 and used to update the *User preference nodes*, *UserUsers*, *UserPopularity*, *UserNovelty* and *UserItems*. (4) Graphic representation of the context. (5) Recommended Papers tab, it presents the recommended list to the user. (6 and 7) Add Researcher and Add Paper tabs, where user can search for researchers using the researcher's name (see Figure 2) and papers using the paper's title, and add them into the context.

Fig. 1. Context configuration screen.

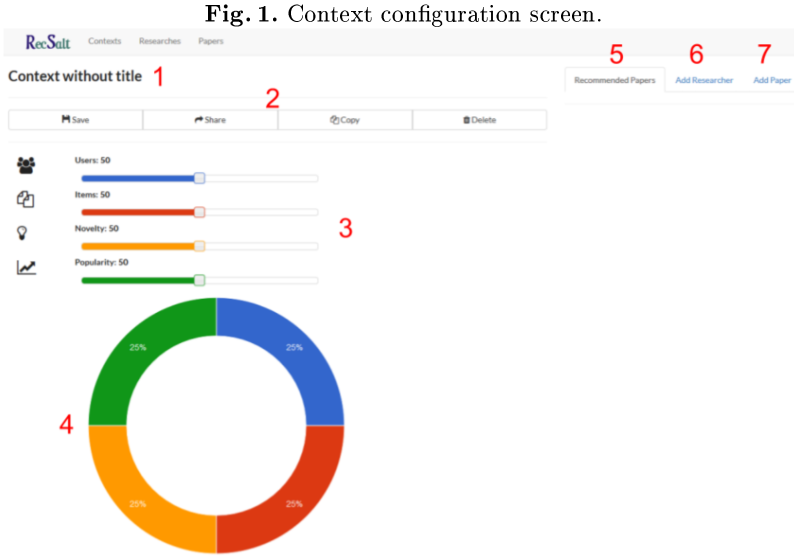

Figure 3 presents an example of configured context, where the user added the researcher D. Parra, author of the paper [7], the papers [3] and [2], and changed the parameters to give more importance to the $Users$ variable. Context is represented by a donut chart, each variable has the same color used in the slider. When the user clicks on the chart, she will see which variable corresponds to that space. The area occupied by each variable is obtained by a rule of three. The researchers and papers inserted into the chart are represented by icons. When the user mouse over an icon, she will see the researcher's name, if it is a researcher, or the paper's title, otherwise.

3 Future Work

For future work, we aim to perform a user study to evaluate the user experience in the system, regarding different controllability levels. Thus, we must define the experiment planning, i.e., define the procedure, subjects, variables, statistical tests, etc.

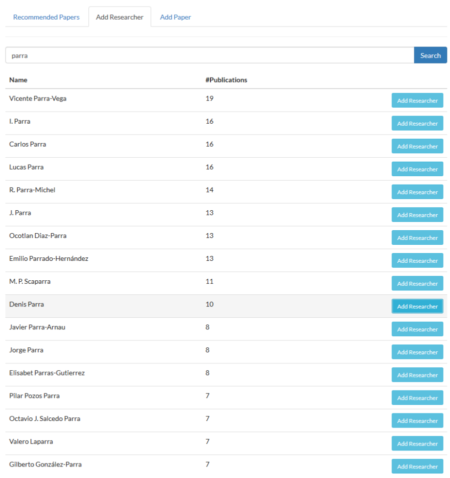

Fig. 2. Searching for a researcher.

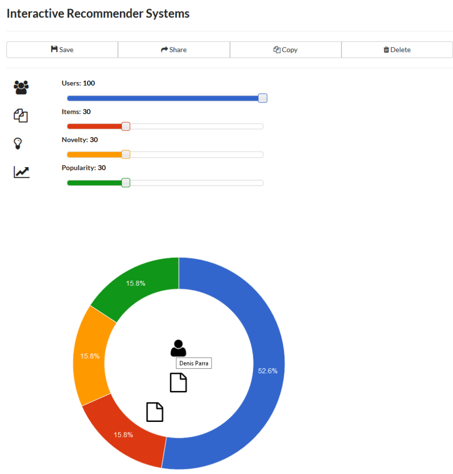

Fig. 3. Example of configured context.

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A mathematical representation for collaborative construction of *SL* blocks

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Abstract

Spatial abilities are positively related to students' attainment in STEM disciplines. SL block is a kind of 3D dissection puzzle and construction building block that may help in practicing spatial skills. With the hypothesis that high level abstractions of spatial relations may reduce the information load in visuospatial problems for learners, a mathematical representation was conceived to facilitate team construction of complex 3D structures. The study uses dual communication channels of descriptive and depictive representations for collaborative construction. The preliminary study is encouraging. Experiments with careful measurements are necessary to derive conclusive result in future studies.

1. Introduction

Many studies concluded that spatial abilities are moderately to significantly correlated with the students' attainment in STEM disciplines [1][2][3][4]. A seeming contradiction is that the correlation becomes less apparent among STEM experts [5]. These lead to the supposition that students with low spatial ability may become STEM experts if assistances are provided for overpassing the spatial ability threshold for STEM domains in early education. The empirical study of [6] disclosed that information overload impedes students with low spatial ability in learning cell biology, a subject in which the comprehension of 3D visuospatial information is important. As pioneer study on chess expertise has uncovered, chucking of domain knowledge might be the propelling force that drives novices to becoming experts [7]. Chunking can be mediated by abstract representations that hide details from interfering in one's cognitive process. Abstraction is indeed the core of languages, including mathematical, computer programming and natural languages. The hypothesis of this research is that chucking of spatial information can be an effective means to mediate learning in STEM education. Some students may progress by chunking spatial relations to overpass the threshold of spatial abilities that may hinder the attainment of STEM education. The study of Ho and Eastman [8] settled the hypothesis that people with lower spatial abilities could significantly improve performances on 3D spatial tasks by adopting approaches of lower information processing load.

Spatial skills are considered as malleable and can be improved by training [5]. Play as children with construction toys was found to be one of the four most significant predictors of success in spatial visualization test such as PSVT:R for first year engineering students [9]. Building blocks such as LEGO™ have been widely accepted as toys for spatial skill training [10]. Solid dissection puzzle such as Soma cubes and Pentomino is another kind of educational toys that is prevalent for training of spatial problem solving. *SL* block [11] is a polycube puzzle element that can be used as building blocks to create large interlocking structures. A mathematical representation based on chunking of spatial relations was devised to mediate the comprehension and composition of complex *SL* block constructions. Integrating knowledge organizing tools into game-based learning tasks is challenging [12][13].

Researchers have recognized that students may display significantly more aggressive learning behavioral patterns with adequate collaborative knowledge mechanism than without [14]. This paper describes a teamwork construction facilitated with the mathematical representation to reduce the cognitive load of visuospatial information. In addition to the conventional graphical representation, the mathematical representation serves as an alternative channel that mediates teamwork communication by encoding complex spatial relations into symbolic structures.

2. *SL* block, string, and strand

SL block is an octocube consisting of an *S*-shaped and an *L*-shaped tetracubes attaching to each other side by side as shown in figure 1.

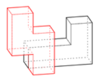


Fig. 1. An *SL* block

The basic relationship of two attaching *SL* blocks is called an engagement. Figure 2 shows 6 pairs of conjugating engagements. The blue (darker) block in each engagement is the host block, which receives a grey (lighter) block as the guest. The geometric transformation that transforms the host to the guest is used to distinguish types of engagements, which are named with upper case letters if the engaging positions are at the *L* parts of the hosts, and named with lower case letters if the engagements take places at the *S* parts of the hosts.

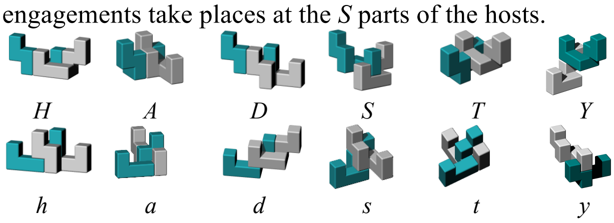
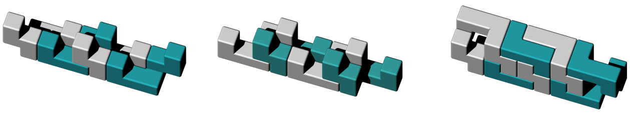


Fig. 2. Six pairs of conjugating engagements of *SL* blocks

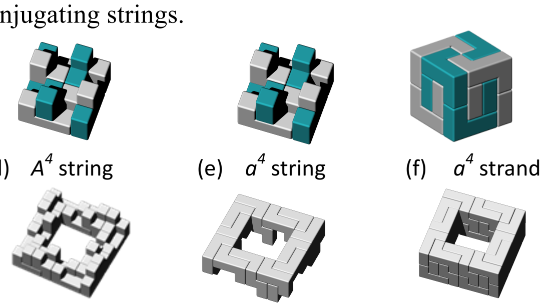
Sequential concatenations of engagements specify the construction of an *SL* string by starting with an initial block and adding on more with each engagement. For example the string *HhH* specifies a string of four *SL* blocks lining up to form the configuration shown in figure 3a. Engagements named after upper and lower cases of the same letter are conjugates to each other. The string *hHh* in figure 3b is the conjugating string of *HhH* in figure 3a. Two conjugating *SL* strings (fig. 3a and 3b) can be placed against each other to form an interlocking structure called an *SL* strand, such as the one shown in figure 3c. For *SL* strands, since engagements always come with their conjugates, the representation may ignore the cases of the representing letters. Exponents represent repetitions of the same engagement.



(a) *HhH* string (b) *hHh* string (c) h^3 strand

Fig. 3. two conjugating *SL* strings make up an *SL* strand.

When the last block comes across the first block of the string, an additional engagement emerges to lock the end with the start of the string to form a cyclic structure. Figure 4 shows two cyclic strands and the corresponding conjugating strings.



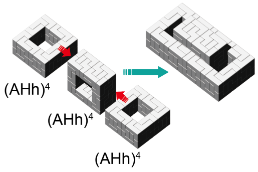
(d) A^4 string (e) a^4 string (f) a^4 strand

(g) $(AHh)^4$ string (h) $(ahH)^4$ string (i) $(ah^2)^4$ strand

Fig. 4. Cyclic strings and strands of a^4 and $(ah^2)^4$.

3. A mathematical representation

A mathematical representation of *SL* block constructions is a member in a non-abelian ring that is defined upon binary operations of addition and multiplication. The ring generating set consists of elements that represent the six conjugating pairs of engagements named after ***h***, ***a***, ***s***, ***t*** and ***y***. The generating set may also consists of the generating set of a group of geometric transformations that are desirable for the construction of block structures. A representation is interpreted as instructions to imaginary robots that are able to move, rotate and insert *SL* blocks. The multiplicative operator of the ring is non-commutative concatenation of instructions to imaginary robots. The additive operator of the ring activates additional robots for parallel construction processes.



A chain of length 3:
$(ah^2)^4 + \boldsymbol{T}(ah^2)^4 + \boldsymbol{T}^2(ah^2)^4$
$= (1+\boldsymbol{T}+\boldsymbol{T}^2)(ah^2)^4$

A chain of length n:
$(1-\boldsymbol{T}^{n-1})(1-\boldsymbol{T})^{-1}(ah^2)^4$

Fig. 5. A chain structure consists of three interlocking squares

Figure 5 shows a structure of three interlocking squares, each of the square is represented as $(ah^2)^4$. *T* is the composition of translation and rotation that transform the first square to the second. *1* is the multiplication identity and the robot would do nothing when given this instruction. The chain structure can be represented as the polynomial: $(ah^2)^4 + T(ah^2)^4 + T^2(ah^2)^4$, or $(1+T+T^2)(ah^2)^4$. A Chain of length *n* can be defined as $(1-T^{n-1})(1-T)^{-1}(ah^2)^4$

Functions define sets of structures. The parameters of a function can be numbers such as the example shown in figure 6.

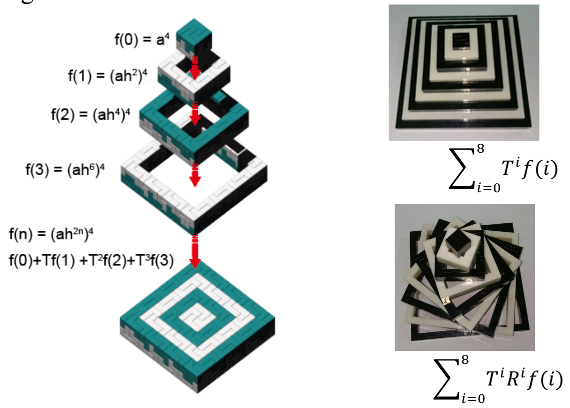
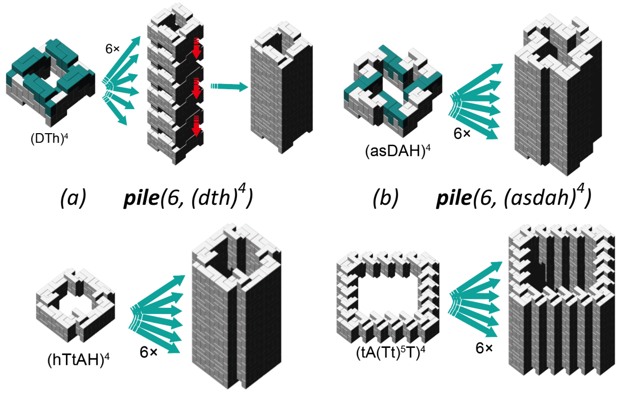


Fig. 6. Functions of *SL* blocks

Functions may have polynomials as parameters. Figure 7 shows four examples represented by the function ***pile***$(n, w) = (1-\boldsymbol{T}^n)(1-\boldsymbol{T})^{-1} w$, where *n* is the number of layers, *w* is the code that makes up one layer, and ***T*** is the transformation that takes the robot to move one layer up.



(a) ***pile****(6, (dth)⁴)* (b) ***pile****(6, (asdah)⁴)*

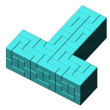
(c) ***pile****(6, (h²t²a)⁴)* (d) ***pile****(6, (at¹⁰)⁴)*

Fig. 7. Applications of the function ***Pile***(*n,w*)

Equations can be used to encapsulate chunks of information into variables. With 40 *SL* blocks, one can build a *T*-shaped pentomino (figure 8). The code for the shape is *hhaahahhhaahhhahaahh*. The string can be simplified into the following equations:

$\boldsymbol{X} = ha^2h, \quad \boldsymbol{T} = h\boldsymbol{X}ah^2\boldsymbol{X}h^2a\boldsymbol{X}h$

With equation systems, complex shapes can be simplified into more compact codes. Equations can also illuminate features that are otherwise not as noticeable. In this example, the variable ***X*** marks three extruded parts of the ***T***-shaped structure. Furthermore, with equations and variables, it is also recognizable that the code for ***T*** shape is indeed a palindrome, which reads the same backward as forward. The fact is concurrent with the left-right symmetry of the constructed shapes.



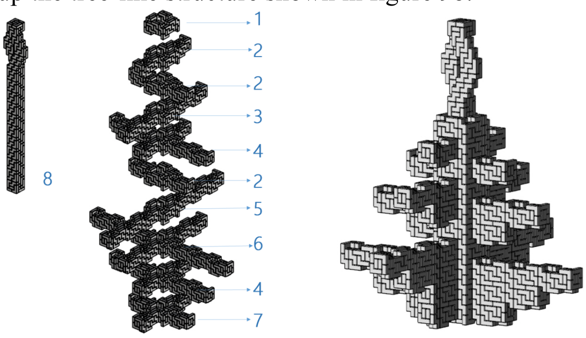
Code: *hhaahahhhaahhhhahaahh*
Equations: $\boldsymbol{X} = ha^2h, \quad \boldsymbol{T} = h\boldsymbol{X}ah^2\boldsymbol{X}h^2a\boldsymbol{X}h$

Fig. 8. ***T***-shaped pentomino and its code

4. Collaborative construction

Collaboration requires that each participant obtains adequate information to uncover uncertainties on subsequent actions. The empirical study of Huk [6] showed that 3D visualizations may lead to cognitive overload problems for some students in learning spatial structures. The cognitive theory of multimedia learning suggests that descriptive and depictive representations are processed in two different channels as duel coding [15] [16]. For the teamwork construction of *SL* blocks, polynomial codes describe the process and 3D visualizations depict the form under construction. It is expected that the dual-coding representations would reduce cognitive loads in the communication and assembly process.

A 232 cm tall Christmas tree consisted of 1024 *SL* blocks of size 8×16×12 cm was constructed by a team of 12 people. Figure 9a shows that 11 *SL* strands of 8 types are arranged into an interlocking configuration to make up the tree-like structure shown in figure 9b.



(a) The 11 parts of the Christmas tree. (b) The completed Christmas tree.

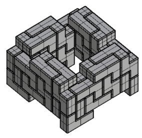
Fig. 9. The 11 parts of the tree.

All *SL* strands are stable structures that can be assembled independently. Eleven strands were assigned to four teams. Each team consists of a leader with model construction experience and two novices. The activity started with 30 minutes introduction to *SL* block and the mathematical representation of using polynomials to describe the construction of *SL* strands. Perspective images and the corresponding codes for *SL* block engagements were given to each group as instructions. Each team was given 60 minutes of time to practice and assemble the assigned *SL* strands (figure 10a). All teams were able to finish construction in time. It took additional 50 minutes for the teams to assemble and complete the setup of the tree (figure 10c). Figure 10b shows the result after construction.

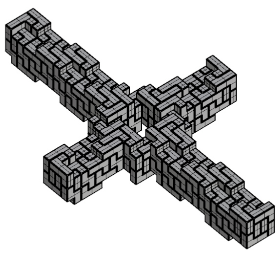
(a) Strand assembly
(c) Tree construction (b) Completed tree

Fig. 10. The construction process and result

Figure 11 shows the perspective images and assembly codes for *SL* strand X_1, and X_4. The strand X_1 consists of 24 blocks, and X_4 consists of 120 blocks.



code for *SL* strand X_1:
hdthdthdthdt = $(hdt)^4$



code for *SL* strand $\boldsymbol{X_4}$:
ahdhsadhdttahdhdhdhsadhdhdh dttahdhsadhdttahdhdhdhsadhdh dhdtt

Equation system:
$\boldsymbol{E} = hd, \ \boldsymbol{F} = hsad,$
$\boldsymbol{f}(n) = a\boldsymbol{E}^{2n-1}\boldsymbol{F}\boldsymbol{E}^{2n-1}t^2$
$\boldsymbol{X_4} = (\boldsymbol{f}(2)\boldsymbol{f}(1))^2$

Figure 11. Perspectives and codes for $\boldsymbol{X_1}$ and $\boldsymbol{X_4}$ strands

The following equation system defines the entire tree:

$\boldsymbol{E} = hd,$

$\boldsymbol{F} = hsad,$

$\boldsymbol{f}(n) = a\boldsymbol{E}^{2n-1}\boldsymbol{F}\boldsymbol{E}^{2n-1}t^2$

$\boldsymbol{X_1} = (\boldsymbol{E}t)^4, \qquad \boldsymbol{X_2} = (\boldsymbol{f}(1)\ \boldsymbol{E}t)^2,$

$\boldsymbol{X_3} = (\boldsymbol{E}t\boldsymbol{f}(2))^2, \qquad \boldsymbol{X_4} = (\boldsymbol{f}(2)\boldsymbol{f}(1))^2,$

$\boldsymbol{X_5} = (\boldsymbol{E}t\boldsymbol{f}(3))^2, \qquad \boldsymbol{X_6} = (\boldsymbol{f}(3)\boldsymbol{f}(2))^2,$

$\boldsymbol{X_7} = \boldsymbol{f}(1)^4, \qquad \boldsymbol{X_8} = a^2h^{21}d^2hd^2a^2d^2hd^2h^{21}$

$\boldsymbol{U} = \textbf{translate}(0,0,4),$

$\boldsymbol{R} = \textbf{rotate}(90),$

$\boldsymbol{T} = \textbf{translate}(-2,-2,0)$

$\boldsymbol{X_{tree}} = \boldsymbol{X_8} + \boldsymbol{T}(\boldsymbol{X_7} + \boldsymbol{U}\boldsymbol{X_4} + \boldsymbol{U}^2\boldsymbol{X_6} + \boldsymbol{U}^3\boldsymbol{X_5} + \boldsymbol{U}^4\boldsymbol{X_2} + \boldsymbol{U}^5\boldsymbol{X_4} + \boldsymbol{U}^6\boldsymbol{X_3} + \boldsymbol{U}^7\boldsymbol{X_2} + \boldsymbol{R}\boldsymbol{U}^8\boldsymbol{X_2} + \boldsymbol{U}^9\boldsymbol{X_1})$

5. Discussion

The mathematical representation opens up a descriptive information channel for spatial reasoning with *SL* blocks. It provides an opportunity for learners to take on non-spatial cognitive skills for spatial tasks that are heavily loaded with depictive information of visuospatial representations. The study attempts to echo prior research findings in two folds. First, hard problems may become easier after being transformed to an isomorphic problem with adequate representations. Learners with mulit-representation skills have more opportunities to take on a feasible strategy for spatial problem solving. The mathematical representation provides methods to encode spatial relations with symbolic structures that are typically regarded as non-spatial. Second, visuospatial representations are often cognitively costly to low spatial ability learners so as to impede their attainment in STEM education. The insignificant correlation of high spatial abilities within STEM experts suggest that the threshold of spatial ability in STEM domains can be overpassed with non-spatial cognitive skills.

It is premature to conclude with conjectures on how the mathematical representation mediates learning of spatial tasks and collaboration in *SL* block construction. However, this study provisions a place to launch further researches on issues regarding the interplay of descriptive and depictive representations, of symbolic and spatial reasoning, and of non-spatial and spatial cognitive skills.

6. Acknowledgement

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The additive effect of collaborative and game-based learning in using an eBook for promoting spatial ability

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Abstract

An eBook was developed and experimented for improving spatial ability of the primary school Fourth to Sixth graders. The content of the eBook was tried out in a previous study and demonstrated to be helpful in improving the children's spatial ability and at the same time, diminishing the gender difference in spatial ability.

In the present study, students were randomly assigned into Self-Learning and Flipped Learning groups. Both groups read and learned the eBook at home without any teaching intervention, however the FL group additionally participated in a collaborative and gamed-based learning program spanning 7.5 hours in three weekends. The group differences were evaluated by a computerized mental rotation test, Technology Acceptance Model and creativity competition, among which only the test score showed that the FL group attained significantly higher than the SL group. The result provides a baseline for observing the merits of self-learning of the eBook, and the additive promoting effect of the collaborative and gamed-based learning.

1. Introduction

The underrepresentation of women in STEM (science, technology, engineering, and mathematics) field has been a long-concerned issue [1, 2, 3]. Research showed that spatial ability can be an important ability and a unique contributor, other than verbal and math abilities, to attain ones' achievement in creativity and technical innovation later in their life span [4]. Research also showed that children and adolescents who have higher spatial skills in middle and high schools are more likely to major in STEM in colleges and to pursue STEM careers [5]. Therefore research in spatial ability is getting momentum in recent years.

Spatial ability is not only inherent but also malleable in earlier ages [5] which encourages educational intervention with an aim to project smaller individual and gender discrepancy to ones' later participation in STEM. In a previous study [3] where primary school students of Grades 4 to 6 attended a collaborative and game-based learning program for improving spatial ability. The content of the program lessons was shown to be effective in improving students' spatial ability and diminishing gender difference in spatial ability as well. The content was therefore promising to transform into an interactive eBook to meet multiple ends such as self-learning, game-based learning and ubiquitous learning. The development of the interactive eBook also adhered to the conclusion made by Jeng and Liu [6] that (test) interactivity is promising to reduce gender difference in spatial ability and therefore to promote females' pursuit of STEM careers.

The interactivity design is to make self-learning the eBook easier, efficient, and fun, so that most functions delivered by traditional paper books and face-to-face instruction are to be replaced. What then challenges the classroom instruction nowadays is that the content instruction should not just repeat what the eBook can do. Instead it should transform into flipped learning to transport different content and skills.

The purpose of the study is then to investigate whether the self-learning of the eBook can be fulfilled and whether the treatment of the flipped learning with collaborative and game-based component can be of additive effect to the learning results.

2. Method

2.1. Design of experimentation

Primary students of Grades 4 to 6 were randomly assigned into Self-Learning (SL) and Flipped Learning (FL) groups. Both groups read and learned the eBook at home without any teaching intervention, took pre- and post-tests of spatial ability, participated in a final one-day competition of creative making of cube combinations and filled out an e-questionnaire about their Technology Acceptance Model (TAM) during the competition.

The FL group additionally attended a collaborative and gamed-based learning program spanning 7.5 hours in three weekends. Children played with cubes and puzzles in this program lessons without duplicating the content lessons of the eBook.

2.2. Participants

There were 7 students in the SL group and 8 in the FL group, with complete attendance and test data. This size of sample is small due mainly by the experimentation requirement to have the iPad to register in the program. Secondly, the society has been experienced low birth rate dramatically in recent years. As a result, the sample of the study can be regarded as representative of a low-birth society and the households having iPads.

2.3. The eBook

The eBook was developed using ibook author, hype 2.0, google sketchup, java, and widget. Their functional relationship and brief introduction is delineated in Fig. 1.

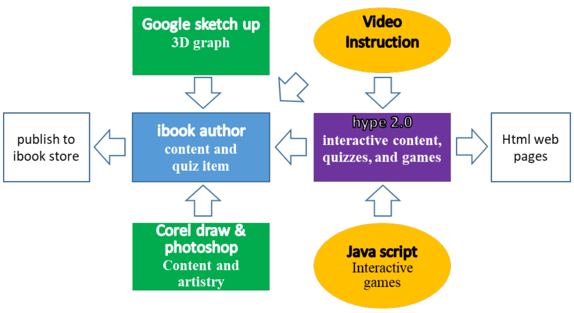

Fig. 1. Relationship of software used in the eBook

2.4. Instruments

There are three quantitative instruments used in the study: The computerized mental rotation test, the eTAM questionnaire, and the final competition score.

Developed by Jeng and Liu [6], the computerized mental rotation test is consisted of 10 pairs of items. In each pair, there is one static 2D and one interactive 3D items, and the figure structures are all the same in the items. The internal consistency of the test is 0.79, a value considered satisfactory for test reliability [7], and therefore provides evidence that the primary school children can be reliably tested with the computerized test version of mental rotation.

There are 8 items in the TAM [8] questionnaire revised for primary school children into an e-questionnaire. The eTAM questionnaire is consisted of two dimensions: Perceived Usefulness (PU) and Perceived Ease of Use (PEU). Since the size of sample in the study is small, the evaluation of the eTAM reliability is postponed until more data is collected in the future.

The creative making competition score is comprised of three dimensions: Structure, artistry, and organization.

3. Results

3.1. eTAM and competition

Given the number of sample students in the study, the results of eTAM and competition were not significantly different in the groups, which can be interpreted that both groups experienced the same degrees of TAM, PU, and PEU (Table 1), and both had equivalent creative performance (Table 2). This result can stand as a baseline for evaluating the merits of the eBook that the content and interactive design in the eBook provided sufficient preparation and mechanism for students to self-learn in the study.

Table 1. eTAM score.

	N	TAM total/item	PU total/item	PEU total/item
FL	8	33.57/4.20	17.57/4.39	16.00/4.00
SL	7	33.57/4.20	16.29/4.07	17.29/4.32

Note.
1. A Likers' five-point scale is used in the eTAM questionnaire.
2. There are four items in PU, and four items in PEU.
3. Two scores are given in each category: the total average in the left hand side, and per item average in the right hand side.

Table 2. Competition score.

	N	Total	structure	artistry	organization
FL	8	89.51	89.76	89.86	88.90
SL	7	89.33	88.95	89.48	89.57

Note. The total score is 100 in each category. The scores of structure, artistry, and organization are averaged into the total score.

3.2. ANCOVA test

As seen in Table 3, after adjusted for the pretest difference, there is significant difference between the groups in the computerized mental rotation test score, due mainly by that the FL increased in the post-test however the SL decreased.

Table 3. ANCOVA for test score.

	N	pre	post	Adjusted mean	F	P
FL	8	15.25	16.13	16.07	20.73	.001
SL	7	13.86	13.00	13.87		

4. Discussion and conclusion

Given the small sample and the short duration of experimentation in three weekends spanning 7.5 hours, the results can be summarized tentatively as follows:

a. As for the eTAM results, the eBook worked equally well in the groups so that both groups of students experienced the same degrees of perceived usefulness and perceived ease of use, which provides evidence that the content and design of the eBook can support sufficient self-learning without teaching intervention.
b. For the creative competition, the eBook also worked equally well in both groups so that there was no group difference in any of the dimensions (structure, artistry, and organization), and the total score as well. This provides further evidence that with good plan and design, the eBook can be implemented in such a way to promote learners' accomplishment in structure, artistry, and organization of learning a subject matter as in the case of spatial ability.
c. However, with an extra activity of 7.5 hours only, the FL students demonstrated a significant difference from the SL counterparts in the computerized mental rotation test score. More interesting is that, the FL group experienced test score increase, nevertheless the SL group experienced test score decrease in the post-test, so that the post-difference was larger than the pre-difference.
d. Although the scenario of the above difference is to be explored further, it can be concluded for the present that the difference can be attributed to the extra activity the FL students took part in.
e. The extra activity provided an environment where students played and explored, and therefore their spatial experience and capability was first built by the eBook and later augmented by the collaboration and game-based component in the activity.

There is a long concerned argument that whether eBooks can support self-learning without any teacher intervention, or even whether eBooks can replace all teaching activities at all. The results of the present study give positive and optimistic answers to the argument. With well-planed content design, even with a subject training demanding substantial multimedia illustration, videos, and interactivity such as spatial ability, the primary school children can read the eBook without difficulty, that is, without teacher intervention, and accepted the eBook equally well as shown in the result of eTAM group comparison. The equal perceived TAM showed that both groups recognized that the eBook is useful for them to comprehend the content material and easy to use as well. Furthermore, the present study challenged to include competition to try to quantify the students' performance in creative and artistic domain such as the spatial ability. The result of the competition also showed that both groups performed equally well.

The only group difference lay in the test score which can be attributed to the extra activity of collaborative and game-based component. Therefore, the present study provides evidence that although the eBook supports self-learning, but extra lesson activity can further contribute to increase the test score. However, it should be reminded that the extra activity as implemented in the study did not repeat the content in the eBook, but rather it provided extra interpersonal collaboration and game-play opportunity which is not able to convey in the eBook. Therefore the implication of the result is that design the eBook well so that it can support self-learning, and for any additive effect aside of the eBook, the classroom activity should focus on the educational objectives that are not able to implement into the eBook such as the interpersonally affective, collaborative, and playful domains as well. And that's how the flipped learning is about.

Lastly, since spatial ability is malleable and due to its special nature, its training would be and should be quite different from the other subject domains. Multimedia is the key solution so that multiple and alternative presentation should be looked for to augment the learning outcomes. The eBook is one of the solutions, and it is very promising that in the future more solutions would be developed for such ends with the expectation that promoting children's spatial ability earlier so that their future participation in STEM fields can be promoted as expected.

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