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Identification of Effective Scaffolding to Novices Using CBLE

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Abstract: The aim of this study is to discover which kind of scaffolding can effectively promote learning. The past studies have shown mixed results in this regard. The process in which a domain expert gives and withdraws support in order to make a novice learner complete the task is known as scaffolding. A total of four distinct scaffold combinations and four groups were made. This experimental study was repeated twice to cross verify the outcomes using computer based learning environment (CBLE). The CBLE was designed with intelligent web program in PHP and jQuery to evaluate the solutions submitted by the learners instantly. The CBLE acted as an intelligent feedback system. In the first study, it was found that there was a significant effect of different scaffolding treatments on the learning outcomes, $F(3,76) = 5.762$, $p=.001$. The result analysis involves multiple comparisons based on Tukey HSD test and indicated that the mean score for the indirect support and adaptive fading ($M=4.45$, $SD=1.191$) was considerably different than the others. Likewise, second study also found that there was a significant effect of different scaffold treatments on the learning outcome, $F(3,76) = 4.258$, $p=.008$. The Tukey HSD test applied during the second study indicated that the mean score for the indirect support and adaptive fading ($M=4.55$, $SD=1.19$) was again significantly different than the others. The present study additionally measured the flow state of all the four groups using Kruskal-Wallis H test and found that indirect support and adaptive fading group was significantly different than direct support and adapting fading group as well as direct support and gradual fading group in both the studies.

Keywords:Computer Based Learning Environment (CBLE), Effective Scaffolding, Intelligent feedback system

1. Introduction

For a long time, it has been a matter of debate that which type of instructional support is effective to enhance the learning outcome. The withdrawal of support is also necessary in this regard for the independent functioning. The process in which a domain expert teacher gives and withdraws support in order to make the novice learners complete the task is known as scaffolding (Anwar, Irawan, & As'ari, 2017; de Pol et al., 2010; van de Pol, Mercer, & Volman, 2019). The scaffolding can be face to face between students and a teacher or it can be a computer based scaffolding. In computer based scaffolding, a specialized software is designed which regularly

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direct and monitor students and prevent them from engaging in superfluous, misleading and unproductive tactics (Azevedo et al., 2010; Hannafin et al., 1999; Saye & Brush, 2002). This specialized software can be a desktop application or web based application (R. Kaushal, Panda, & Kumar, 2020).

The past studies emphasized primarily on two main characteristics of scaffolding namely “Support or Contingency” and “Fading Support or Withdrawing Support”. This study extended this work by further classifying these two key characteristics and designed an experimental study to find the best combination of scaffolding. In addition, this study also disclosed that which of scaffolding combinations engaged the participants more.

2. Related Work

Scaffolding refers to dynamic expert advice to novices in order to complete the task and enhance learning (Collins et al., 1989; de Pol et al., 2010; van de Pol, Mercer, & Volman, 2019; Wood et al., 1976). In scaffolding, expert instructor design tasks and plan strategies which learner can pursue to enhance learning. It is also known as soft scaffolding (Saye & Brush, 2002; Sharma & Hannafin, 2007). Scaffolding cannot function independently rather it is utilized with existing instructional approaches like PBL (Problem Based Learning) (Saye & Brush, 2002), learning by design (Puntambekar & Kolodner, 2005) or CBL (Case-Based Learning (Lajoie et al., 2001).

It is recommended that once learner achieves certain competence level, scaffolding should be withdrawn by the expert to encourage independent functioning (van de Pol & Elbers, 2013). It is necessary to transfer the responsibility back to learners (Pea, 2004; Puntambekar & Hubscher, 2005). The expert can decide when to withdraw scaffolding by observing each student’s performance. The studies in this area agree that there are two essential characteristics of scaffolding, giving support and withdrawing the support, also known as contingency and fading (de Pol et al., 2010; Smit et al., 2017).

In the recent years, computer-based scaffold (CBS) is being utilized to improve learning by supplementing expert instructor scaffolding (Azevedo et al., 2010; Hannafin et al., 1999; Saye & Brush, 2002). In this environment, a software is designed which continuously direct and monitor students and prevent them from involving in superfluous, misleading and unproductive tactics (Pea, 2004). CBS emerges due to advancement in technology (Devolder et al., 2012). Most computer-based scaffolding systems are static as tasks and strategies are fixed and cannot be changed at runtime. CBS is also known as fixed and hard scaffold (Saye & Brush, 2002; Sharma & Hannafin, 2007).

Moreover, the tasks designed in computer-based scaffold should neither be too easy nor too difficult (Applebee & Langer, 1983; Bliss et al., 1996; Gaffney & Anderson, 1991). One biggest challenge with computer-based scaffold is to decide when to withdraw scaffolding. Generally, it is withdrawn at some fixed point (Li & Lim, 2008) or when learners himself do not need it (Metcalf, 1999). Building an intelligent computer based scaffold that can judge and fade support automatically is difficult (Puntambekar & Hubscher, 2005).

Most of the studies in this area did not consider learner characteristics. In fact, learner characteristics should also be considered in computer-based scaffolding (Hannafin et al., 1999). The learner characteristic like prior knowledge can influence the learning outcome in a scaffold environment (Devolder et al., 2012). Majority of the studies in this area are observational (Cazden, 1979; Englert, 1992; Langer & Applebee, 1986) and very few studies are experimental based (Palincsar, 1986, 1991; Palinscar & Brown, 1984) and has proved the effectiveness of scaffolding.

The related literature primarily highlights on two essential characteristics of scaffolding, giving support and withdrawal of support. But, a research is still required to find which combination of scaffolding can effectively promote learning as support and withdrawal can further be categorized. The “support characteristic” can be classified as direct and indirect support. The “withdrawal of support or fading characteristic” can be classified as adaptive fading and gradual fading. The present study examines the most effective way of scaffolding by making all possible combinations of scaffolding characteristics by keeping the fact in mind that each combination must have one element of support and one element of fading. The CBLE helped the domain expert in this context.

3.Objective

The aim of this study is to find which combination of scaffold characteristics can effectively promote learning. A total of four distinct scaffolding combinations and four groups were made. The learning outcomes of all the groups were compared to find the effective combination. The null and alternate hypotheses are stated below.

H0: $\mu 1 = \mu 2 = \mu 3 = \mu 4$

H1:Mean of two or more groups would be different

The null hypothesis states that all combinations of scaffold characteristics would be equally effective. Another objective was to investigate which combination of scaffold characteristics would highly maintain the flow level. The null and alternate hypothesis of the second objective is stated below.

H0: $\mu 1 = \mu 2 = \mu 3 = \mu 4$

H1:Mean of two or more groups would be different

4. Methodology

This study investigated the most effective combination of scaffold characteristics by making all possible combinations of scaffold characteristics by keeping the fact in mind that each combination must have one element of support and one element of fading. All possible scaffolding combinations and associated groups are stated below.

1. Direct Support & Adaptive Fading (Group 1)

2. Indirect Support & Gradual Fading (Group 2)

3. Direct Support & Gradual Fading (Group 3)

4. Indirect Support & Adaptive Fading (Group 4)

Thereafter, an experimental study was designed and the participants were randomly allocated to one of the four groups where each group faced a unique combination of scaffold characteristics.

A. Participants

The study was conducted twice, firstly at Chitkara University, Punjab state and then at Chitkara University, Himachal state. Total 93 students of BCA (Bachelor of Computer Applications) first year willingly participated in the first study. In the second study, 101 students of CSE (Computer Science Engineering) second year have participated. The study was conducted twice to cross-verify the outcomes. All participants were of age group between 19-20 years.

B. Material

A CBLE was developed to conduct the study. The CBLE acted as a resource platform and was designed in WORDPRESS, PHP and JQuery. It consists of animated tutorials on the topic used in the study. The idea was to teach the concept of "infix to postfix conversion using stack" using CBLE. The students were directed to use headphones/earphones during the study. The students were also educated to move to "Take the Challenge Section" of CBLE once they felt confident in solving the tasks.

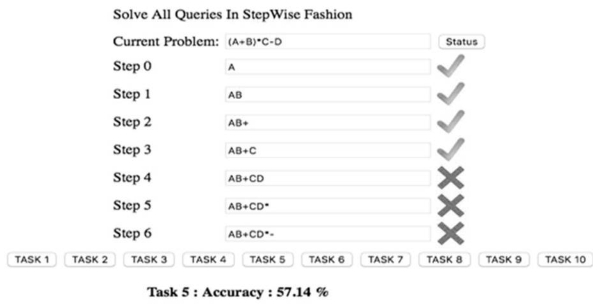

Fig. 1: CBLE immediate feedback environment

The CBLE was designed with 10 challenges/tasks. The domain expert teachers were instructed to support the students in solving the tasks during task solving phase. The support and withdrawal of support by the domain expert were distinct in each group.

The CBLE was designed to automatically evaluate the solutions submitted by the participants. The CBLE web platform was smart enough to track which student belongs to which group due to the mandatory registration process required before the start of the study. This automatic evaluation was performed through the jQuery and PHP code at the backend. The backend logic was using data structures algorithm to track the accuracy of the learner's solution. As a result, participants could get instant feedback in terms of accuracy level in percentage. This feedback helped the domain expert to decide when to withdraw support. The CBLE environment is shown in the Fig. 1. Introducing CBLE into scaffolding has already proved effective in the past. (González-Gómez & Jeong, 2019) also used such learning platform while scaffolding and named it as computer based blended scaffolding. (Denny et al., 2019) also supported the use of software tools during the metacognitive scaffolding. This learning platform was designed using Adobe Captivate 6 and HTML 5. The poor accuracy level was subject to more support and higher accuracy level was subject to withdrawal of support. All the four groups faced the same challenges.

C. Procedure

A prior knowledge test was conducted before dividing the subjects into groups. The idea was to include low prior knowledge students in the study. A prior knowledge test comprises of 8 multiple choice questions was conducted.

The study was conducted on the data structures concept of “infix to postfix conversion using stack”. All participants who scored more than 3 marks were excluded from the study as the study only needs low prior knowledge students. As a result, 13 participants were excluded from the first study due to the exclusion criteria. The remaining 80 participants were randomly allotted to one of the four groups (20 students in each group). Similarly, 21 participants were excluded from the second study after prior knowledge test.

Both the studies were restricted to incorporate 80 participants only as the university allotted only four labs of 20 computers each for the study. Thus, first 80 students were included according to the inclusion criteria. Due to this, we had to exclude some students even after they matched the inclusion criteria.

A separate lab was allotted to each group along with a dedicated expert teacher. Four university teachers of computer applications department took part in conducting the study. A CBLE (Computer Based Learning Environment) was also introduced to all the groups which acted as a learning portal and for automatic evaluation of student’s performance.

Once the study is completed, a post-test, including 3 infix to postfix problems and 3 multiple choice questions, of 40 minutes was conducted to measure the learning outcomes of each group. The participants were instructed to switch off the computers before appearing for the post-test exam. Additionally, a questionnaire was given to participants of each group to measure the level of flow.

The one-way ANOVA test was applied to post-test data of both the studies to measure the performances.

The Kruskal-Wallis H test was applied on questionnaire data-set to measure which combination of scaffolding maintains a higher level of flow.

The flow theory was initially established by Csikszentmihalyi and it was defined as the state in which a participant feels entirely engaged in the activity and focuses completely on the task at hand (Csikszentmihalyi, 1990). He also proposed flow items to be used in a flow questionnaire. Later on, Jackson and his colleagues worked on the same theory for improvement purposes. They modified some of the original items.

After validity and reliability testing, a short flow state scale and a questionnaire were proposed along with the way of measuring flow score (Jackson et al., 2008; Martin & Jackson, 2008) by Jackson and his colleagues. This study was not aimed at establishing new flow constructs and scales. As a result, it utilized the same well-established constructs and scale to measure the flow scores. A total of 9 questions were asked based on the 9 constructs (See Table 1) to measure the flow state score.

The Likert scale based on five-point were used in the questionnaire, 1 being the lowest (Strongly Disagree) and 5 being the highest (Strongly Agree). Jackson and his colleagues also suggested that flow score of each participant should be measured by calculating the sum of all nine responses and then dividing the total by nine. The similar method was applied in this study.

5. Treatment In Various Groups

The four groups were made in the study due to four distinct scaffolding combinations. In each group, there was one element of support and one element of fading. All the groups faced different treatments due to distinct scaffolding combinations during solving the tasks. The CBLE was incorporated with 10 distinct challenges/tasks. The nature of all the scaffold characteristics (direct support, indirect support, adaptive fading, and gradual fading) are discussed below.

The domain experts were instructed to provide and withdraw support during the problem solving phase. The domain expert support was classified as direct and indirect support. The way of direct support was to support students by highlighting their mistakes and

Table 1 : Flow-State constructs and corresponding statements

Construct (Flow)	Corresponding Statement
"Balance Between Challenge and Skills"	"I felt I was competent enough to meet the demands of the situation"
"Merging Actions and Awareness"	"I did things spontaneously and automatically without having to think"
"Focus on Clear Goals"	"I had a strong sense of what I wanted to do"
"Feedback (Unambiguous)"	"I had a good idea about how well I was doing while I was involved in the task/activity"
"Concentration (Task at Hand)"	"I was completely focused on the task at hand"
"Sense Over Control of Actions"	"I had a feeling of total control over what I was doing"
"Loss of Self Consciousness"	"I was not worried about what others may have been thinking of me"
"Transformation (Time)"	"The way time passed seemed to be different from normal"
"Experience (Autotelic)"	"I found the experience extremely rewarding"

then by giving solution directly through demonstration. The way of indirect support was to support students in completing the task by giving them hints, clues or suggestions. So, in this kind of support domain experts were bound for not giving direct solution through demonstration.

The fading characteristic was classified as adaptive and gradual fading. The adaptive fading indicates that the support needs to be completely withdrawn when the performance is satisfactory and support should be delivered again when the performance degrades. In fact, learners were allowed to call domain expert for help whenever they faced problems in solving a task.

The gradual fading indicates that support needs to be withdrawn gradually in decreasing order. The students were told to solve all 10 tasks during the study on CBLE. In gradual fading, students were allowed to take support for any number of mistakes committed while solving the first task. So, 100% support of domain expert was available. In the second task, they were eligible to take help only if they got a minimum of 20% marks. So, it means they could only get remaining 80% support from the domain expert. In the third task, they were eligible to take help only if they got a minimum of 30% marks. So, it means during the third task they could only get remaining 70% support from the domain expert. In the second last task, the accuracy needed to get support was 90%. So, domain expert could only support for remaining 10% mistakes. The support was fully withdrawn in the last task.

Initially, students were not aware of their groups. Once all the groups settled down in their dedicated labs, the domain expert teacher informed them their group number and the type of treatment. Thereafter, the participants were instructed to register themselves on CBLE. It was mandatory for the participants to register themselves in their corresponding group on CBLE.

6. Results

A. Study 1 Results

The post-test data of the first study was analysed using IBM SPSS 23. The Shapiro-Wilk normality test was applied on the post-test scores of all the four groups, 20 subjects in each group, and data was found normally distributed with a p value of 0.323 for direct support and adaptive fading group (DSAF), 0.096 for indirect support and gradual fading group (ISGF), 0.075 for direct support and gradual fading group (DSGF) and 0.050 for indirect support and adaptive fading group (ISAF).

The Shapiro-Wilk test assumes normality if $p>=.05$. Thereafter, the present study conducted a Levene test and discovered that the assumption of homogeneity of variance was met, $p=0.532$; therefore, one-way ANOVA was carried out (See Table 2).

The different combinations of scaffolding had positive impact on the learning outcome, $F(3,76) = 5.762$, $p=.001$. A Tukey HSD post-hoc comparison test was conducted (See Table 3) to identify which combination of scaffolding outperformed in the study.

The Tukey HSD test showed that the mean score for the ISAF (M=4.45, SD=1.191) was considerably different than DSAF (M=3.15, SD=1.53), ISGF (M=3.15, SD=1.66) and DSGF (M=2.60, SD=1.42).

Table 2 : One-way ANOVA test results on post-test scores

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
DSAF	ISGF	.000	.463	1.000	-1.22	1.22
	DSGF	.550	.463	.636	-.67	1.77
	ISAF	-1.300*	.463	.031	-2.52	-.08
ISGF	DSAF	.000	.463	1.000	-1.22	1.22
	DSGF	.550	.463	.636	-.67	1.77
	ISAF	-1.300*	.463	.031	-2.52	-.08
DSGF	DSAF	-.550	.463	.636	-1.77	.67
	ISGF	-.550	.463	.636	-1.77	.67
	ISAF	-1.850*	.463	.001	-3.07	-.63
ISAF	DSAF	1.300*	.463	.031	.08	2.52
	ISGF	1.300*	.463	.031	.08	2.52
	DSGF	1.850*	.463	.001	.63	3.07

*. Significance at 0.05

The present study also evaluated that which combination of scaffolding maintains higher level of flow. To measure this, Kruskal-Wallis H test was applied on the questionnaire data-set which implied a considerably significant difference in flow state between different scaffolding treatments, X2(3) =19.774, p=.001, with a mean rank score of 37.25 for DSAF, 43.05 for ISGF, 24.80 for DSGF and 56.90 for ISAF. Dunn's pairwise tests were then conducted for all pairs of groups. There was a convincing evidence (p<0.001, after the Bonferroni correction) of a difference between DSGF and ISAF group. The difference between DSAF and ISAF was also significant (p=0.045, after the Bonferroni correction). There was no evidence of a difference between the other groups.

Table 3 : Tukey Post-Hoc comparison results

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
DSAF	ISGF	.000	.463	1.000	-1.22	1.22
	DSGF	.550	.463	.636	-.67	1.77
	ISAF	-1.300*	.463	.031	-2.52	-.08
ISGF	DSAF	.000	.463	1.000	-1.22	1.22
	DSGF	.550	.463	.636	-.67	1.77
	ISAF	-1.300*	.463	.031	-2.52	-.08
DSGF	DSAF	-.550	.463	.636	-1.77	.67
	ISGF	-.550	.463	.636	-1.77	.67
	ISAF	-1.850*	.463	.001	-3.07	-.63
ISAF	DSAF	1.300*	.463	.031	.08	2.52
	ISGF	1.300*	.463	.031	.08	2.52
	DSGF	1.850*	.463	.001	.63	3.07

**. Significance at 0.05*

B. Study 2 Results

The post-test data of the second study was also analysed using IBM SPSS 23. The Shapiro-Wilk normality test was applied on the post-test scores of all the four groups, 20 subjects in each group, and data was found normally distributed with a p value of 0.119 for direct support and adaptive fading group (DSAF), 0.093 for indirect support and gradual fading group (ISGF), 0.416 for direct support and gradual fading group (DSGF) and 0.050 for indirect support and adaptive fading group (ISAF). The Shapiro-Wilk test assumes normality if p>=.05. Thereafter, the present study conducted a Levene test and discovered that the assumption of homogeneity of variance was met, p=0.98; therefore, one-way ANOVA was carried out (See Table 4).

Table 4:One-way ANOVA test results on post-test scores

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	31.638	3	10.546	4.258	.008
Within Groups	188.250	76	2.477		
Total	219.888	79			

The different combinations of scaffolding had positive impact on the learning outcome, F (3,76) = 4.258, p=.008. A Tukey HSD post-hoc comparison test was conducted (See Table 5) to identify which combination of scaffolding outperformed in the study.

The Tukey HSD test showed that the mean score for the ISAF (M=4.55, SD=1.19) was convincingly different than DSAF (M=3.1, SD=1.37), ISGF (M=3.05, SD=2.01) and DSGF (M=3.15, SD=1.59). These results matched with the study 1.

The flow state was measured using Kruskal-Wallis H test which indicated that there was a significant difference in flow state between different scaffolding treatments, X2(3) =11.362, p=.010, with a mean rank score of 31.73 for DSAF, 40.53 for ISGF, 35.13 for DSGF and 54.63 for ISAF. Dunn's pairwise tests were then conducted for all pairs of groups. There was a considerable evidence (p=.011, after the Bonferroni correction) of a difference between DSAF and ISAF group. The difference between DSGF and ISAF was also significant (p=0.047, after the Bonferroni correction). There was no evidence of a difference between the other groups.

Table 5 : Tukey Post-Hoc comparison results

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
DSAF	ISGF	.050	.498	1.000	-1.26	1.36
	DSGF	-.050	.498	1.000	-1.36	1.26
	ISAF	-1.450*	.498	.024	-2.76	-.14
ISGF	DSAF	-.050	.498	1.000	-1.36	1.26
	DSGF	-.100	.498	.997	-1.41	1.21
	ISAF	-1.500*	.498	.018	-2.81	-.19
DSGF	DSAF	.050	.498	1.000	-1.26	1.36
	ISGF	.100	.498	.997	-1.21	1.41
	ISAF	-1.400*	.498	.031	-2.71	-.09
ISAF	DSAF	1.450*	.498	.024	.14	2.76
	ISGF	1.500*	.498	.018	.19	2.81
	DSGF	1.400*	.498	.031	.09	2.71

7. Discussion and Conclusion

The results of both the studies suggests that the indirect support and adaptive fading was the most effective scaffold combination to enhance the learning outcome. This group outperformed in both the studies. The indirect support might have encouraged the subjects to shift to deep thinking as they were getting support only in the form of hints, clues, and suggestions. The element of deep thinking positively reflected in their post-test scores. Moreover, the adaptive fading made their life easier as they could take help anytime and support could be increased and decreased accordingly. The direct support prevents students to shift towards deep thinking.

The indirect support and gradual fading treatment was very close in nature to indirect support and adaptive fading. Both the treatments differ only in the fading mechanism. The difference in fading mechanism also reflected in the post-test scores. The similar effect was observed with direct support and adaptive fading group and direct support and gradual fading group. So, we conclude that apart from the type of support, the type of fading also plays a vital role in the learning outcome.

The study also investigated that which combination of scaffolding maintains a higher level of flow. In both the studies, it was found that the flow state level of indirect support and adaptive fading group was significantly higher than direct support and adaptive fading group and direct support and gradual fading group.

The environment in which participants got indirect support was more challenging which in turn helped in making a more competitive environment. This competitive environment led to a higher level of engagement to solve the tasks in hand and thus reflected in the higher level of flow. Such competitive environment needs regular support to maintain the flow. That is why the flow level of ISAF group was statistically higher then DSAF and DSGF groups as they could ask for help anytime and for any number of mistakes. The adaptive fading (support based on performance) along with indirect support helped the participants in maintaining their flow level.

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