THE EFFECTIVENESS OF SIMULATION-BASED LEARNING FOR POLYTECHNIC LEVEL ENGINEERING STUDENTS

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ABSTRACT

Simulation-based learning (SBL) has been widely used and accepted in the industry (think aircraft simulation for example). In education, computer simulations have been used in a wide variety of context, ranging from collaborative learning and skill needs learning to supporting differentiated learning. This study investigates the outcome of using SBL in Machining Technology, an engineering based subject at the polytechnic level by looking at two aspects: student learning and their motivation to learn. It is hypothesised that SBL, which provides learners with interactive experiences, will enhance student learning and motivation in content-heavy subjects. In the study, students in the control group received conventional instructions and workshop practice while the experimental group had conventional instructions, SBL sessions, followed by workshop practice. Both groups receive an equal amount of time on the subject. A post intervention test followed by a survey based on a framework of self-determination theory (SDT) was administered at the end of the study. Although the equal variance t-test indicates that students using SBL as an augmentation tool obtain better results, it was found that the students themselves were mostly exhibiting introjected regulatory behaviour.

KEYWORDS

Simulation-based learning, machining technology, interactive digital media, motivation

INTRODUCTION

Studies have shown that students performed much better when they “learn by doing” compared to when they only read about the subject [1-4]. Interactive training in the form of computer based training, simulations, and virtual environments are often used in these "learning by doing" approaches. Recent advances in technology have made it possible to use such approaches at much lower costs as compared to actual product mock-ups, physical simulators and other non-digital approaches. A simulation environment closely resembles the physical system while allowing learners to explore situations not possible with the actual systems [5]. They are usually interactive visualisations which allow learners to change input variables by entering data or by manipulating visual objects to observe the consequences of these changes in the dynamic visualisations as well as in additional representations such as numeric displays, formulas or text labels.

In academic settings, simulation-based learning is used to enhance lectures, supplement laboratories, and to engage students. In the workplace, they are cost-effective training mechanisms. In engineering education at the tertiary level, the use of computer simulation to enhance student learning process and to enhance understanding has been well documented in a variety of contexts ranging from skill transfer, collaboration, to problem solving and performance [6-9]. However, there were fewer reports on testing the effectiveness of using simulation-based learning (SBL) for post secondary engineering education at the Polytechnic level. As most engineering education at this level is focused on practice-oriented learning and skill training to prepare for the future workforce, it is even more important to find out if such a tool could be used to enhance learning.

In seeking to provide an interactive environment in which students could be effective in their learning process, the following research questions were raised in this paper:

- Could the three-dimensional (3D) SBL technology help improve students' learning processes when compared to traditional classroom methods? How did it help?

- By accessing information in a variety of media formats and in an interactive fashion, could students make useful associations?

- Were students motivated by the experience?

- Which aspects of using SBL assisted in the learning process?

This paper will present findings from 2 instruments, mainly a post intervention test and a survey. Before embarking on this main study, a pilot study was conducted with a small sample of students. These were reported in Fang et al. [10] and Koh et al. [11]. Fang et al. reported that students using SBL were more focussed, exhibited self belief, and were competent in being able to handle tasks in the workshop. They also exhibited self regulatory behaviour and made use of cognitive strategy in their learning. Students attributed these behaviours to using the SBL software. An equal variances t-test at the .05 level was used to gauge if there was a statistical difference between the test score of the experimental and control group. With a degree of freedom at 56, t-value at 2.68 and p-value at .01, the t-test, $t(56) = 2.68$, $p=.01$ showed that there was indeed a significant difference, and that the experimental group using SBL seem to be doing better. A large effect size, $d=0.7$ indicated that SBL has a large impact on students' results. Koh et al. perceived that students using SBL experienced greater satisfaction of their basic psychological needs due to their exposure to SBL. Enhanced perceived needs satisfaction lead to higher self efficacy and intrinsic motivation, but reduced extrinsic motivation. It was reflected that students' perceived satisfaction to be highest for competence, followed by relatedness and lastly autonomy support. Koh et al. noted that there was low internal consistency obtained for the extrinsic motivation subscale. Unlike intrinsic motivation, extrinsic motivation tends to be multifaceted, and exists as a continuum ranging from external regulation (most controlled) to identified regulation (most autonomous). In the reports, the outcome of the pilot showed that SBL has a positive effect on students' learning as well as motivation. However, it was recommended that instruments used in the survey must be modified to include the subscales related to extrinsic motivation.

Other literature such as Bodemer [12], highlighted that in order to benefit from interactive simulations, students must have the necessary prior knowledge to maximise benefit from the complex visualisation. Students who do not know enough about the domain area have problems processing the simulation and interacting with them in a goal-oriented way [13-14]. Hence there is a need to provide a preliminary mental framework whereby a mental model connecting the simulation to the physical system is introduced.

METHOD

This study was based on Machining Technology, a year two subject of the 3 year Mechatronics diploma. In this subject, students learn the fundamentals of machining, including the features, functionality, operations and processes that they can perform. Course instructors often observed that students have difficulties using machines such as the lathe, milling, sheet metal bending and shearing machines. One reason could be that they were intimidated by the complexity and size of the machine. Secondly, they may not be able to remember the functionality and specific use of machines itself. It was felt that the introduction of interactive 3D machine simulations could augment student learning by enhancing confidence and their mastery of the required knowledge and skills. The interactive 3D simulations were then built from scratch to cater to the unique requirements of the subject. There would be introductory modules for exploring the various machines and their components, modules for rehearsal of individual machine operations, modules which allow combination of different machine operations as well as modules for assessment.

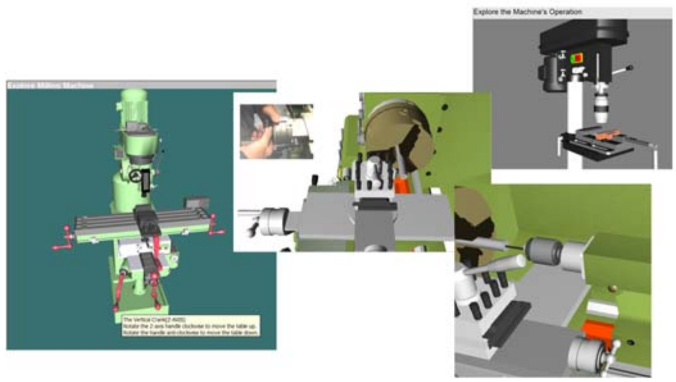

Figure 1. Screen captures of SBL modules

Research Hypothesis

Polytechnic level students studying Machining Technology using Simulation-Based Learning (SBL) as an augmentation tool (Experimental Group) will demonstrate significantly better content assimilation and retention, develop more extensive mental models and experience greater learning motivation as measured by quantitative results from a written assessment and an analysis of students' replies to a survey question when compared to those students using traditional learning strategies (Control Group).

Participants

Table 1
T-test results of the CGPA scores for Group C and Group E students

	M **($\bar{x}$)**	**SD** **(σ)**	**t-test *** **(df = 119, p < 0.05)**
Group C (n=49)	2.88	.88	*t = 1.81* *p= .12* *d=.29* Not Significant
Group E (n=72)	3.14	.91	
*assumption on equal variances tested			

Participants in this study were 17-37 year old students (average age 21.12 year) attending the Mechatronics Engineering course in Temasek Polytechnic. The sample of 121 students (91 male, 30 female) were drawn from the same pool that is, students who passed the common year 1 examinations. The students were further broken down into two groups, a control group (C Group) consisting of 49 students (36 male, 13 female) and an experimental group (E Group), consisting of 72 students (55 Male, 17 female). An equal variances t-test, carried out to assess the equivalence of the groups in terms of academic ability, showed no statistically reliable difference between the mean Cumulative Grade Point Average (CGPA) scores between the Control (C) and Experimental (E) Group students, $t(119) = 1.57, p = .12, d = .29$

Intervention Procedure

The intervention was conducted over a period of 6 weeks. Whilst the C Group goes through the normal route of lecture and workshop activities, the E Group has to attend a lecture, laboratory and workshop. The number of hours the student undertake were similarly capped at 24 hours (4 hours per week). Whereas the C Group students undergo a 2-hour lecture, followed by a 2-hour workshop, the E Group spent 1.5 hours at lecture, .5 hour at a laboratory using SBL, followed by two hours of workshop. Both groups visited the workshop in Week 1 to allow them to form connections and establish some prior knowledge between their workshop practices and their theoretical studies as recommended by literature [12].

A combination of a post intervention test and a survey questionnaire was used. The post intervention test was conducted for both groups in Week 7, followed by a survey. The test was designed by a domain expert to ensure that students understand how a simple part could be manufactured from a combination of machine procedures in the workshop. The test was marked “blind” by the same domain expert.

The survey was adapted from a framework based on self-determination theory (SDT), to understand students’ motivation when they use the SBL modules and also from Pintrich & De Groot [15] to understand the cognitive strategies used by the student. The survey consists of 47 five-point Likert based items which were posed to all the students from the C and E Groups. The items were scored based on a 5 point Likert-type scale ranging from 1 (strongly disagree) to 5 (strongly agree). The learning subscales are: self efficacy, self regulation and cognitive strategy use. The psychological needs subscales are: perceived autonomy, perceived competence and relatedness. The motivation subscales are intrinsic motivation, external regulation, introjected regulation, identified regulation and Amotivation. Table 2 shows the details.

Table 2
Survey Subscales

Subscales	**Items**	**Adapted from:**
Self efficacy	6	Self Efficacy Scale (GSE) [16]
Perceived autonomy	5	Learning Climate Questionnaire [17]
Perceived competence	5	Intrinsic Motivation Inventory [18]
Relatedness	3	Intrinsic Motivation Inventory [18]
Intrinsic motivation	5	Academic Self-Regulation Questionnaire [19]
Self regulation	4	Self Regulated Learning [15]
Cognitive strategy use	8	Self Regulated Learning [15]
Extrinsic motivation :		Academic Self Regulation Questionnaire [19], Modified Harter’s [20] Scale for measure of individual differences in motivation [21]
- External Regulation	2	
- Introjected Regulation	2	
- Identified Regulation	4	
- Amotivation	3	

Additional clarifications were sought from students through informal conversations to add further dimension into interpreting the survey feedback. A total of 15 additional students were involved in this process. This study also includes a qualitative portion which took into consideration the instructor's feedback, student interviews as well as video recordings of the student at work. The current paper discusses the post intervention test and survey outcomes, whereas the qualitative results will be presented in a forthcoming paper.

RESULTS

Post-Intervention Test

There were a total of 121 participants. An equal variances t-test, showed that there was a statistically reliable difference between the mean post intervention test scores of the Control (C) and Experimental (E) Group students, $t(119) = 2.48$, $p = .015$, $d = .46$ as indicated in Table 3. Group C students have a mean score of 3.42 compared to 4.60 in Group E. The effect size at .46 indicates that SBL has a medium effect on the result.

The Box Plot in figure 2 shows that the inter-quartile range (middle 50% of scores) in Group C students was bigger than Group E students (4.0 vs. 2.75). This indicated that Group E students have less variation in the understanding of the topic. The highest score in Group C is 9 compared to 10 for Group E. The lowest score is the same for both groups at 0. Group C students have a median score 3.0 compared to 4.5 in Group E.

Table 3
T-test results of Post Intervention Test for Group C and Group E students

	M ($\bar{x}$)	**SD** (σ)	**t-test *** (df = 119, p < 0.05)
Group C (n=49)	3.42	2.51	$t = 2.48$ $p = .015$ $d = .46$ Significant
Group E (n=72)	4.60	2.60	
*assumption on equal variances tested			

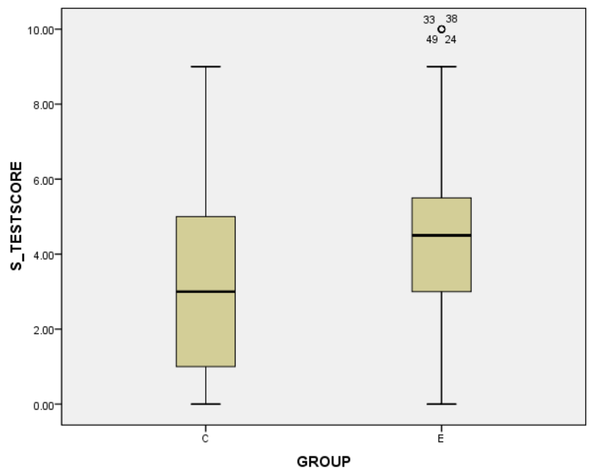

Figure 2. Box Plot of Post Intervention Test for Group C and Group E students

Survey

Likert Questions

There were a total of 114 respondents in the survey, 45 from the C Group and 69 from the E Group. A t-test showed that the overall scores for the E Group were not significantly different from those of the C Group. Further analysis of individual subscales (table 4) showed significant differences only in the perceived autonomy subscale $t(112)=2.40$, $p=.02$, $d = .46$. A comparison of the mean (M) and standard deviation (SD) between the C and E group is shown in table 4.

Table 4
Subscales Scores

	C Group		E Group		
Subscale	M_C	SD_C	M_E	SD_E	**Alpha**
Self Efficacy	3.67	0.55	3.78	0.57	0.76
Perceived Autonomy	3.85	0.46	3.58	0.65	0.76
Perceived Competence	3.74	0.72	3.82	0.64	0.86
Relatedness	3.50	0.81	3.58	0.71	0.78
Intrinsic Motivation	3.88	0.80	3.73	0.69	0.83
Self Regulation	3.26	0.64	3.42	0.71	0.75
Cognitive Strategy Use	3.67	0.44	3.62	0.61	0.79
External Regulation	2.71	0.90	2.54	0.99	0.60
Introjected Regulation	2.21	0.84	2.40	0.91	0.73
Identified Regulation	4.04	0.58	4.03	0.61	0.73
Amotivation	2.33	0.85	2.22	0.82	0.75

Cronbach's alpha, was used to assess the internal consistency of the components. This coefficient of reliability is used to gauge reliability of survey instruments. The results showed that all the components in the study were consistent (with a value of more than .7) except for external regulation which has a value of .60.

The questions on learning were taken from the self efficacy, self regulation and cognitive strategy use subscales. Table 4 shows that students in the E group perceived that they have higher self efficacy ($M_E=3.78$, $SD_E=.57$ vs $M_C=3.67$, $SD_C=.55$) and self regulation ($M_E=3.42$, $SD_E=.71$ vs $M_C=3.26$, $SD_C=.64$) but lower cognitive strategy use ($M_E=3.62$, $SD_E=.61$ vs $M_C=3.67$, $SD_C=.44$) in their learning.

Self efficacy is the belief that one can perform a novel task or cope with difficulty. Perceived self efficacy facilitates behaviour such as persistence, effort investment and self regulatory behaviour. Self regulation includes students' metacognitive strategies for planning, monitoring and modifying their cognition, as well as management and control of their effort on tasks. For example, this can be seen in how students plan/prepare for learning, stay engaged in their tasks and monitor their learning. Students use different cognitive approaches such as elaboration, rehearsal, and organizational strategies to help them learn, remember and understand. It was at first puzzling how students could perceive that they have higher self efficacy and self regulation but lower use of cognitive strategies in the learning. However, further analysis of the individual items in the cognitive strategy use subscale showed that although these students perceived that SBL helped them in connecting concepts (M_E=3.74, SD_E=.87 vs M_C=3.72, SD_C=.86) and enforce rehearsal (M_E =3.71, SD_E =.81 vs M_C =3.35, SD_C =.77), students perceived SBL to be harder to learn from (M_E =3.54, SD_E =.92 vs M_C=3.61, SD_C=1.11) as they had to tediously work through the tasks in the software. As the method was still new to them, E group students also felt less confident that the software can indeed replace their study material. This is shown throughout the various items on ease of learning (M_E=3.54, SD_E=.92 vs M_C=3.62, SD_C=1.11), communications (M_E=3.55, SD_E=.83 vs M_C=3.56, SD_C=.81), assessment (M_E=3.42, SD_E=.93 vs M_C=3.53, SD_C=.66), task recognition (M_E=3.75, SD_E=.93 vs M_C=4.00, SD_C=.52) and understanding (M_E=3.67, SD_E=.1.05 vs M_C=3.84, SD_C=.64), leading to a lower overall score. This is also consistent with feedback from students during the informal conversation sessions.

According to self determination theory [22], learner motivation is enhanced and becomes more self-determined when the three basic psychological needs for autonomy, competence and relatedness are satisfied. The results from table 4 showed that students in the E group perceived that they have less autonomy support (M_E=3.58, SD_E=.65 vs M_C=3.85, SD_C=.46) but higher levels of competence (M_E=3.82, SD_E=.64 vs M_C=3.74, SD_C=.72) and relatedness (M_E=3.58, SD_E=.71 vs M_C=3.50, SD_C=.81) compared to students in the C group.

Feelings of competence are important because they facilitate the students' goal attainment and provide a sense of satisfaction from engaging in an activity at which they feel effective. This is also consistent with Group E's response to self efficacy items where they show strong belief in their ability to handle difficult tasks. Here they draw satisfaction from their ability to complete an activity given to them. The need for relatedness is satisfied when students feel that they are accepted and valued by their peers and instructors within the learning environment.

According to SDT, students' perceive their need for autonomy support to be satisfied when they are granted an acceptable degree of volition and independence in their learning. In this study, students perceived that a number of their suggestions were discounted by the instructors. The situation arose because after going through the SBL modules, student felt that they could make some changes to the process. However, the instructor's view was that students should not deviate from safety procedures.

It appeared that students in the E group perceived that they were less intrinsically motivated compared to students in the C group (M_E=3.73, SD_E=.69 vs M_C=3.88, SD_C=.80). The items used assessed the students' interest, enjoyment, effort, and tension when learning. The reasons Group E students provided for giving a lower score were related to time pressure. Students in this group felt pressurised as they felt that they need more time to go through the exercises in the SBL modules. In the study, students from both the control and experimental groups were taught over a period of 24 hours, distributed over 6 weeks. Students also gave reasons such as the effort needed to "mine" information from the software.

In the various extrinsic motivation subscales used in the study, students in the E group perceived that they have a lower level of external regulation (M_E=2.54, SD_E=.99 vs M_C=2.71, SD_C=.90), identified regulation (M_E=4.03, SD_E=.61 vs M_C=4.04, SD_C=.58) and amotivation (M_E=2.22, SD_E=.82 vs M_C=2.33, SD_C=.85) but higher level of introjected regulation compared to their peers in the C group. Extrinsic motivation is perceived to exist as a continuum of increasingly self-determined behaviours [22], ranging from external regulation (least internalised) to identified regulation (most internalised). Internalisation leads to more autonomous behaviour.

External regulation is behaviour that is externally reinforced. Further analysis on the individual items in the external regulation subscale showed that students in the E group were not motivated by punishment (M_E =2.42, SD_E = 1.12 vs M_C =2.87, SD_C =1.15) but more by reward (M_E =2.67, SD_E = 1.17 vs M_C =2.52, SD_C =1.05). However, care should be taken when interpreting results from this subscale as it has a low alpha value of .6.

Introjection refers to behaviour that is prompted by guilt avoidance or ego enhancement. It was felt that students wanted to do well due to being part of the experiment so as to gain some imagined approval and they put pressure on themselves. This was consistent with their replies in the intrinsic motivation subscale where they perceived more tension and pressure and complained about having to "mine" for information. This finding is also consistent with Ryan & Deci [23], where it was found that introjected regulation was related to more anxiety and to poorer coping skills. It was also consistent with their feedback in the learning subscales where they feel less confident regarding being able to learn from the software although they perceive that they have higher self efficacy and self regulation.

Identified regulation refers to accepting values as personally important. The finding that E group students are less identified regulated is also consistent with them perceiving that they lean more towards introjected regulation.

Students are said to be amotived when their behaviour lacks intentionality and a sense of personal causation [23]. It results from not valuing an activity and not feeling competent and belief that the activity will not yield a desired outcome. Students in the E group are less amotivated compared to the C group. It was noted that students felt that the interactive aspect managed to arouse more interest than merely reading about the information on paper.

Correlation of Group E Subscales

Table 5 shows the correlations between the subscales used. Most of the subscales were significantly correlated at the .01 level. The three psychological needs, autonomy support, competence and relatedness were significantly correlated at the .01 level. Deci & Ryan [24] presented in cognitive evaluation theory that feelings of competence during learning can enhance intrinsic motivation for learning because they allow satisfaction of the basic psychological need for competence. They further specify that feelings of competence will not enhance intrinsic motivation unless accompanied by a sense of autonomy. This could explain why, despite having higher perceived competence and relatedness scores, students in the E group (having lower autonomy support scores) perceived that they have lower intrinsic motivation. Thus students must experience satisfaction of the needs of both competence and autonomy to achieve a high level of intrinsic motivation. In this study, there is a high correlation between perceived competence and self efficacy (r=.775), perceived competence and intrinsic motivation (r=.730).

In the learning subscales, self efficacy was positively correlated to cognitive strategy use (r=.413). Self regulation is also positively correlated to cognitive strategy use (r=.553), indicating that self efficacy and self regulatory behaviour affects how cognitive strategy were used by the students. Parallel to this finding, intrinsic motivation has a positive correlation with cognitive strategy use (r=.655).

Intrinsic motivation of Group E students have a moderate correlation to identified regulation (r=.622) and negative correlation with amotivation (r=-.581).

E group students have a higher introjected regulation score. Extrinsically motivated behaviours must initially be externally prompted, the reason students are likely to do the behaviours is that they are valued by significant others (eg. peers and instructors) to whom they feel connected. There is a positive correlation of introjected regulated behaviour to the subscale relatedness (r=.382). The higher scores of E group students in relatedness can be one reason used to explain why students lean towards introjected regulated behaviour. . Intrinsic motivation is also positively correlated to introjected regulation.

Table 5
Correlation matrix of Group E Students

	Self Efficacy	Perceived Autonomy	Perceived Competence	Related-ness	Intrinsic Motivation	Self Regulation	Cognitive Strategy Use	External Regulation	Introjected Regulation	Identified Regulation	Amotivat-ion
Self Efficacy	1.000										
Perceived Autonomy	.319**	1.000									
Perceived Competence	.775**	.416**	1.000								
Relatedness	.237*	.587**	.347**	1.000							
Intrinsic Motivation	.587**	.590**	.730**	.587**	1.000						
Self Regulation	.261*	.486**	.300*	.614**	.450**	1.000					
Cognitive Strategy Use	.413**	.679**	.671**	.548**	.655**	.553**	1.000				
External Regulation	-.039	.182	-.043	.123	.019	.187	.127	1.000			
Introjected Regulation	.072	.354**	.194	.382**	.320**	.319**	.337**	.608**	1.000		
Identified Regulation	.336**	.530**	.514**	.485**	.622**	.576**	.613**	.068	.226	1.000	
Amotivation	-.346**	-.295*	-.507**	-.243*	-.581**	-.151	-.390**	.272*	.040	-.437**	1.000

** Correlation is significant at the .01 level (2-tailed)
* Correlation is significant at the .05 level (2-tailed)

CONCLUDING DISCUSSIONS

Could the three-dimensional (3D) SBL technology help improve students' learning processes when compared to traditional classroom methods? How did it help?

The t-test showed that there was a significant difference in the mean post-intervention test scores obtained by students in the E and C group, with the E group having a higher mean. The effect size showed that SBL has a medium effect on the student result. The box plot showed that E group students' have a narrower inter-quartile range, indicating that they have less variation in their understanding of the subject.

Research in visual perception [25-27] suggests that if information provided to students is encoded both visually and semantically, then knowledge could be more efficiently constructed, retained and retrieved. Intense and passionate involvement resulting from interacting with activities that are well crafted and causally related leads to catharsis and hence promotes engagement. Other elements such as learning by doing, contextual activities, achieving goals by stages, exploration, testing and reflection, fantasy, enactment, practice and closure provides satisfaction, resulting in engagement.

Once the psychological needs of autonomy, competence and relatedness are met, it is believed that this would lead to increased intrinsic motivation, hence leading to behaviour such as self efficacy, self regulation and the use of cognitive strategies such as rehearsal, persistence, planning, goal setting and so on. In this study, although E group students perceived that they were competent and had higher scores in relatedness, they believed that they had less autonomy support. Correspondingly, this group of students had lower intrinsic motivation scores. The reasons given was that they had to work harder to retrieve information from the modules (compared to just reading it or getting it from notes), leading to insufficient time spent on the topics. Hence they felt less confident of that they will be able to do better than their peers.

The students' score in the learning subscales of self efficacy, self regulation and cognitive strategy use showed that Group E students had higher scores in their self efficacy and self regulation but weaker scores in the use of cognitive strategies. Again here, students found that SBL helped them by promoting some self regulatory behaviour through strategies embedded into the modules, such as reflection, assessment in a "safe" environment, planning, monitoring, hence improving their self efficacy and competence. However, low autonomy support, low intrinsic motivation lead to introjected related behaviour and low use of cognitive strategies. One possible direction of further improving the learning process is to highlight to students the different cognitive and self regulatory strategies available to them which they could use within or outside SBL. This could further help to boost their self efficacy beliefs and lead to the use of cognitive strategies. Hence, the teaching to students about different cognitive and self-regulator strategies may be important before the onset of SBL.

SBL may be highly interactive in that they allow students to see the dynamic consequence of entering different data or manipulating visual objects in a digital learning environment. The results have shown that it is possible to achieve an improvement in the learning but students have to self-regulate their learning behaviour in order to discover the underlying conceptual model which is assumed to lead to deeper domain knowledge. However, autonomy support is important and could cause difficulties in the learning process if absent.

By accessing information in a variety of media formats and in an interactive fashion, could students make useful associations?

Analysis of the individual items in the use of cognitive strategies showed that E group students were able to help them connect concepts and associations. However, they perceived that SBL is harder to learn from and perceived that they have not used many of the strategies. One reason could be that SBL often use multiple representations such as animation, video, audio, texts and symbolic representations. Students may not be able to systematically relate these multiple representations. As a result, they fail to integrate the representations into a coherent mental model, resulting in fragmented or disjointed knowledge structures. It is possible that dynamic visualisation may overburden the students' cognitive capabilities due to large amounts of continuously changing information. Could it be possible that in order to cope, students frequently make use of strategies that limits their processing to selected aspects of SBL?

Whilst the design of the SBL software modules could incorporate instructional design principles, perhaps it will also be useful to teach students the different cognitive and self-regulator strategies before the onset of SBL.

Were students motivated by the experience?

Students seem to produce better results but they do not feel that they enjoy the learning process and are not intrinsically motivated.

In contrast to literature findings, for example, Bryne [28], Lewis [29] and Osberg [30], enjoyment and interest leading to intrinsic motivation was not significant. Whereas Lewis carried out his experiment on children, Osberg's subjects were 15-18 year olds. Osberg noted that there was a maturation effect and the students' enthusiasm was noticeably less than in primary school students. This could be due to the fact that older students were more able to mentally visualise the concepts. The average age of the students in this study was 21.

E group students in this study mostly exhibit introjected regulation behaviour. Introjection connotes a formerly external regulation or value that has been internalised and is now enforced through internal pressures such as guilt, anxiety or related self esteem dynamics. According to SDT, a regulation that has been internalised may be only introjected, and that type of regulation could well leave students feeling satisfaction of their needs for competence and relatedness. However, to only introject a regulation and thus to be controlled by it will not leave the students feeling self-determined. SDT suggests that autonomy support is necessary to facilitate internalisation. This is similar to our research findings in that students perceived they are competent, relate to their peers and instructors, exhibit self regulatory behaviour and self efficacy, perceived they have less autonomy support and are not intrinsically motivated.

Such students could attribute their maladaptive coping skills to having insufficient time to do their work, having to "mine" for information, to instructors rushing them on their work and to instructors not giving them enough autonomy in the workshops.

Which aspects of using SBL assisted in the learning process?

Students in the survey felt that they were able to connect concepts between the virtual simulation and the physical machines as well as the operations the machine could perform. SBL allowed "rehearsal" and students were able to assess them in a "safe" space where they could afford to make "trial and error" mistakes without repercussions. These aspects promoted self regulation and self efficacy. SBL also promoted planning and organisation aspects of the learning as shown from the post intervention test results. The test assessed students on their ability to produce a process plan to produce a part requiring processes from different machines.

Students need to have both the "will" and the "skill" to be successful in the classrooms and there is a need to integrate these components in our models of classroom learning. Very often we seek to use technology to enhance the student "skill" and in so doing may have neglected the "will". The in-depth qualitative portion of the research will expand on the findings of this paper to reveal how students felt when they were learning using SBL and how they were able to cope with the new method of learning.

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