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A design software to facilitate learning via repeated practice by Chemical Engineering students

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ABSTRACT

A design software was developed within the paradigm of Technology Enhanced Learning (TEL) to facilitate learning via a repeated practice approach by Chemical Engineering students reading a core module called Fluid-Solid Systems. The software was developed to be able to generate detailed solution steps to typical engineering design problems encountered within this core module. Students were able to utilize the software to generate complete solutions to such problems for comparisons with their own hand calculations and thereby apply a repeated practice approach towards their learning of engineering design calculations. Highly favorable responses were received from students with regards to the utility of the software towards enhancing their abilities to apply the knowledge they had acquired in the module, engage in independent learning of the subject outside of formal classroom hours and understand concepts that were discussed during lectures and tutorials. Students who utilized the software more frequently throughout the semester performed better in the final examination. Interestingly, a minimum threshold in usage frequency of the software seemed to be necessary for the positive effect on performance in the final examination to be significant. As a TEL intervention to enhance students' learning via a repeated practice approach, this pedagogical intervention was deemed highly scalable to large class sizes and effective in overcoming constraints relating to limited classroom hours.

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1. Introduction

Undergraduate students pursuing Chemical Engineering at a 20 University are likely to be interested and proficient in Math-21 ematics, Physics and Chemistry at the high school level. In 22 Singapore, most students who decide to major in Chemical 23 Engineering would have acquired good knowledge of these 24 subjects and strong problem-solving skills through a rigorous 25 high school education which emphasized mastery learning 26 by a repeated practice approach. However, mastery learning 27 28 by repeated practice is usually not applied at the University 29 level due to various logistical constraints, educators' beliefs 30 and other factors. It is thus common to hear Chemical Engi-31 neering students commenting that more example problems

should be discussed in what are already very lengthy lectures 32 or more tutorial problems should be provided for practice. 33 Many Chemical Engineering students learn well by having 34 a teacher discuss many example problems during lectures, 35 solving many problems within each topic by themselves and 36 then having a tutor discuss the solutions to these problems in 37 details. Such an approach for teaching and learning may be 38 feasible at the high school level where each subject, such as 39 Physics or Chemistry, is taught over a span of two to three 40 years but is unlikely to be possible at the University level 41 where every module is taught over three to four months. Con-42 sequently, some of the best and brightest students who had 43 excellent mastery of Mathematics, Physics and Chemistry at 44 the high school level and who major in Chemical Engineering 45 at the University for their undergraduate education may not be 46 able to achieve their fullest potential in mastering the various 47 subjects in a typical Chemical Engineering curriculum. Q2 48

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In a recent review on the application of technology in engineering education, Deshpande and Huang (2011) concluded that simulation games have the potential to enhance transferability of academic knowledge and uplift engineering education. Philpot et al. (2005) developed two computer-based 53 games to facilitate engineering students to learn the sub-54 ject of Statics. Students rated the games as more effective 55 than the textbook for learning the subject and the authors 56 concluded that games are an effective teaching tool for fun-57 damental engineering topics that require repetition or practice 58

to master. Deliktas (2011) applied computer technology such as models, graphics, animations and interactive problems to enhance teaching and learning of an Engineering Mechanics course. The approach was found to be effective in enhancing higher order thinking, analytical thinking and reducing learning by rote. Llado and Sanchez (2011) developed an education software to assist their teaching of Dynamics to first-year engineering undergraduates. The software simulated the 3D movements of various components of a washing machine and students were able to explore the effects of different

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🣣 Рпе atic Transport (calculation) $\begin{array}{l} \begin{array}{l} \begin{array}{l} \begin{array}{l} \begin{array}{l} \text{Parsport (calculation)} \\ \hline Parside \ \ Size \ x=0.001000\ m \\ \hline Particle \ \ Size \ x=0.001000\ m \\ \hline Particle \ \ Density \ \ \rho_s=1.200\ \ kg/m^3 \\ \hline Particle \ \ Density \ \ \rho_s=2000.000\ \ kg/m^3 \\ \hline Particle \ \ Density \ \ \rho_s=2000.000\ \ kg/m^3 \\ \hline Particle \ \ Density \ \ \rho_s=2000.000\ \ kg/m^3 \\ \hline Particle \ \ Density \ \ \rho_s=2000.000\ \ kg/m^3 \\ \hline Particle \ \ Density \ \ \rho_s=2000.000\ \ kg/m^3 \\ \hline Particle \ \ Density \ \ \rho_s=2000.000\ \ kg/m^3 \\ \hline Particle \ \ Density \ \ \rho_s=2000.000\ \ kg/m^3 \\ \hline Particle \ \ Density \ \ \rho_s=2000.000\ \ kg/m^3 \\ \hline Particle \ \ Density \ \ \rho_s=2000.000\ \ m^s \\ \hline Particle \ \ Density \ \ \rho_s=20000\ \ m^s \\ \hline Particle \ \ Density \ \ \rho_s=20000\ \ m^s \\ \hline Particle \ \ Density \ Density \ \$ Total Pressure O Evaluate pressure drop Horizontal O Evaluate parameters O Evaluate pressure drop Vertical $\begin{array}{ccc} A & 0.007854 \\ \hline \\ Determining other parameters \\ \hline \\ To find void fraction \epsilon_{\rm H}: \\ U & = U \\ \end{array}$ Evaluate parameters O Evaluate pressure drop $U_{po} = \frac{U}{\epsilon_{oot}} - U_T$ From $\epsilon_{oottimuity}$, $G = \rho_p (1 - \epsilon_o) U_{po}$ (2) (1) Bends Substituting equations (1) and (2), $\epsilon_{\sigma}^{2}U_{T} - \left(U_{T} + U + \frac{G}{g_{\sigma}}\right)\epsilon_{\sigma} + U = 0$ O Evaluate parameters $\begin{array}{l} From \ graph, \ U_{\rm F} = 6.42444 \ m/s \\ Therefore, \ 6.42444\epsilon_{\rm e}^2 - 28.44212\epsilon_{\rm e} + 20.00000 = 0, \ \rightarrow \ \epsilon_{\rm v} = 0.9987 \end{array}$ O Evaluate pressure drop Validate Velocity To find actual particle velocity U_{pv} : _______G 35,367765 Choking Velocity $U_{pp} = \frac{G}{\rho_p (1 - \epsilon_p)} = \frac{35.307703}{(2000.000)(1 - 0.9987)} = 13.6016 \text{ m/s}$ O Saltation Velocity To find actual fluid velocity \mathbf{U}_{ff} : $U_{f\tau} = \frac{U}{\epsilon_{v}} = \frac{20.00000}{0.9987} = 20.02604 \text{ m/s}$ Terminal Velocity To find fluid friction factor fg : Show working From Colebrooke equation, $\frac{1}{\sqrt{f_s}} = -4.0 \log_{10} \left(\frac{e/D}{3.7} + \frac{1.256}{1.256} \right)$ Assuming smooth pipe, $e = 0 \rightarrow \frac{1}{\sqrt{f_s}} = -4.0 \log_{10} \left(\frac{Re\sqrt{f_s}}{Re\sqrt{f_s}} \right)$ $Re = \frac{\rho_f UD}{\mu} = \frac{1.200(20.0000)(0.100)}{0.00018} = 13333.3333$ O Show graph Substituting Re=133333.3333 and using trial and error, $f_g=0.00424$ A Pneumatic Transport (calculation) Parameters given Partiele Size x = 0.001000 mFluid Density $\rho_p = 1.200 \text{ kg/m}^3$ Partiele Density $\rho_p = 2000.000 \text{ kg/m}^3$ Viscosity $\mu = 0.000018 Pa \cdot s$ Fluid Superficial Velocity U = 20.00000 m/sPartiele Mass Flow Rate $M_p = 1000.0000 \text{ kg/h} = 0.277778 \text{ kg/s}$ Pinc Dicemeter D = 0.10000 mTotal Pressure 🔿 Evaluate pressure drop Particle Mass Flow Hate $M_p = 1000,0000 \ kg/h = 0.277778 \ kg/s$ Pipe Diameter $D = 0.10000 \ m$ Vertical Pipe Length $(Up) \ L_{s,town} = 0.000 \ m$ Vertical Pipe Length $(Down) \ L_{s,town} = 0.000 \ m$ Vertical Pipe Length $(Total) \ L_s = L_{s,uw} + L_{s,town} = 100,000 + 0.000 = 100,000 \ m$ Cross - sectional Area $A = \frac{\pi D^2}{4} = \frac{3.1416(0.10000)^2}{4} = 0.007854 \ m^2$ Mass Flux $G = \frac{M_p}{A} = \frac{0.2777478}{0.007854} = 35.367765 \ kg/(m^2 \cdot s)$ Horizontal O Evaluate parameters Evaluate pressure drop Vertical O Evaluate parameters $\frac{Parameters\ calculated}{Actual\ Fluid\ Velocity\ U_{fs}} = 20.02604\ m/s$ Evaluate pressure drop Actual Particle Velocity $U_{po} = 13.60160 \text{ m/s}$ Actual Particle Velocity $U_{po} = 13.60160 \text{ m/s}$ Void Fraction $\epsilon_H = 0.9987$ Fluid Friction Factor $f_g = 0.00424$ Bends O Evaluate parameters $\begin{array}{l} \hline Determining \ Pressure \ Drop \\ \hline Since \ mixture \ was \ already \ accelerated, \ (-\Delta p) = F_{fw} \ L_* + F_{pw} \ L_* + (-\Delta p)_{grov,f} \ + \ (-\Delta p)_{grov,f} \ + \$ Evaluate pressure drop
$$\begin{split} F_{fw} & L_{\rm e} = \frac{2 f_{\rm g} \rho_{f} U^2 L_{\rm e}}{D} = \frac{2 (0.00424) (1.200) (20.00000)^2 (100.000)}{0.10000} = 4070.51066 \ {\rm Pa} \\ F_{gw} & L_{\rm e} = 0.057 G L_{\rm e} \sqrt{\frac{g}{D}} = 0.057 (35.367765) (100.000) \sqrt{\frac{9.81}{0.10000}} = 1996.71912 \ {\rm Pa} \end{split}$$
Validate Velocity Choking Velocity $(-\Delta p)_{grov,p} = \rho_p (1-\epsilon_{\rm s}) g(L_{\rm s,up} - L_{\rm s,down} \) = 2000.000 (1-0.9987) (9.81) (100.000 - 0.000) \ = \ 1175.66948 \ {\rm Pa}$ Saltation Velocity $(-\Delta p)_{grav,f} = \rho_f(epsilon_v)g(L_{v,uv} - L_{v,down} \) = 1.200(0.9987)(9.81)(100.000 - 0.000) \ = \ 2550.86076 \ \mathrm{Pa}$ Terminal Velocity Therefore, $(-\Delta p) = 4070.51066 + 1996.71912 + 1175.66948 + 2550.86076 = 9793.7600$ Pa O Show working Show graph

Fig. 1 - Graphical User Interface of the design software developed to facilitate repeated practice by Chemical Engineering students.

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