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Knowledge transfer in engineering and technology education in universities

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ABSTRACT: Knowledge transfer between teachers and students determines the quality of teaching at university. Knowledge transfer includes the flow of knowledge from the teacher to students, and students' knowledge absorption and conversion to boost their own ability. Based on knowledge transfer theory, this article establishes a system dynamics model of knowledge transfer in engineering education. The article shows that the incentive and transfer threshold can improve the effect of teaching, and that knowledge innovation can encourage knowledge transfer. The article also advises universities to build a rational incentive mechanism and increase education funds to motivate knowledge transfer between teachers and students.

INTRODUCTION

It is important to study knowledge transfer strategy in university engineering education. Knowledge is a concept, a theory, a set of skills and an experience. Knowledge can flow and be disseminated like information. Teece first proposed the concept of knowledge transfer in 1977 [1]; thereafter, concepts of knowledge creation, transformation and utilisation were gradually produced. Davenport and Prusak pointed out that knowledge transfer included knowledge transmission and knowledge absorption, and successful knowledge transfer means that those receiving that knowledge understand it fully and are able to act accordingly [2].

Knowledge transfer takes several forms, such as individual to individual, individual to team and team to team. The formal type of knowledge transfer and knowledge sharing include education, training and mentoring [3][4]. The proportion of the various ways by which people get knowledge is shown in Figure 1. From Figure 1, it can be seen that people gain most of their knowledge from education, which amounts to over 80%. Engineering education in universities is important, but people must study at school to grasp the basic and core knowledge and improve their ability to adapt to social life and work, and acquire knowledge from work or other ways.

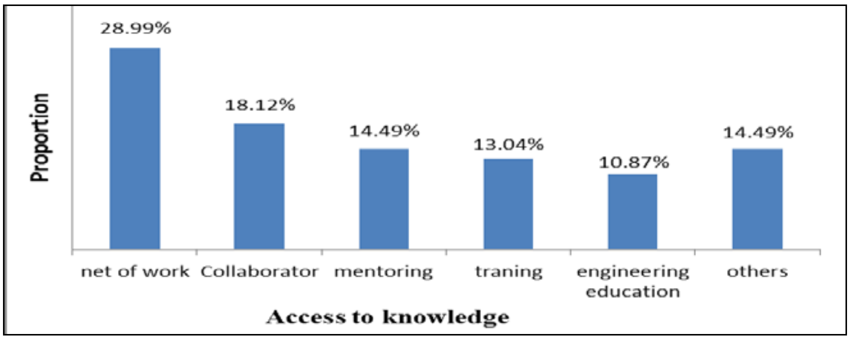

Figure 1: The proportion of various ways to access knowledge.

Universities are knowledge generation, systematisation and dissemination organisations, and knowledge comes from all university activities. It is the core element of that university, so effective knowledge transfer is the university's main task. Engineering education in universities is to convert a variety of educational resources into knowledge collection and provide knowledge management in order to achieve knowledge production, transfer, using and sharing [5-7].

Ever since they formed spontaneously in the 12th or 13th Centuries in Europe, universities have been a *knowledge hub* and their main purpose has been to impart knowledge. As knowledge holders, professors directly enrolled students and collected student tuition fees as their income, so teachers managed their own teaching and directly bore the responsibility of ineffective teaching. Poor teaching quality would decrease their income. Links between teachers within the university were relatively loose; Millett called this organisational model an *academic community*, this means a *dynamic consensus organisation* [8]. In this loose and pure academic community, teachers were also directly involved in the management of the university. It is obvious that there was democratic governance. From an economic perspective, the relationship between teachers and students can be seen as being typical of the principal-agent relationship, and evaluation of teaching quality and incentive mechanism was simple.

In modern society, universities were established by a range of organisations, particularly by governments. The subsidies or financial assistance provided by governments to set up the universities led to more and more complex tasks. It is generally believed that universities should undertake three functions: teaching, scholarly research and social services. It gave rise to administrative bodies, which were responsible for these tasks directly. Universities' power gradually became more concentrated. There were three main types of personnel: teachers, administrative staff and management decision-makers. Management analysed problems, evaluated various solutions and made decisions, and administrative staff execute those decisions [9]. Teachers are personnel for the dissemination of knowledge and realise the functions of university. However, because teachers only impart knowledge to students, other work, such as student management and financial management are undertaken by administrative staff. Students do not directly study with an individual teacher, but study within a discipline-based system at university. These important changes cut the link between teachers' work and students' knowledge learning effect. Assessing the quality of teaching and motivating knowledge transfer becomes a problem.

Recently research on knowledge transfer focuses mainly on the mechanisms of knowledge transfer and influencing factors [3][10]. At the same time, there are problems, such as a lack of systematic research, less quantitative research, and so on. For this article, cybernetics and system theory were used to build a system dynamics model of knowledge transfer in engineering teaching in universities. The knowledge transfer model was used to produce simulations, and these were analysed in order to study the knowledge transfer phenomenon and find the effective incentive mechanism to improve knowledge transfer in engineering education.

CAUSALITY ANALYSIS AND A SD MODEL OF KNOWLEDGE TRANSFER IN UNIVERSITIES

System dynamics (SD) is based on cybernetics with systematic feedback and relies primarily on computer simulation technology. It can be used to study the dynamic behaviour of a system quantitatively [11]. In fact, the knowledge transfer between teachers and students has clear boundaries and fixed patterns of interaction and feedback. Knowledge transfer follows the basic rules of education; and moreover, the overall amount of knowledge can increase with knowledge dissemination and transfer [12][13]. So knowledge transfer can be seen as an SD model.

Causal Analysis of Knowledge Transfer in Engineering Education

The model by which students acquire knowledge is shown in Figure 2. It can be seen that people can be divided into three types in the knowledge transfer in universities, which are teachers, students and management decision-makers. The management decision-makers evaluate the effect of knowledge transfer by investigating students' knowledge and innovation performance and, then, they create an incentive policy to motivate the knowledge transfer.

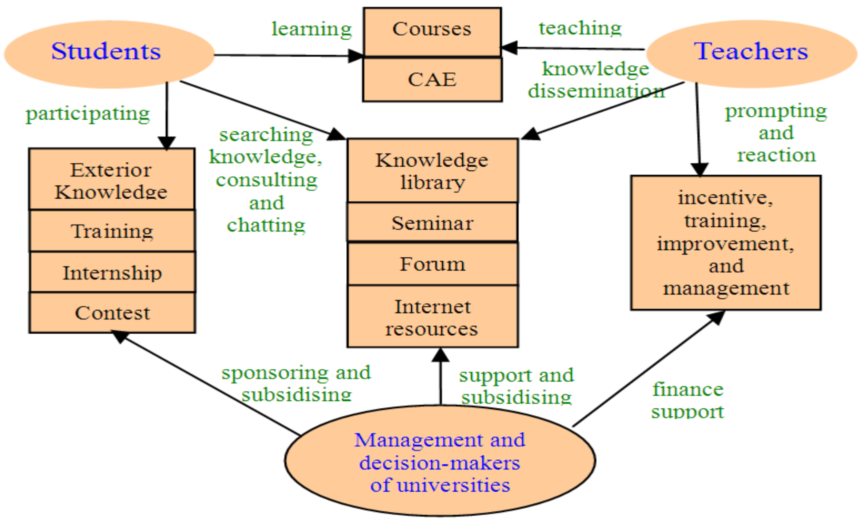

Figure 2: Model of knowledge transfer in universities.

Many factors have been found to affect knowledge transfer, including relationships, incentives, knowledge management systems, knowledge absorption ability, and so on. The knowledge growth of teachers is driven mainly by knowledge innovation and knowledge forgetting. The students' knowledge growth depends on three main factors: knowledge innovation, knowledge forgetting and knowledge transfer. Knowledge from the transfer process does not completely match the need of learners and absorption ability can affect knowledge transfer. Knowledge transfer is the premise and the basis of knowledge innovation.

There are seven main circuits in the causal diagram based on the above assumptions, which are listed as below:

1) Amount of knowledge of students $\rightarrow^{+}$ Correct rate of students' innovation $\rightarrow^{+}$ Amount of knowledge of students' innovation $\rightarrow^{+}$ Amount of knowledge of students; 2) Transfer threshold $\rightarrow^{+}$ Amount of knowledge transfer $\rightarrow^{+}$ Amount of knowledge of students; 3) Knowledge absorption ability of students $\rightarrow^{+}$ Amount of knowledge transfer $\rightarrow^{+}$ Amount of knowledge of students; 4) Knowledge oblivion of students $\rightarrow^{-}$ Amount of knowledge of students; 5) Knowledge gap between teachers and students $\rightarrow^{+}$ Amount of knowledge transfer $\rightarrow^{+}$ Amount of knowledge of students; 6) Amount of knowledge of teachers $\rightarrow^{+}$ Amount of knowledge transfer $\rightarrow^{+}$ Amount of knowledge of students; and 7) Amount of knowledge of teachers $\rightarrow^{+}$ Amount of knowledge of teachers' innovation $\rightarrow^{+}$ Amount of knowledge of teachers.

System Flow Diagram, Government Equations and Main Variables

In this system, there are two level variables (L), five flow variables (R), six auxiliary variables (A) and nine constants (C). In Figure 3, the system flow diagram of the SD model of knowledge transfer in engineering education in universities is shown.

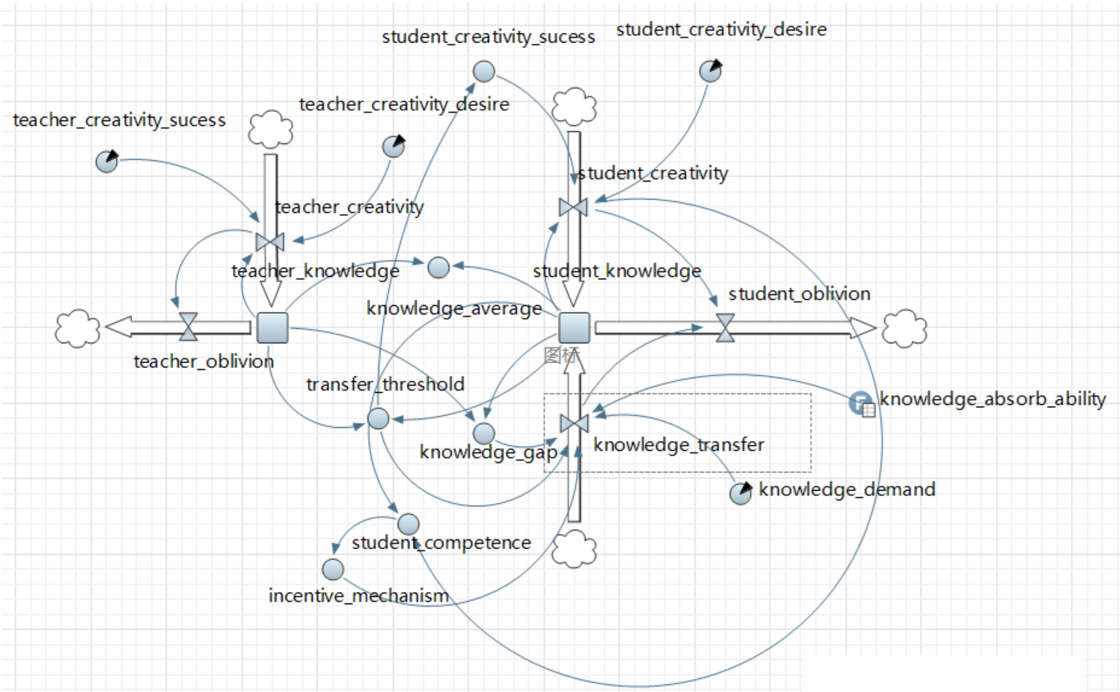

Figure 3: The system flow diagram of the SD model of knowledge transfer.

Government equations of the system, five flow variables and three important auxiliary variables are defined here:

L. Amount of knowledge of teachers = INTEG (*R. Amount of innovation knowledge of teachers* – *R. Amount of knowledge oblivion of teachers*, 100)

L. Amount of knowledge of students = INTEG (*R. Amount of innovation knowledge of students* – *R. Amount of knowledge oblivion of students* + *R. Amount of knowledge transfer*, 0)

R. Amount of innovation knowledge of teachers = *R. Amount of knowledge of teachers* × *R. Correct rate of innovation of teachers* × *C. Teachers' desire for innovation*

R. Amount of knowledge oblivion of teachers = STEP (0.1 × *R. Amount of innovation knowledge of teachers* + 0.25, 20)

Here the step function is used to simulate the process of knowledge forgetting. It is set that teachers begin forgetting knowledge from Step 20, to the end of simulation, the initial amount of knowledge will be forgotten with only remaining 25%. Teachers' forgetting rate of innovation knowledge is only 10%.

R. Amount of innovation knowledge of students = *R. Amount of knowledge of students* × *R. Correct rate of innovation of students* × *C. Students' desire for innovation*

R. Amount of knowledge oblivion of students = STEP (0.1 × *R. Amount of innovation knowledge of students* + 0.2× *R. Amount of knowledge transfer* + 0.2, 20)

R. Amount of knowledge transfer = DELAY1 [IF THEN ELSE (*A. Ratio of knowledge between teachers and students* < *A. Transfer threshold*, *C. Knowledge absorption capacity* × *C. Knowledge demand* × *A. Knowledge gap* × *A. Incentive mechanism*, 0), 3,0]

Here the article uses the delay1 function to simulate the amount of knowledge transfer. When the ratio of knowledge between teachers and students reaches the limit of transfer threshold, the teachers would not continue to transfer knowledge.

A. Average level of knowledge = *L. Amount of knowledge of teachers*/100 + *L. Amount of knowledge of students*/100

A. Knowledge gap = *L. Amount of knowledge of teachers* — *L. Amount of knowledge of students*

A. Ratio of knowledge between teachers and students = *L. Amount of knowledge of teachers*/*L. Amount of knowledge of students*

RESULTS OF SIMULATION AND SYSTEM OPTIMISM

Model simulation was undertaken using SD software. The initial value of knowledge of every teacher was set to 100, and the initial value of each student's knowledge was set to zero.

Validation of the Model

Validating the model has to be undertaken to verify whether the information and behaviour of the model reflects characteristics and variations in the actual knowledge transfer. In this article, the validating method of theory testing has been used [12][13]. Nine important time points were selected, which are shown in Table 1, and Figure 4 shows the simulation results of the model.

Table.1: The contrast of value of key variables in different time points.

Key variables	Values of key variables in different time points							
	1	5	10	20	30	50	80	100
A. Average level of knowledge	0.106	0.149	0.218	0.298	0.383	0.619	1.418	2.625
A. Knowledge gap	10.235	9.535	8.049	5	3.365	3.264	7.562	15.081
R. Amount of innovation knowledge of teachers	0.416	0.489	0.597	0.695	0.834	1.303	2.987	5.552
R. Amount of knowledge oblivion of teachers	0	0	0.39	0.404	0.425	0.495	0.748	1.133
R. Amount of innovation knowledge of students	0	0.012	0.063	0.176	0.293	0.527	1.206	2.206
R. Amount of knowledge oblivion of students	0	0	0.286	0.259	0.241	0.27	0.496	0.848

As can be seen from Figure 4: 1) *A. Average level of knowledge* is constantly rising and its growth gradually accelerates with knowledge transfer. The increase of amount of knowledge of students results in an increase of the transfer threshold and correct rate of innovation; furthermore, it promotes the students' knowledge in accelerated growth; 2) *A. Knowledge gap* shows an intermediate trend of reduction. In the initial stage, students just start to accumulate knowledge and their innovation is weak. It results in a short-term enlargement of the knowledge gap. When students increase their knowledge with the help of their agile minds and lower forgetting rate, the knowledge gap shrinks. When the knowledge of the students reaches a high level, the decreasing knowledge gap and transfer threshold reduces the amount of knowledge transfer. Only with increasing teacher innovation, the knowledge gap increases again and produces a spiral curve. Then, the knowledge of students rises to a high level; 3) *R. Amount of innovation knowledge of teachers* and *R. Amount of innovation knowledge of students* are in gradually accelerating growth and students have faster growth than teachers; and 4) *R. Amount of oblivion knowledge of teachers* is greater *than R. Amount of knowledge oblivion of students*. Teachers forget knowledge faster than students. Knowledge oblivion is a delay process. Teachers are busier than students, so they have a greater rate of knowledge oblivion than students.

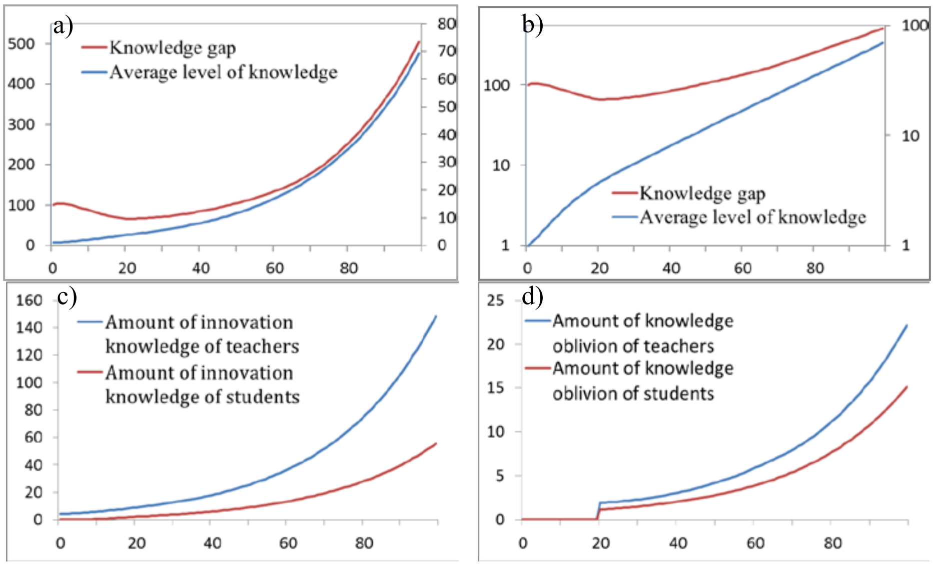

Figure 4: a) Curve of *A. Average level of knowledge* and *A. Knowledge gap* of in Linearity coordinates; b) Curve of *A. Average level of knowledge* and *A. Knowledge gap* of in Logarithm coordinates; c) Curve of *R. Amount of innovation knowledge of teachers* and *R. Amount of innovation knowledge of students*; d) Curve of *R. Amount of knowledge oblivion of teachers* and *R. Amount of knowledge oblivion of students*.

It is obvious that the SD model of knowledge transfer is consistent with the actual teaching in the simulation results. It also shows that the model can describe the real process of knowledge transfer within universities and can provide valuable reference information.

Parameters Optimisation and Sensitivity Analysis of System

Optimising parameters and system analysis is to change the parameters in the model and run the model to compare the output of the model and to provide policy advice [12][13]. In this model, two important parameters are changed for system analysis, which greatly influence the knowledge transfer. The two parameters are incentive and transfer threshold.

In parameter optimisation, the incentive coefficients are set to 0.1, 0.3, 0.5 and 0.7. The simulation results of different parameters are shown in Figure 5. As can be seen from Figure 5a, the greater the value of incentive, the greater the growth rate of the amount of knowledge of students. An incentive coefficient of 0.3 produces a significant improvement in contrast with incentive at 0.1. But the higher incentive in 0.5 and 0.7 cannot produce the obvious improvement on students' knowledge compared with 0.3. At the same time, it can be seen from Figure 5b that the greater the value of incentive, the lower the rate of increase of knowledge gap between teachers and students in knowledge transfer. When the value of incentive exceeds 0.3, the degree of reduction is relatively small. It can be concluded that the higher incentive can bring the more knowledge transfer, while incentive reaches a high level, the effect of promoting knowledge transfer is gradually weaken by continuing to improve incentive. Therefore, management and decision-makers of universities need to take other measures to improve the quality of teaching by improving incentive.

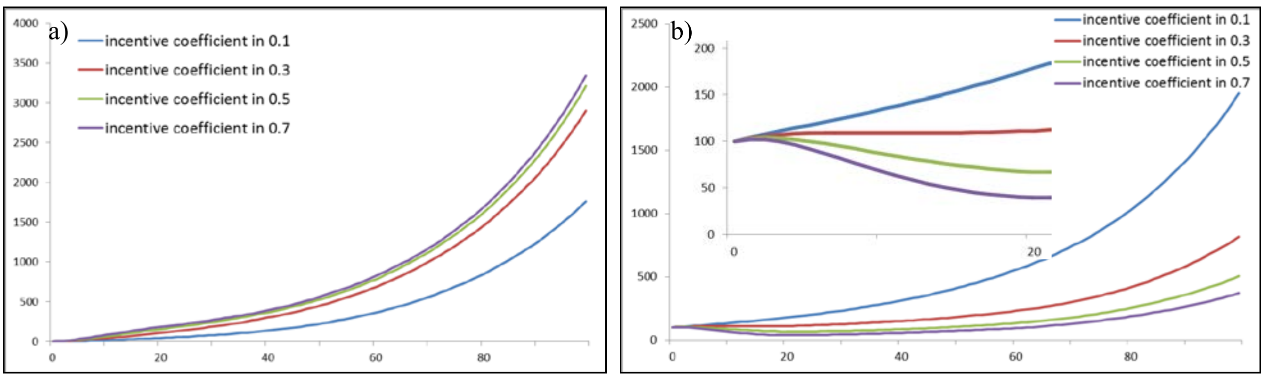

Figure 5: Sensitivity analysis of the knowledge transfer for incentive: a) Curve of *L. Amount of knowledge of students* in different incentive; b) Curve of *A. Knowledge gap* in different incentive.

Looking at parameter optimisation on transfer threshold, setting the transfer threshold to 0.9, 0.8, 0.7 and 0.6 in the government equation to obtain its influence on knowledge transfer was examined. The results of simulations are shown in Figure 6. With the increased transfer threshold, process of knowledge transfer is made more adequately, so the amount of students' knowledge would increase at a greater speed. This can be seen from Figure 6a and Figure 6b. In actual teaching, when the amount of students' knowledge is growing, the variable of *A. Ratio of knowledge between teachers and students* reaches the limit of transfer threshold. Then, because teachers need to maintain knowledge superiority, knowledge transfer would stop. When teachers' knowledge increases because of innovation, the knowledge gap would widen, and the *A. Ratio of knowledge between teachers and students* drops below the limit of transfer threshold. Therefore, the process of knowledge transfer starts again until the next stop. The curve of *A. Ratio of knowledge between teachers and students* has steady and regular fluctuations at the latter half, and the transfer threshold is smaller, the ratio reaches the *ceiling* sooner, which is as shown in Figure 6c. In order to improve the efficiency of knowledge transfer, teachers should be more open-minded and transfer more knowledge to students.

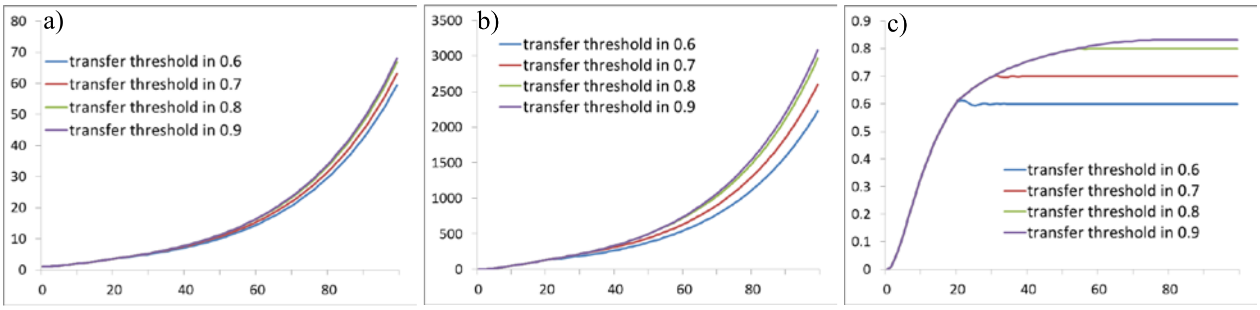

Figure 6: Sensitivity analysis of the knowledge transfer for transfer threshold: a) Curve of *A. Average level of knowledge* in different transfer threshold; b) Curve of *L. Amount of knowledge of students* in different transfer threshold; c) Curve of *A. Ratio of knowledge between teachers and students* in different transfer threshold.

CONCLUSIONS

This article is about knowledge transfer in engineering education in universities based on cybernetics and system dynamics. The article builds and simulates an SD model and, then, analyses some influential and important factors, such as incentive and transfer threshold. It is proposed in the article that those responsible for the management of universities should improve incentives and take other measures to improve teaching quality.

It is also advisable that teachers should be more open-minded to prompt knowledge transfer between teachers and students. The model corresponds to the actual knowledge transfer process in universities. It also shows the system dynamics method of knowledge transfer is valuable. The knowledge transfer on system dynamics can help in similar scopes.

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