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Knowledge integrated engineering design education

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ABSTRACT: The new knowledge and experiences acquired in engineering design educational courses offered at the University of West Bohemia, Pilsen, Czech Republic, are presented in this article. The educational process is based on a new approach to the educational process and a flexible systematic strategy of transfer, and the use of engineering design knowledge. The proposed educational models are open, interlinked, generally applicable and able to be integrated into a broad spectrum of engineering educational programmes. The compatibility of the models has been achieved by using a uniform terminology based on engineering design science. The other characteristics of the proposed models were achieved through the exploitation of a flexible systematic strategy. This new approach to the educational process ensures its further development and higher effectiveness, as well as confirming the transfer of the required knowledge into research and engineering practice.

INTRODUCTION

The enhancement of the flexibility and effectiveness of the educational process requires new educational approaches and knowledge, and their subsequent transfer to users. In order to fulfil this task, it is necessary to analyse the current state of engineering education. For this purpose, three hierarchical levels of the strategy for utilising the required engineering knowledge in the design process have been defined. These levels can be structured, very roughly, as follows:

- *Intuitive strategy* (level I): based mainly on previously acquired knowledge and experience.
- *Methodical strategy* (level II): based mostly on prescriptive or normative instructions. These are usually in the form of previously acquired summarised general knowledge, special theories and the practical experience of their authors.
- *Flexible systematic strategy* (level III): based mainly on a framework of structured knowledge – Engineering Design Science (EDS) – that is obtained by scientifically *mapping* both theory and practice [1].

Engineering knowledge can best be used in engineering design education, practice and research in the form of a system-*map* (level III). Even if not perfect, it can provide, in most instances, better controls to ensure the required course leading to the *goals*, and to maintain a *balance* between the *goals* of the educational process. This philosophy supports very effectively the necessary optimal transitions between systematic, methodical-empirical and intuitive ways of thinking (transitions III <=> II <=> I), which can be called knowledge integrated engineering design education.

INTUITIVE STRATEGY

The experienced engineer, teacher or student using this approach can spontaneously find a fairly useful solution. These solutions are usable, but hardly ever of optimal quality. The main reason for this is that the procedures used for evaluation and decisions about the best type of solution (partial or full) are again intuitive, ie again mostly very subjective (Figure 1). The process of finding a solution is usually very quick, but good solutions usually need considerable experience within the related field. Education and engineering design practice frequently tend towards these approaches, mostly due to their *user friendliness* and *effectiveness*, especially for talented, skilled and experienced designers and teachers in keeping with their creative activities, etc. This new knowledge and experience need only be complemented individually. Yet with regard to its entirety, compatibility and consistency, any knowledge system can be hardly checked.

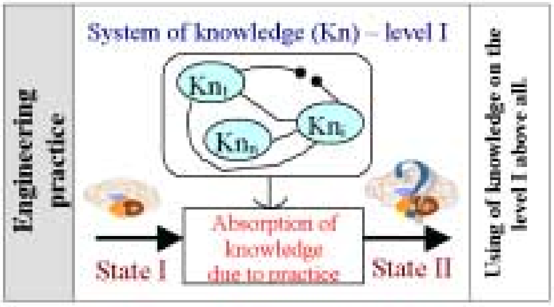

Figure 1: Intuitive use of knowledge in engineering practice.

METHODICAL-EMPIRICAL STRATEGY

The traditional methodical-empirical (or often, in fact, only mnemonic) approaches are favoured in engineering design education because they enable engineering design procedures to be explained more or less rationally. Students are often overloaded during the educational process with a huge quantity of information, mainly in the form of various instructions. They find it difficult to grasp what is important in the information obtained in this way, and are not able to find and understand the relationships between facts or even add and combine them.

If difficulties occur during engineering design, the use of rigid instructions becomes considerably problematic. In most cases, it leads to the return to level I and to attempts to solve the design problem intuitively. The probability of a successful solution on level II is generally higher than on level I. The design problems to be solved have to conform to the methodology available and to related tools. If unsuitable problems are solved, then the effectiveness of the achievement of the given aims falls considerably. Figure 2 shows a model of the educational process at level II, while Figure 3 illustrates the transfer of knowledge from the educational process to practice.

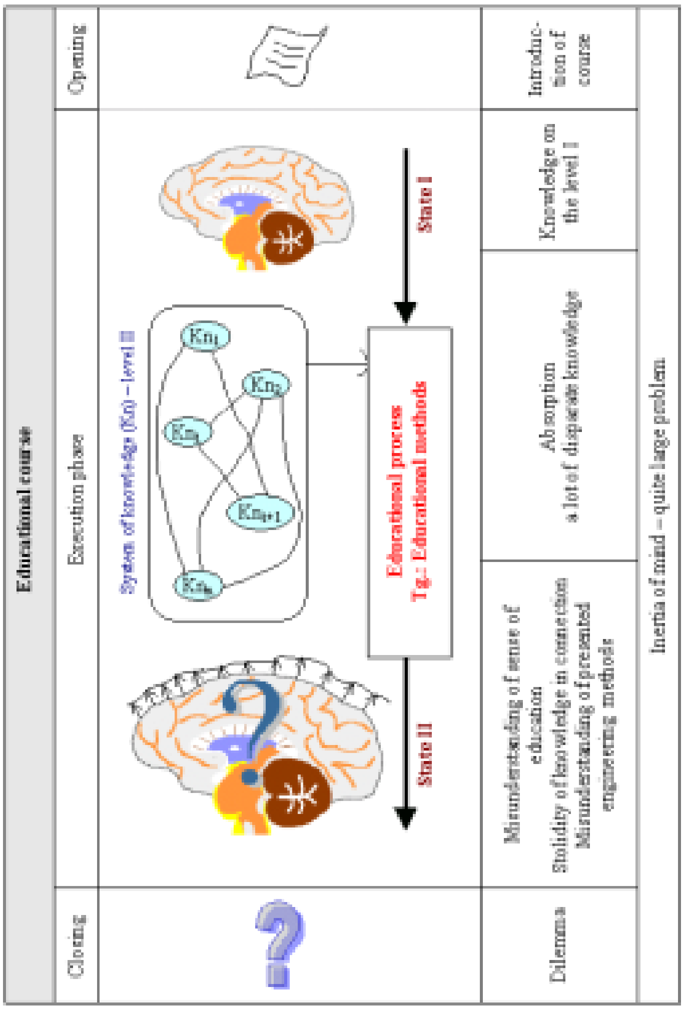

Figure 2: Model of the educational process at level II.

FLEXIBLE SYSTEMATIC STRATEGY

During the educational process realised at level III, it is necessary to provide students with a system of integrated and structured, both common and special, knowledge that is based on a uniform terminology. This terminology creates a unified interface among both the monodisciplinary and interdisciplinary pieces of knowledge. These facts are important for an efficient use of previously, as well as newly, obtained knowledge during problem-based education [2]. When problem solving, students can find the right solutions very quickly and efficiently due to the transparent links to the structured base of knowledge (level III). However, this does not mean that these solutions have to be optimal [3].

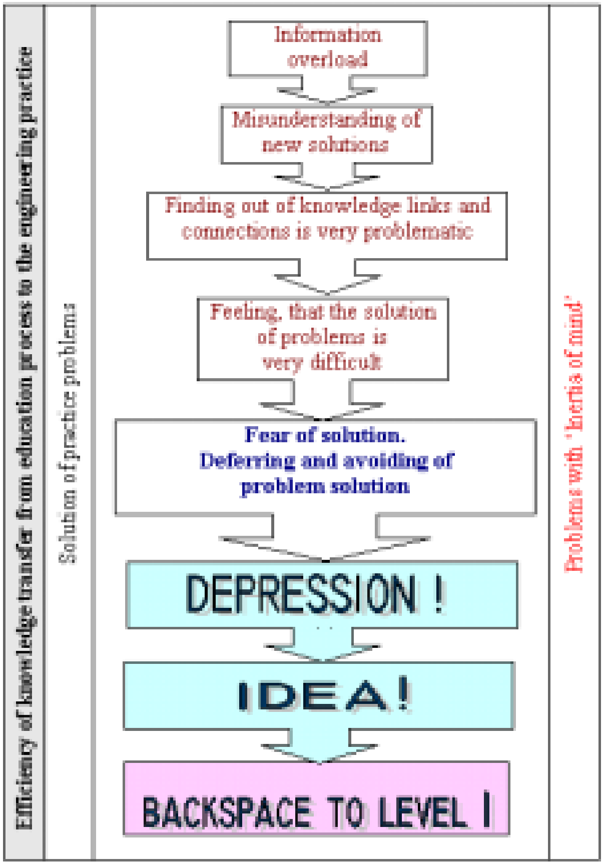

Figure 3: Transfer of knowledge from the educational process to practice.

ANALYSIS

The analysis proved that most students are aware of the considerable blocking of useful ideas using internal and external knowledge at level I. Despite this, many prefer this level due to its simplicity and tradition. Unfortunately, they refuse the other approaches (levels II and III), even without any familiarity and practice. The main reason for this is their previous education was carried out, at best, on a methodical level II. The strict assertion of these principles evokes, due to their rigidity and internal incompatibility, psychological barriers that prevent their use. On the other hand, methodical procedures themselves develop the talent and practical skills of students slowly – or may even repress them. From this, it follows that students confronting the knowledge acquired during their education find it insufficient or even useless.

Regrettably, this rather unfortunate situation persists and results in a gradual breaking of links between the educational system and engineering practice. The authors' experience gained in the education of undergraduates and PhD students in discussions with company representatives has confirmed this tendency. It has, therefore, become necessary to find new ways of introducing new concepts and procedures into the educational process and also into engineering practice (Figure 4). The most important and most difficult task was to balance the educational triangle (top of Figure 4), thereby creating better conditions for the establishment of strong and, at the same time, stable links between engineering education and practice. If this balance is achieved successfully, the conditions for balance of the triangle describing the state of engineering practice (bottom of Figure 4) will also improve. Then the regions represented by the triangle vertexes can also be more intensively developed.

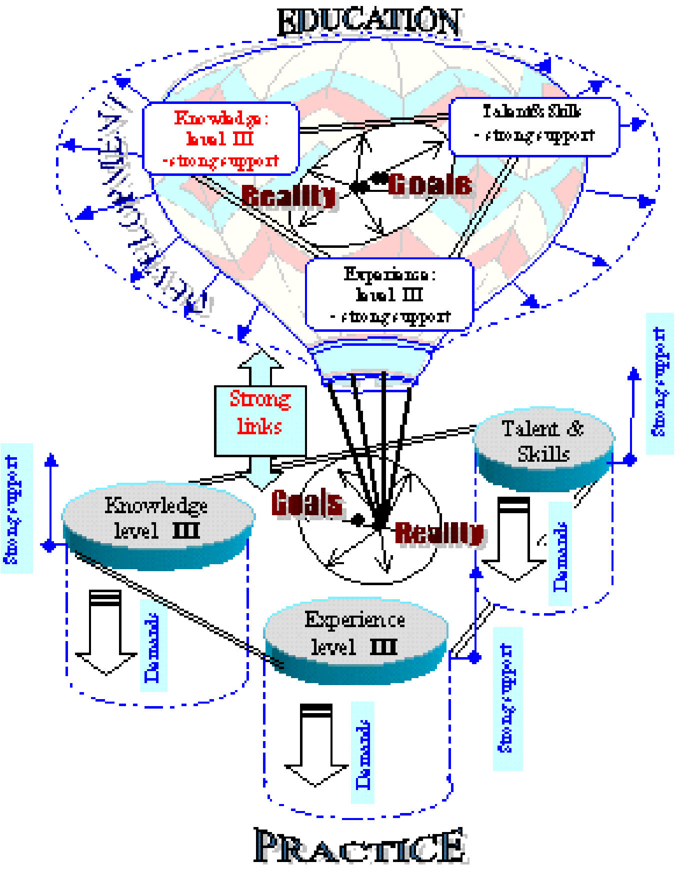

Figure 4: Education and practice at level III.

As such, it becomes necessary to bring the centre of gravity of the educational triangle (reality) closer to the geometrical centre of this triangle (goals) and the curve, which determines the region and represents the level of the educational process, degrades in the limit case to a point. At present, rigid approaches at level II are strongly criticised, and teachers, students and engineers find it difficult to distinguish substantial differences between levels II and III.

Under such circumstances, it is possible to achieve the relevant aims, only if industrial enterprises recognise the need to change the current state and make the required effort to change the educational processes and systems. This condition is currently being accomplished in manufacturing enterprises in the Czech Republic, namely because of the following factors:

- The absence of the generation continuity of workers and, as such, reduced levels of experience.
- The absence of know-how continuity in many new established enterprises.
- Insufficient and inefficient use of knowledge, including difficult transfers of information from very specialised disciplines, which in turn decreases product competitiveness.
- Additional modifications of products and manufacturing processes based on customers' experience of use, which may damage a company's reputation.
- The time and economically demanding nature of the processes taking place at level I.
- Difficulties in introducing the necessary knowledge, including methods at level II, into practice.
- Problematic multicriterial optimisation and evaluation of processes with regard to time, cost and product quality for the whole lifecycle of the technical product.

KNOWLEDGE INTEGRATED ENGINEERING DESIGN EDUCATION

The proposed concept of the new engineering design educational system is shown in Figure 5. The initial conditions for the implementation of this system are based on a previous concept (Figure 2). Above all, students exploit knowledge at level I, but have a considerable degree of aversion to level II approaches and transfer this aversion to level III. Under such circumstances, it is not possible to implement new approaches from the very start of the educational process. Students have to first become familiarised with the fundamental knowledge of constructional philosophy, but only cursorily without any force. In this way, they will only become acquainted with new approaches and nothing more should be expected from them.

From the very beginning, students solve real problems that are closely related to industrial needs. First, they are asked to solve these problems in a manner that is normal for them and is best in their opinion at that point. Due to limitations in the possibilities of finding acceptable solutions at their favourite level (level I), students are soon faced with problems that cannot be solved, or are very difficult to solve at this lowest level. This is the right moment to introduce the ample possibilities of solving given problems by utilising knowledge at level III because students now accept it as helpful.

The authors' experiences have proved that students tend to be very reserved and sceptical, often showing initial disapproval of new approaches that are forced on them in examining new ways to discover solutions. It is confirmed here that when new knowledge is not promoted as a broad fixed system only (level II), but rather as a flexible *road map* (level III), its acceptability grows with the growing number of cycles executed during problem solving. This results in a higher degree of flexibility and effectiveness of the work team and each team member. In this way, solving problems in a step-by-step manner develops naturally and spontaneously, with the dynamic knowledge base structured in a systematic fashion. Both teachers and students are able to orientate themselves in this knowledge base very well; they are able to look for and discover coherence of knowledge and they move naturally in both forward and backward directions. The terminological interface to the terminology of engineering design science develops simultaneously [4]. It is necessary for the transition of knowledge from the lower levels to level III, and vice versa.

The authors' practical experience confirms that problems of *mental inertia* become less important with the implementation of this new educational strategy. An important effect of the presented educational strategy is that students are able to transfer their knowledge into practice, thereby naturally building conditions for a gradual development of strong links between the educational system and industrial practice (see Figure 5).

Practical experience also confirms this; the introduction of new approaches also makes the problems of the mental inertia less significant than are those on the lower hierarchical levels. Investigations performed among graduates, both immediately after graduation and during their career in industrial practice, are proof of that. However, the introduction of new forms to continuous education of designers is demanding for lecturers and requires close cooperation with the management of industrial enterprises.

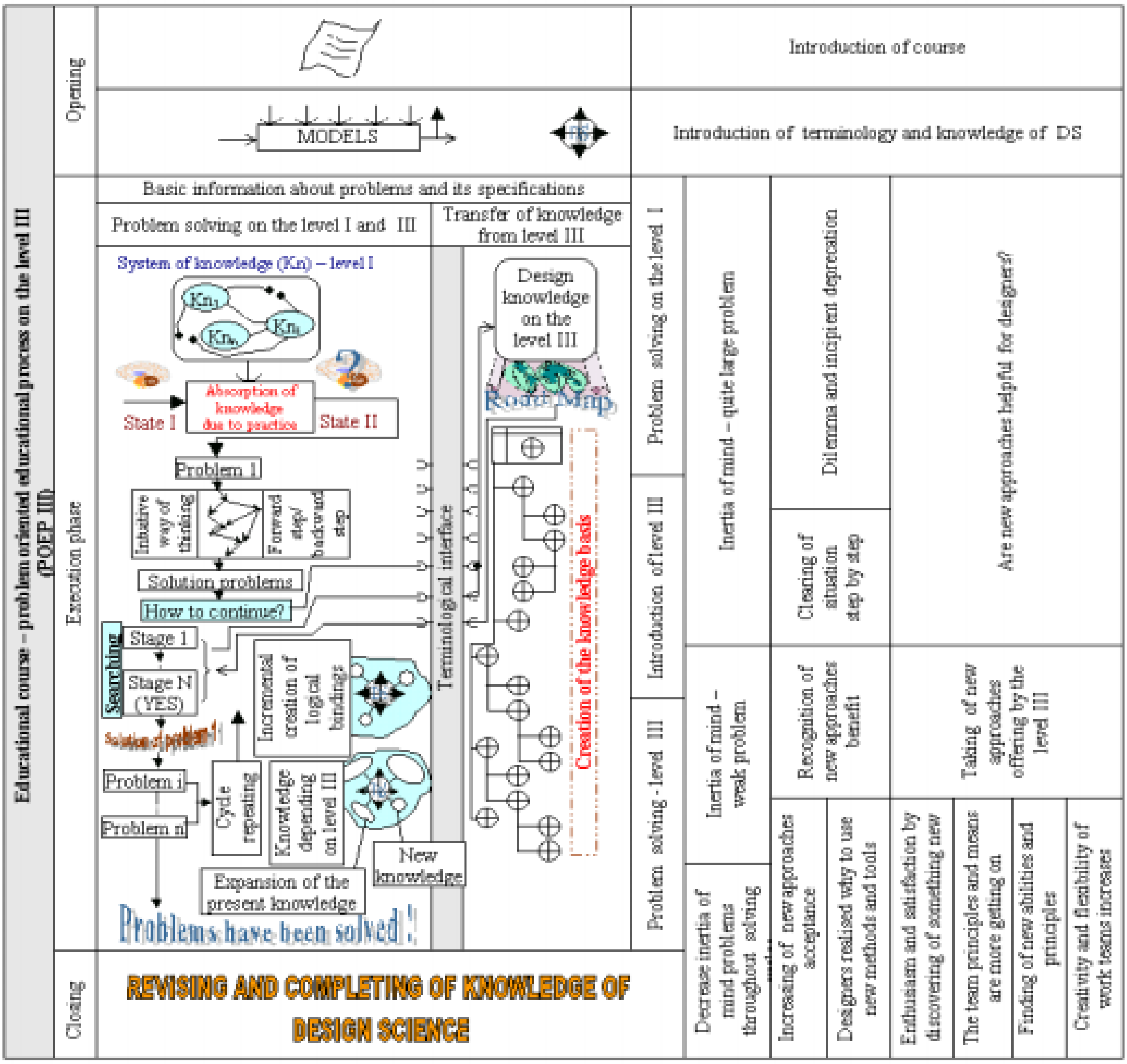

Figure 5: Knowledge integrated engineering design education - level III.

CONCLUSION

In conclusion, it is necessary to note that the new conception of engineering design education was successfully implemented in a series of courses in the Department of Machine Design at the University of West Bohemia, Pilsen, Czech Republic. Students' interest in a successful and efficient solution of many problems rose during their work on engineering design projects. Another positive result was the significant growth of technical knowledge gained and successfully used – both general and specific.

The efficient and effective transfer of knowledge was made possible by means of the new model of knowledge-integrated education with the support of a unified terminology interface. The new educational model was favourably accepted by local and foreign students.

Taking into account the authors' experiences and the positive feedback, it is believed that this flexible (non-rigid) systematic educational process can significantly help to overcome mutual incompatibilities in educational systems at both national and international levels, thereby contributing to the globalisation of engineering education.

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