Potential role of well-rounded case studies in engineering education

Peter Scharle
Széchenyi István University, Győr, Hungary
scharle@sze.hu

Abstract - **Educational levels classified in the Bologna paradigm can be described adequately with respect to their approaches to teaching common or advanced engineering models. Actually, regular post secondary courses can be conceived as introductions to the world of models, and to the model selection and application skills. Cognitive psychology offers a good conceptual framework for differentiating between BS and MS levels of knowledge and competency. The general considerations are similar for most of the professional fields (such as engineering, economics, architecture or law), therefore case studies have analogous roles and prove to be useful in all of them. However, significant differences may exist between fields of knowledge seemingly close to each other, too. Structural mechanics and geotechnics, for example, face many similar problems; nevertheless, case studies (should) have different roles and in their teaching should convey different messages. Recognizing and understanding these similarities and differences could help faculty and researchers to streamline their case studies presented worldwide in professional conferences and periodicals.**

Index Terms – BS and MS competency, modelling skill, streamlined case studies, civil engineering education levels.

INTRODUCTION

Case studies play significant roles in the different fields of engineering education, even if their selection and style of presentation may be highly influenced by the content and level of a course, its elaboration, aspects and thoroughness.

Textbooks, conference proceedings and websites offer a rich assortment of interesting professional case studies worth considering and incorporating into classes. However, the presentation of the problems involved, explanation of the considerations taken, and the conclusions are often poor. From the lecturer's perspective, the lack of questions raised and answers given in a case study can make it difficult, or even impossible, to use several case studies for educational purposes.

Analysis of hundreds of case studies results in a somewhat surprising experience: many of their authors are prolific and come from faculty ranks. Obviously, there are reasons why case studies written by academics have various faults, why they do not deal with essential issues, but in many cases it seems clear that simply the lack of attention or awareness results in unintended deficiencies. There is some hope that a closer scrutiny of the quality of case studies would help increase the didactic value and eliminate the weaknesses of many forthcoming reports and papers that would be worthwhile of presentation based on their subject.

To approach this goal, the paper starts with a short look at the Bologna-process, briefly outlines a framework of concepts taken from cognitive psychology [1], and proven to be useful for defining competency levels in engineering [2], then focuses the attention on the role and quality of case studies applied in engineering education, and concludes with some proposals. Instead of a brand new approach it presents a somewhat less trivial perspective.

REMARKS ON THE BOLOGNA PROCESS

By the end of the last millennium, European education policy makers arrived at the conclusion that the traditional higher education (HE) system has to be restructured. The Bologna declaration (1998) opened a new era where the linear structure of bachelor's (BS) and master's (MS) levels dominates. Nowadays 40-50 % of age groups enter BS (undergraduate) education and some 15% make a further step to the MS level. The system works, albeit diversity of courses, differences in requirements, impact of the declining secondary school performance have been and will continue to be discussed. In particular, the content of the professional subjects became less plausible, for at least four reasons:

- There is a conflict of interest between the dealers of the accumulated faculty knowledge and those of the actual industry needs.
- The market value of any knowledge is instable; there is a considerable time-lag between the waves of education supply and employment demand.
- Economic constraints drive HE institutions to attract as many students as possible with popular courses.
- By and large, secondary education seems to be unable to prepare its pupils for the competencies needed for traditional university entrance.

Since the main goal of restructuring is to make Europe more competitive globally *via* more practical knowledge of more people, educators, politicians and researchers are continually occupied with questions such as

- How long should BS and MS programs be when separated, or built together?
- Should there be different tracks of BS programs preparing students for employment versus preparing for graduate work?
- To what extent should BS programs prepare for MS programs in the basic sciences?

- What financial quotas should be allocated for BS and MS programs?

In this academic environment the clear identification of the BS and MS levels becomes more important then before, even in those cultures where the linear structure of HE is a tradition [3]. Additionally, there arise the questions of how the role of case studies must be reinterpreted, and how their content and presentation style could be developed to better support the practical side of academic education.

COMPETENCY IDENTIFICATION

Researchers exploring artificial intelligence have been for decades investigating the learning and experience building mechanisms that are typical for the learning and validation of a profession. They found that different levels of professional knowledge and preparation can be suitably described by the number and complexity of cognitive structures associated with each, as well as their organization. The system of these structures building on each other provides a good framework for a number of considerations regarding the mechanisms of cognition. Its basic concepts and considerations can be illustrated using *chess as an example* (explained in depth by Mérő [1]).

Chess players with their skill level rated through tournaments all see the same board. The moves of the pieces are governed by strict and unambiguous rules, the number of possible positions is large but finite. However, since the knowledge, experience, mental state and even the physical condition of the players are greatly varied, by using the conceptual framework of cognitive psychology we may distinguish characteristically different knowledge levels. Mérő highlights four of these.

The *beginner* is familiar with the rules and recognizes the possible moves in a given position. He is able to calculate the immediate consequences of his move, and whether it is to his advantage or detriment. He knows and uses a few dozen simple schemes.

An advanced, *second class* chess player is familiar with those low-degree-of-freedom positions (openings, endgames) in which the options of the players can be calculated, and applied as the result of calculations already done by others. The outcome of his matches in these simpler situations now depends more on his thus obtained knowledge than on judging each and every position. The number of schemes employed is a few hundred.

The *master candidate*, as a result of having played hundreds of matches and analyzed the games of others, is able to assess the middle game positions unfolding from openings. He is familiar with position improving options and recognizes similar or analogous precedents. Weighing these he manoeuvres to achieve a preferred (because familiar) endgame. The number of known and employed schemes is several thousand, a large percentage of which is complex.

The *grandmaster* also knows the strategic principles of manipulating games, he judges positions based on the opportunities of folding one into another. He sees the possibilities for improvement and damage (for example, he may give up or offer a draw when the positions are still confusing for a beginner or advanced player). He formulates strategic plans that encompass entire games, utilizing several tens of thousand simpler or more complex schemes that are embedded in one another.

The players perceive or comprehend the positions in the patterns and schemes they understand. They weigh their options over the collection of these. The grandmaster does not necessarily figure out more moves and combinations in a more complicated middle-game, but he is able to judge with greater certainty when such actions are truly required. Sometimes he will make a fast move precisely because he can see considerably fewer reasonable moves than a beginner. The application of certain complex schemes well known at more advanced levels may become obvious to the lower-rated player if a detailed explanation is given. However, he would not be able to judge its applicability in other instances.

The measurable differentiation between chess playing competence levels is an important starting point for cognitive psychology. The classification, in an analogous sense, can be transferred to very different fields from medicine to the command of a language. By and large, the master candidate level, for example, can be equated to a traditional European university degree that encompasses the BS and MS levels.

Naturally, levels of professional competency must be qualified more comprehensively in the cases of more complex knowledge bases and professional paradigms. At different levels, besides the number of cognitive schemes, their quality (simple or complex, common or professional character), the handling of problems, the jargon, and the extent of consciousness of thinking can vary from profession to profession.

In most instances, however, four levels introduced through the example of chess can be characteristically applied for a great variety of professions. Small differences can naturally result from the nature of individual professions' paradigms and their stability (thus it may matter whether a profession's interrelatedness and models are rooted in the deterministic laws of nature, statistical economic principles, or in man-made laws that reflect societal conditions). The number of competency levels worthy of distinction may also vary by professional fields. For example, architecture studies are difficult, indeed, to split into two levels, since they prepare for artistry. Jurists opposing graded education of law may be right, as well, but for a different reason: their 10 semester long curriculum results in a BS level competence (acquisition of artificial concepts and simple legal models used in this profession takes a longer term than needed in natural sciences).

However, the road leading to knowing the rich collection of complex schemes and to using professional and everyday language adequately and at a high level can be recognized even in such particular fields as architecture or law. And case studies can serve education at all stages and in almost any profession.

LEVELS OF ENGINEERING COMPETENCY

In the case of professional engineering knowledge, a whole group of concepts parallel the chess concepts of position, analysis and move in terms of a problem. In this group belong, among others the

- observation, recognition, understanding, and anticipation of the phenomenon, situation, and process;
- recognition and description of tasks related to the progression;
- identification and analysis of the necessary and possible interventions;
- clarification and handling of expectable consequences;
- determination and technical execution of intervention steps.

For the technical "jargon" *model* is probably the most expressive one among the common expressions such as outline, script, model, pattern, sample, and prototype that are analogous with the concept of scheme and are also used by professional languages.

The definition of model in this regard is very broad. It may consist of simple elements; it can be elementary or complex. It also encompasses all mathematical, physical, technological and material-tectonic relationships that approximate reality and its behaviour to an (in the given circumstances acceptable) extent. The application of the model may consist of simple steps, or form a closely related sequence of steps.

From this perspective *the essence of higher education in the engineering fields is the introduction of technical models of phenomena and processes*. The curriculum includes theories and relations that more or less describe reality, explores the validity and applicability of these models, and discusses the prerequisites, methods and steps of application. Simpler or more complex models can describe simpler or more complex facts or events. A well-educated professional is familiar with the most common and important phenomena, s/he knows the relevant models, and is able to select and apply them properly to solve a particular technical problem. Case studies serve as common and important tools to establish these engineering competencies.

At this point it is sensible to differentiate between levels of professional expertise from the perspective of their relationship to this *inventory of models* in light of the considerations outlined earlier. It is probably not possible to assign one "natural" classification. However, it proves practicable to accept a four-level classification system of *apprentice*, bachelor, master, and *doctor* [1].

The significance of differentiating between these levels lies in their relationship to recognizing phenomena and processes, and to the models used for their understanding and intervention. Without striving for completeness, the BS and MS levels are described by competencies as follows:

Bachelor – BS

- Recognizes frequently occurring facts and events.
- Is familiar with the profession's simpler models and their application.
- Correctly selects the models that can be applied for simple phenomena.
- Is able to involve the apprentice in model application by creating simple subtasks.
- Understands and executes the master's instructions.

Master – MS

- Recognizes phenomena and correctly appraises their complexity.
- Knows the profession's inventory of models and the prerequisites and limitations of their applicability.
- Is able to cooperate with masters of other fields in the solution of a complex problem.
- Is able to select the optimal model to solve a particular problem.
- Grasps the complete process of intervention, and in particular steps is able to incorporate the expertise of the apprentice and bachelor according to their skills.
- Recognizes phenomena that require the further development of the model inventory, understands the way doctors think, and can utilize their recommendations.

ROLE AND EDUCATIONAL POTENTIAL OF CASE STUDIES

For engineers, as a rule, it is almost impossible to possess all abilities listed for the BS and MS level without a shorter or longer experience in practice. Nevertheless, during the HE term, case studies are at hand to illustrate all points and arguments of the subjects engaged with model creation and application. Moreover, analysis of case studies must be an indispensable part of engineering courses at both levels.

Through scrutinizing well-rounded case studies, undergraduates can better prepare themselves to

- recognize frequently occurring facts and events,
- select correctly the models that can be applied for simple phenomena,
- understand, and execute instructions given by a master.

Students of MS courses can accelerate and improve their development with case studies helping them to

- recognize and correctly appraise complex problems,
- select the optimal model to solve a particular problem,
- comprehend the complete process of intervention,
- understand the way doctors think, and utilize their recommendations.

This perception of case studies, of course, is neither a new development nor a consequence of the Bologna paradigm. Yet, it seems to be stressed, as did a report released by the US National Academy of Engineering recently [3].

Obviously, adaptability and efficiency of a case study can highly depend on many conditions:

- Cases can be presented either as narrative descriptions or instructive explanations. The first alternative works well for BSc students, the second one for MS students.
- Hegemony interests and to-be-protected employment positions can distort correct narrative descriptions or instructive explanations.
- Many case studies convey very simple business messages ("look how interesting is the problem we have solved", "we are skilled masters of our technology", "you can trust us to fulfil all your demands"). Others reflect admitted or veiled prejudices about technologies or methods other than their own ones.

Even these types of case studies can help in stimulating the interest of the BS students in the subject, can give impetus for the MS student to think about the case itself but have a low value for teaching or learning. There is a general interest in increasing the number and improving the quality of case studies edited and written with attention to educational demands.

EDUCATIONAL QUALITY OF CASE STUDIES

From the point of view of her or his purposes, the teacher has to scrutinize a case study whether it contributes to the course performance effectively or even might be obscure.

Efficient engineering case studies are characterized with features such as:

- correspondence between the problem or phenomenon and the model is controlled and straightforward;
- essential data of geometry, materials, constraints, impacts etc. are illustrated properly and quantitatively for understanding the problem;
- material characteristics and assumptions (linearity, time-dependency, etc.) are clearly explained;
- kinematics of the engineering behaviour (both expected, and observed) is commented as clearly as possible;
- applied computational methods are described explicitly, with their assumptions and essential characteristic;
- failures, mistakes made in selecting and applying adequate models are considered and discussed openly.

Many case studies do not correspond with these demands. A lot of papers appear in professional periodicals, conference proceedings and corporate PR folders or leaflets distributed at exhibitions with shortcomings such as:

- data of marginal importance are given ("the site was at a distance of 4 km northwards from the capital");
- information is unbalanced because of the primary competence or partial interest of the author;
- function, importance or attractiveness of the building involved in the case are stressed ("the runway was highly wanted by the regional industry");
- derived variables are used instead of physical state or material properties;
- statements are made about safety, economic evaluation or efficiency without comparison with other similar constructions or alternative solutions ("the method we had applied gave a sound solution to the problem");
- calculations are referred to inadequately ("displacements were computed with the finite element method"),
- inadequate illustrations are attached to the case (the street with a multi-storey glass and steel office complex is shown to demonstrate the successful action against settlements caused by a tunnelling shield passing beneath the building in the depth of 20 m; successful treatment of collapsible soils is illustrated with the view of the hotel protected).

Experienced case study writers and users can easily add further items to these lists (even sarcastic ones, remembering case studies written explicitly for doctors of the profession). At the same time, one has to know that only a few cases allow a perfect study with all the necessary features but without shortcomings.

Beside the general characteristics, there are particular points, too, depending on the subjects involved [4]. In civil engineering, for example, structural mechanics and geotechnics are closely related as professional fields (both of them are based on the sound knowledge of mechanics and material sciences). Yet,

- The structural engineer's goal is to find an optimal model (structural arrangement) for a function and find the best construction technology to realize it. Imagine a bridge where all efforts made by the constructors have to correspond with the demands raised by the most advanced dimensioning theory. Case studies provide examples of technology development serving the application of the best theories.
- Geotechnicians are more anxious about their models extended beyond the engineering structure to its surrounding. Imagine a tunnel or a dam where adequate assumptions about the interaction between structure and soil or rock are a part of the modelling lesson, but there is no way to gain enough information with regard the expectable kinematical behaviour of the latter one. This is why the proceedings of geotechnical conferences open so large a space for case studies: they pay more attention to explaining their modelling efforts.

Further debates and discussions can result in more consolidated comprehension and practice. Nevertheless, all points and examples seem to prove that the academic world has valuable reserves for creating and using better case studies in higher education.

CONCLUSIONS

Discussion of case studies must be an integrated part of engineering courses, both at the BS and MS levels. There are many case studies available in the professional literature for such purposes, but only a few of them are written and documented in a well-rounded and streamlined form for educational purposes. New features could be added to and faults should be eliminated from most of them.

Authors of case studies (often members of academic and research faculty) can improve the quality of their papers about cases with some effort and more attention if they are aware their own needs as users of such studies in higher education. Students of BS and MS courses would benefit from these efforts, too.

REFERENCES

[1] Mérő, L., *Ways of thinking. The limits of rational thought and artificial intelligence*, World Scientific, 1990

[2] Scharle, P., *Sustainable levels and attitudes in the higher education of engineering*, EESD 2004, CIMNE, p. 100, ISBN 84-95999-60-9,

[3] *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*, The National Academy of Sciences, National Academies Press, 2005

[4] Scharle, P., *Cognitive psychological structure of education and research in geotechnics*, Proceedings of the 16th ICSMGE, Osaka, 2005, 2157-2161