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Performance support system in higher engineering education – introduction and empirical validation

Slavi Stoyanov*
Open University of the Netherlands,
Educational Technology Expertise Centre,
PO Box 2960,
6401 DL Heerlen, The Netherland
Fax: +31 45 576 2893
E-mail: slavi.stoyanov@ou.nl
*Corresponding author

Piet Kommers
Faculty of Behavioural Sciences,
University of Twente,
PO Box 217,
7500 AE Enschede, The Netherlands
E-mail: p.a.m.kommers@gw.utwente.nl

Theo Bastiaens
Institut für Bildungswissenschaft und Medienforschung,
FernUniversität in Hagen,
Lehrgebiet Mediendidaktik,
Universitätsstr. 11/TGZ,
D-58084 Hagen, Germany
E-mail: theo.bastiaens@fernuni-hagen.de

Catalina Martínez Mediano
Faculty of Education,
National University of Distance Education,
Madrid 28040, Spain
E-mail: cmarme@edu.uned.es

Abstract:
The paper defines and empirically validates the concept of performance support system in higher engineering education. The validation of the concept is based upon two studies: a pilot and an experiment, on the effect of performance support system on achievements and attitudes of students. The experimental study confirmed the expectation that the performance support system produced significantly better results than the traditional method of teaching when achievements of students were compared. The analysis of the students' attitudes towards the method revealed that the operationalisation of support was better implemented in the performance support software application than performance.

Keywords:
learning adaptation; higher engineering education; learning to solve problems; performance support system.

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Biographical notes:
Slavi Stoyanov is an Assistant Professor at the Educational Technology Expertise Center of the Open University of the Netherlands. His current research interests include instructional design for e-learning, learning to solve ill-structured problems, cognitive mapping and individual differences in learning.

Piet Kommers is an Associate Professor in the Faculty of Behavioural Sciences at the University of Twente, The Netherlands. His specialties are media, education and communication.

Theo Bastiaens is a Professor of media didactic at the University in Hagen, Germany. His domains of expertise are didactic of e-learning, human resources development and instructional design.

Catalina Martínez Mediano is a Professor at the Faculty of Education of the Spanish National University for Distance Education (UNED). Her research interests include distance education, adult learning and programme evaluation.

1 Introduction

Determining the most effective and efficient conditions for supporting performance of the learners in higher education has always been considered by learning designers, curriculum developers and teachers as a one of the most important and challenging tasks (Spiro and Jehng, 1990; Brown, Collins and Duguid, 1996; Merrill, 2002; Ericsson, 2006; Van Merriënboer and Kirschner, 2007). While the consensus among experts on the role of performance support in higher education is increasing, there is a disagreement on what does performance support mean. Before exploring in-depth this issue, first, a more specific question should be addressed, namely, which learning outcomes performance is related to? Is it memorising of information, understanding of principles, applying rules, or acquiring of so called high-order cognitive skills (Spiro and Jehng, 1990; Brown, Collins and Duguid, 1996; Van Merriënboer and Kirschner, 2007). These types of learning outcomes require different types of instructional support. There is a tendency in the contemporary learning design paradigm for paying more attention to the higher levels of learning taxonomy. Some authors rather prefer to use the term problem solving rather than high-order cognitive skills (Jonassen, 2000, 2004; Merrill, 2002). They argue that the problem solving is conceptually more concrete, meaningful and comprehensive concept than high-order cognitive skills. Jonassen (2000) considers problem solving as one of the most important cognitive activities. According to Merrill (2002), involving learners in solving real-world problems is one of the first principles of instruction. Most of the studies on learning to solve problems have investigated well-defined, often artificial problems, rather than ill-structured, authentic problems. Ill-structured problems are the problems that students are more likely to face in future professional settings. However, directly confronting students, who do not have sufficient understanding of a particular domain, with ill-structured problems, can be detrimental for their learning if not an appropriate support is provided (Clark and Mayer, 2003; Renkle, 2005). In contrast, a simplification of the instructional arrangement for advanced learners may cause expertise reversal effect (Kaluga et al., 2003). Another issue related to learning to solve complex problem is that more attention is paid to the support for problem solving process, with the focus on problem solving phases, rather than to operational problem solving support, which emphasises on the use of concrete techniques and tools (Stoyanov and Kommers, 2006). The successful promotion of the idea of problem solving performance support depends very much upon the relevant operationalisation of this concept in practical instructional design solutions. A possible way to achieve this is to identify a similar and successful instructional approach in other professional domains and to apply it to higher education. Such an instructional approach with a growing popularity in technology-enhanced learning that brings a new perspective to supporting learning while performing complex tasks is the idea of Electronic Performance Support Systems (EPSS), which has established a stable tradition in business and industry training (Gery, 2002; Greenberg and Dickelman, 2002; Raybould, 2002). What are the characteristics of EPSS? What are the messages of this movement to higher education? What are the implications of introducing this concept to higher education? Which attributes of the concept can be directly implemented in education, which of them should be carefully interpreted before applied to education and which attributes should be abandon? These are the questions that Section 2 addresses.

2 Electronic Performance Support System – characteristics and functions

EPSS integrates conceptually and defines operationally performance, support and technology system. EPSS emerged as an attempt to address effectively and efficiently the issues with the traditional training. The traditional training has been considered as

1. 1 experienced outside the work context
2. focused on knowledge rather than doing
3. making application of skills problematic
4. being short in integrating different approaches from different domains to address real problems.

Another reason for the introduction of performance support systems in industry is what is happening in the work settings nowadays: people get overwhelmed with the need to learn and implement new products, and constantly changing processes, procedures, rules and requirements.

EPSS is considered as a reconceptualisation of both work and training environments. The idea of EPSS put together the worker, the learner and the work situation in an integrated whole. (Laffey, 1997). The shortest, but probably the most distinctive definition of EPSS is just-in-time, just-enough and just-at-the-point-of need computer support for an effective and efficient job performance. The essence of EPSS could be expressed with the following thought: with EPSS "people who do not know what they are doing can do it as if they did" (Gery, 2002, p.29). People do not need to spent time to develop in advance knowledge and skills, it is the interface and functionality of a performance support system that supports a worker to do the job. An EPSS is an integrated learning environment structured in a particular way to provide immediate access to the full range of information, advice, guidance and tools allowing for effective and efficient job performance. Some of the typical characteristics of an EPSS but not limited to are:

1. 1 it is computer-based
2. it is used on the job
3. the control is on the worker
4. it reduces the need for prior training
5. it allows adaptation for different level of knowledge and learning style
6. it can be easily updated. Most of the EPSS include

   - an advisory component
   - an information component
   - a training component
   - an user-interface component.

It is tempting to believe that the idea of EPSS, can be directly implemented in higher education curricula and instruction. However, there are theoretical assumptions and practical arrangements regarding EPSS that are not acceptable for higher education. The EPSS movement in industry defines performance as its primary concern, while learning is considered as the second important issue (Bastiaens et al., 1997; Gery, 2002). Focusing mainly on how to do something without reflecting on why it has to be done may hinder learning (Clark, 1992). Students need a theoretical framework within which to construct their knowledge. Emphasising on small chunks of information without showing any explicit relation to knowledge structures may prevent from drawing a whole picture of the issue and understand the principle behind it. The idea of putting entire learning locus of control on novices learners may create uncomfortable situation for them. There should be a gradual shift from external towards internal learning locus of control (learning locus of control scaffolding). Another concern is that too much reliance on technological tools may lead to loss in transferring of skills.

There could be some positive consequences of introducing the idea of EPSS in higher education but the concept needs further to be elaborated and adapted to address the specific goals and characteristics of higher education. Here are some of the features of EPSS that could be considered in higher education:

1. focus on active learning, acquisition and application of skills
2. the immense power of technology in addressing instructional issues
3. appropriate representation and filtering of learning resources
4. integrative approach for operationalising performance support.

The orientation to active learning, learning by doing and skilled performance is not new for higher education, but EPSS concept requires practical measures for their implementation. There is no doubt about the role of technology for an effective and efficient implementation of instructional design approaches, the question is how relevant the functionality and the interface of a particular technological tool is to reflect the instructional design approach implemented in it. Representing and filtering bring the attention to carefully selecting the content that is necessary for learning and finding the appropriate format for presenting it in order to avoid extraneous cognitive load (Van Merriënboer and Sweller, 2005). The idea of EPSS also forces instructional designers to undertake an integrative approach to existing theories in attempt to build up effective and efficient Performance Support Systems for Learning Purposes (PSSL). The instructional approaches such as Cognitive Apprenticeship approach (Brown, Collins and Duguid, 1996), Cognitive Flexibility theory (Spiro and Jehng, 1990), theory of Deliberate Practice (Ericsson, 2006), Four-Components Instructional Design Model (Van Merriënboer and Kirschner, 2007), Design Theory of Problem Solving (Jonassen, 2004) and Cognitive Load Theory (Van Merriënboer and Sweller, 2005) deal with some of the aspects of performance support but no one of them attempt to address comprehensively the whole spectrum of issues. The performance support instructional approach has to be constructed taking into account the achievements of these theories.

This paper introduces and empirically validates the concept of performance support systems in higher technological education exploring the following research question:
what is the effect of web-based performance support systems on learning achievements and attitudes of students in higher technological education? The first step in exploring this research question is to define operationally the concept of performance support system in education.

3 Performance support system in education

Performance support system is not completely strange concept for higher education, as it might be thought. A number of performance support systems is developed to facilitate mainly the group of university instructors coupling their domain-specific expertise with instructional design and curriculum development support. (Gettman, McNelly and Muraida, 1999; Merrill and Tompson, 1999; Nieveen and Gustafson, 1999; De Croock et al., 2002. See also the commercial software Designer's Edge, 2006; Adapt-it Designer, 2007). Developing performance support systems for instructors follows the same motives that have driven the idea of EPSS in industry. However, the number of studies, reporting on performance support systems for students in higher education are rather limited (Van Merriënboer and Kirschner, 2007). In order to provide a comprehensive operational definition of the concept of performance support for learning purposes we define first each of the components of this concept – performance, support and system in the context of higher education.

3.1 Performance

The concept of performance support in higher education requires practical measures for reducing the gap between higher education and the requirements of future working environments. The first step in this direction is identifying the so-called reference situation of a particular study. These are professional settings where students are going to apply what they have learned. From this perspective, performance in the conceptual configuration of performance supports for learning purposes can be operationalised as

1. defining a set of authentic problems and constituting tasks related to a specific working environment
2. shifting the focus from the lower levels of the learning taxonomy such as knowledge and understanding, towards its higher levels such as solving real-world problems
3. applying adequate summative performance-oriented assessment methods.

A reference situation provides the real context of learning. Problems and constituting tasks should be presented in an adequate way given the level of prior knowledge and the extent to which learners have immersed in a particular discipline. Shifting to higher levels of learning taxonomy does not mean that lower levels are forgotten issue. Lower levels are integrated within higher levels of learning taxonomies. Problem solving can include both well-defined and ill-structured problems.

3.2 Support

Support in the formation of PSSL can be operationalised by the following instructional design solutions:

1. designing a sequence of easy-to-complex tasks
2. creating opportunities for deliberate practicing these tasks
3. gradually diminishing the amount of support (scaffolding)
4. providing variety of instructional stimuli (resources)
5. allowing constant access to learning resources
6. giving formative performance feedback
7. adapting instruction to level of knowledge and learning style of students.

Ideally, the problem to be solved is divided into a sequence of easy-to-complex learning tasks, which brings variety of experience (Van Merriënboer and Kirschner, 2007). The instructional support for learning tasks gradually decreases as they are progressing to the end, an effect known as scaffolding. Students can start with work-out examples to prevent extraneous cognitive load and than continue with completion problem and finish with solving conventional real-world problems. The level of control given should be related to the level of prior knowledge of students. The higher level of knowledge and the higher level of learners' control.

Practicing does not suggests that students have to acquire first the needed knowledge and skills and then to apply them, but rather learning while practicing performance tasks within the context of solving problems. Practicing integrates learning experience and performance. Practice should be deliberate, that is with clear goals of achieving gradually high performance, reflecting on the process to refine performance, and an endeavour for increasing the ability for control, self-monitor and asses own performance (Ericsson, 2006).

Providing variety of instructional stimuli implies a particular structure of learning resources consisting of the following categories:

1 background information with facts, definitions, principles and theoretical frameworks
2 examples in the format of worked-out examples, modeling examples, demonstrations and simulations
3 procedures, techniques and tools.

Students can select at each moment of need one or a combination of several of these content types, as the order can also be different. Some students may wish to start with background information, while others may prefer to look first at examples, and a third group may begin with selecting techniques and procedures. Learners can define their learning preferences by selecting a type, a level and an order of learning resources.

Learning adaptation has two sides:

1 adaptation of instruction to learners' characteristics with the focus on the level of knowledge and learning style of students
2 adaptation of learners to the goals and requirements of instruction.

Implementing the idea of performance support implies that level of knowledge and learning style should be accommodated within the structure of learning resources, which affords learners to determine the level and the order in the selection of the learning content – background information, examples, and procedure, techniques and tools. The system can also provide run-time adaptation based on the inputs of the learners as it suggests some options for level of knowledge, which the learners can select from.

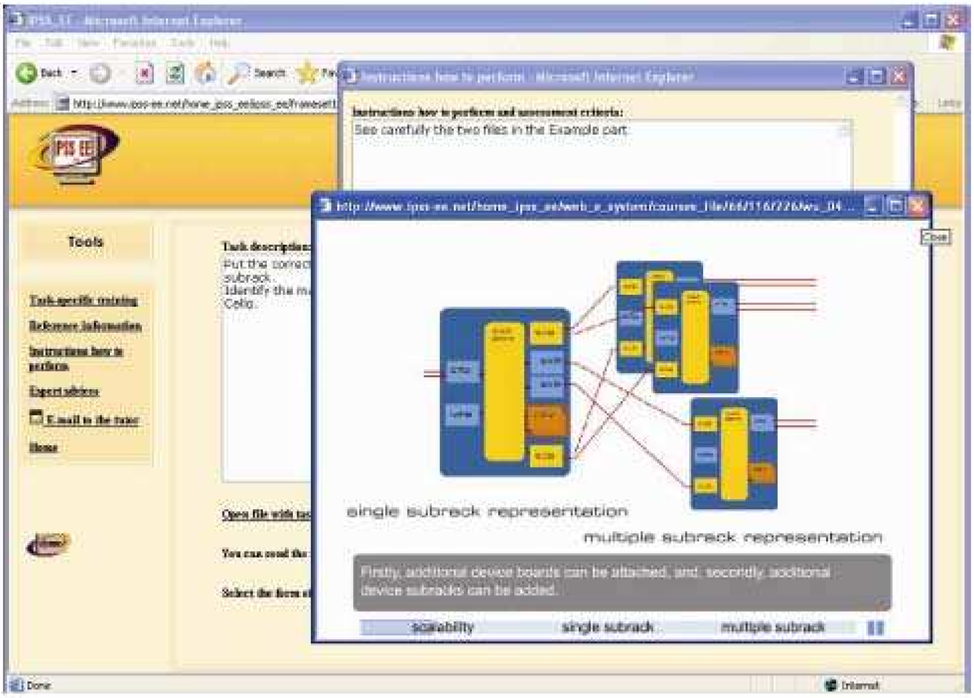
Feedback provides a formative evaluation informing learners about how well they have performed a particular task, what is the next step, and gives recommendations based on students' progress and learning preferences.

3.3 System

The term system suggests design and development of software applications using recent developments of Information and Communication Technologies (ICT). Performance support should be embedded into the interface and functionality of the application (Gery, 2002). Without technology the idea of just-in-time, just enough and at the point-of-need performance support would not be completely accomplished. An effective Performance Support System for Learning purposes (PSSL) requires a balance of its three core components: performance, support and system. Taking separately, each of them is a necessary, but not a sufficient condition for an effective and efficient PSSL. System depends very much upon how comprehensively performance and support are defined and how well they are operationalised in the architecture and the interface of a system. The potential of support and performance can be fully explored only in an advanced technology-based system Figure 1. A PSSL includes

1 an advisory component
2 an information component
3 a training component
4 a user-interface component.

Figure 1 A screenshot of the Performance Support System for Learning purposes (see online version for colours)



These components provide the necessary technical framework of the system, but it is crucial what content and instructional activities are implemented in the components.

To validate empirically the concept of performance support system for educational purposes we first implemented it in a prototype of a web-based PSSL. Building components and attributing functionality of the prototype is an efficient way of operationalising the concept of PSSL. Secondly, we conducted two empirical studies. The first one was a pilot study with a limited number of students. The purpose was to get some initial ideas on the impact of PSSL on the participants' achievements and attitudes, to fix interaction and technical design problems if any, and to improve the measurement instruments, if needed. The second study involved more participants and applied a stronger experimental design to draw conclusions on the effect of PSSL on performance results of higher education students and their attitudes towards the method.

4 Pilot study

4.1 Subjects, instruments and procedure

Nine first-year students studying Physics Engineering voluntarily agreed to participate in this study, which applied post-test only experimental group design. The study compared the performance results of this group of students working first under traditional conditions and then using PSSL on different content modules. Traditional instruction included face-to-face lectures and laboratory exercises. In addition, there was a supplementary website with some additional information and instructions how to perform tasks. Apart from comparing the performance achievements of students under the traditional and performance support conditions, we checked the attitudes of the experimental group towards the characteristics of the PSSL.

For the purposes of this pilot study, two measurement instruments were developed: a post-test reflective questionnaire, and a performance test. The post-session questionnaire includes statements that reflect the characteristics of the PSSL as they were described in Section 3. It consists of 18 items, 9 of which are indicative for performance, and 9 – for support. The performance sub-scale includes items that indicate

1 problem-based organisation of the method
2 orientation of the method (knowledge vs. skills)
3 perceived readiness for solving real-world problems)
4 transfer of skills
5 evaluation (knowledge vs. skills)
6 levels of learning taxonomy achieved (knowing learning content, understanding learning content, applying knowledge to learning exercises and applying knowledge to solving real-world problems).

The statements constituting the sub-scale of support are as follows:

1 availability of learning resources
2 learning adaptation (matching learning styles and level of knowledge)
3 structure of learning activities (fixed vs. flexible)
4 structure of learning resources (background information, examples, and procedures, techniques, tools)
5 formative feedback
6 just-in-time help.

The performances items reached reliability of 0.71 (Cronbach alpha), while the support sub-scale reached the value of 0.76. The format of the questionnaire proposes a list of statements and students are asked to identify the extent to which they agree with a particular statement on a 5-points scale. The performance test included 15 performance tasks.

4.2 Analysis

A paired-samples *t*-test was conducted to check the effect of PSSL on students' achievements and attitudes towards the method of instruction. There was a statistically significant increase in performance of students from Time 1 when they worked under traditional settings ($M = 8.4$, SD = 1.8) to Time 2 when they used PSSL ($M = 9.7$, SD = 0.7, $t(8) = 2.63$, $p < 0.05$). The 2 statistic (0.46) indicated a large effect size.

The experimental group scored high on the following items of the reflective questionnaire: getting examples ($M = 4.3$, SD = 0.7); evaluation of skills (4.2 SD = 0.7); availability of learning resources ($M = 4.2$, SD = 0.8); just-in-time help ($M = 4.1$, SD = 0.6); knowing learning content ($M = 4$, SD = 0.9); applying knowledge to learning exercises ($M = 4$, SD = 0.5); and getting additional background information (M = 4, SD = 0.9). The experimental group scored relatively lower on items such as readiness for solving real world problems (M = 2.8, SD = 0.8); flexible learning activity structure (M = 3, SD = 1.2); focus on knowledge (M = 3.1, SD = 0.9); and transfer of skills (M = 3.1, SD = 1.1). Apart from this data, the instructors who conducted the experiment collected a pool of opinions of the students, which indicated highly positive attitudes towards the PSSL. The students found that the PSSL increased their motivation for studying; improved their achievements; it was pleasant to work with the system; it helped self-learning, and it should be used in teaching other courses. At the same time, the students reported that at the beginning they needed some time for getting acquainted with the system.

The pilot study provided some clues about the direction of our assumptions on the impact of PSSL on learning achievements and attitudes of students in higher engineering education. A further research with a stronger experimental control was needed to test these expectations and build up an evidence-based theoretical ground for practical recommendations.

5 The effect of PSSL on students' learning and attitudes, Experimental study

The independent variable of this study is method of instruction with two levels, namely traditional instruction and PSSL. Traditional instruction includes face-to-face lectures and laboratory exercises. In addition to the traditional instruction, there is a supplementary website with description of the tasks, instruction how to perform them, and reference information. The students in the experimental group work with the PSSL prototype.

There are two dependent measures: performance of students on tasks and students' reflections on the instructional method. The research design controls for a possible effect of students' experience with computers.

The assumption is that the experimental group, working with the PSSL, will score significantly higher than the control group, which works under the traditional conditions, on tasks performance. To test the assumption, we apply a post-test with a control and an experimental group research design.

5.1 Subjects, instruments and procedure

Forty (N = 40) first year students in the second semester of their study during the course 'Information technology for physicists' were divided equally to form two groups, which were then randomly assigned to the experimental and the control conditions. The pattern of their study achievements during the first semester was similar.

Three measurement instruments were developed for the purposes of the experimental study: attitudes towards computers questionnaire, reflective questionnaire and performance test. The pre-session attitude questionnaire was aimed at measuring the students' attitudes towards computers in general and computer-based learning in particular. This questionnaire included 18 items. Nine of them formed a sub-scale that was intended to test the attitudes of students towards computers with a reliability score of .72 (Cronbach alpha). The remaining nine items completed the learning-by-computer sub-scale and had a reliability score of 0.81.

The reflective questionnaire was the same used in the pilot study. The performance test included 17 tasks.

Prior to the treatment, both the experimental and the control group filled out the learning-by-computers attitude questionnaire. Then the subjects in the experimental group worked with the PSSL. The control group followed the traditional method of instruction. The students were assessed on how well they did the performance tasks on a 6-point scale as six is the highest grade and three is the threshold of passing the exam. In addition, the experimental group filled out the reflective questionnaire.

5.2 Analysis

One-way Analysis of Variance Significant Test (ANOVA) with a confidence alpha level of .05 confirmed the hypothesis that the experimental group using the performance support system scored significantly higher then the control group, which worked under the traditional instructional conditions – $F(1, 38) = 9.875$, $p = 0.003$). However, it could be suspected that attitudes towards computers and experience with computers for learning purposes might contribute substantially to explain a significant variation in the data. The results from the attitude questionnaire were checked to determine whether the size effect is due really to the performance support system method rather than to attitudes towards computers and learning experience with computers. The independent-samples t-test indicated a difference between the experimental group ($M = 4.03$, SD = 0.53) and the control group ($M = 3.53$, SD = 0.58) on the learning-by-computer sub-scale as the experimental group scored higher [t (38) = 2.81, $p < 0.05$)]. It could be an indication that the students in the experimental group have had experience with using computers for educational purposes, while the students in the control group have not. To determine the extent to which learning-by-computer experience of the experimental group contributed to the explanation of the variance in the performance test results, we applied a multiple regression analysis. The procedure included three steps:

1 testing for multicollinearity, outliers and independence of residuals
2 evaluating the model
3 evaluating each of the independent measures.

The figures of correlation between independent and dependent variables, the collinearity diagnostics through tolerance and variance inflation values, the distribution of residuals, the Mahalanobis values and the Cook's distances indicated that the data were safe for a further analysis as no violation of the multiple regression assumptions were detected.

The next step was to evaluate how much of the variance in the performance of the experimental subjects could be explained by the model. The value of R^2 was 0.215, which represents a large effect size, according to generally accepted criteria (Cohen, 1988; Tabanchick and Fidell, 2001; Pallant, 2005). The data showed, after the regression, that the significance due to applying PSSL was still quite stable [$F(2, 37) = 5.061$, $p = 0.011$]. The Table 1 presents the regression coefficients of treatment (instructional method used) and experience with using computers for educational purposes.

Table 1 Summary of regression analysis for the variables predicting significance of performance scores

Variable	*B*	*SE*	*Beta*
Treatment	–0.930	0.361	–0.412*
Learning-by-computer	0.192	0.303	0.102

Note: A $N = 40$; dependent variable: performance-test scores; $^*p < 0.05$.

The instructional method makes a significantly stronger unique contribution to explain the test scores ($t = -2.573$, $p = 0.014$). Learning-by-computer factor has not reached statistically significant value ($t = 0.634$, $p = 0.53$). In addition to this analysis, Part correlation coefficients indicate that treatment variable alone explains 14% (part correlation value is −0.375) of the variance in the test scores, while learning-by-computer experience explains less than 1% (part correlation value is 0.092) in the variance of the dependent variable. From the analysis, it is concluded that the significant difference in the performance-test results of the experimental and the control group should be attributed to using the PSSL.

We also compared the reflections of the experimental group towards the characteristics of the concept of PSSL in terms of orientation to real problems; possibilities for getting just-in-time, just enough and at the point of need supportive information, examples, procedures, techniques and tools; providing just-in-time feedback; matching learning styles; learning taxonomy's levels achieved (knowledge, understanding, applying knowledge and skills to learning exercises, and applying knowledge and skills to real-world problems). The mean figures in descending order are given in Table 2.

Table 2 Means and SD of the items in the reflective questionnaire *N Statements M SD*

N	*Statements*	*M*	*SD*
1	Getting additional background information	4.6	0.5
2	Availability of resources	4.3	1
3	Flexible structure of learning activities	4.2	08
4	Focus on knowledge	4.2	0.9
5	Matching individual way of learning	4.2	0.8
6	Problem-based organisation	4.2	0.9
7	Run-time remediation	4.2	0.7
8	Understanding learning content	4.1	0.5
9	Knowing learning content	4	0.6
10	Feedback	4	1
11	Just-in-time help	3.9	1.2
12	Getting procedures	3.9	0.9
13	Evaluation of skills	3.8	1.2
14	Applying knowledge to learning exercises	3.7	0.9
15	Applying knowledge to solving real-world problems	3.6	1.1
16	Getting examples	3.5	1.1
17	Readiness for solving real world problems	2.4	1.1
18	Transfer of skills	2	1.3

Note: $N = 20$; an item represents the meaning of a statement; Figures are in a descending order.

The experimental group scored high on getting background information but lower on getting procedures and examples. The group scored high on problem-based organisation of the study, but relatively lower on perceived readiness for solving real-world problems and transfer of skills. The group scored high on knowing and understanding of content, but lower on applying knowledge to learning exercises and applying knowledge to realworld problems. The students scored also high on availability of learning resources, flexible structure of learning activities; matching individual preferences to learning, and feedback, but got relatively lower scores on evaluation of skills.

6 Discussion

The study provided empirical evidence to prove that PSSL can be an effective instructional approach in higher engineering education. The analysis reveals positive indications that the idea of performance support system could substantially contribute to the attempts of providing sound instructional design solutions for effective performance support of students in their preparation to face the challenges of future working environments. The reflective questionnaire showed patterns of responses that are in favour of the idea of performance support system in higher education. In general, the students demonstrated high positive attitudes towards the idea and were enthusiastic about its implementation across the curricula. In this particular study, the approach was more effective in the practical implementation of the ideas related to support and system in the concept of performance support system, but less effective for the performance part.

The data confirm the assumption that performance support systems for educational purposes create opportunities for just-in-time, just enough and at the-point-of-need support and transform these opportunities in practical solutions for individualisation of learning. One of the most promising ideas in this respect is structuring the information resources as particular categories such as background information (definitions, mental models and theoretical frameworks), examples (work-out examples, simulations and demonstrations), and procedures (guidelines, techniques and tools). Structuring the resources in this way promotes the idea of embedded learning adaptation (Stoyanov and Kirschner, 2004). Embedded adaptation means that a performance support system accommodates implicitly learning styles and knowledge level of students in its content structure. The functionality and the interface of the system afford students to select what they need and when they need it. The basic assumption behind embedded adaptation is the relationship between the types of learning content (background information, examples, procedure and techniques) and learning style categorisation (theorist, reflector, pragmatist and activist, after Honey and Mumford, 1992). Students having reflective learning style could start with some examples. Students with pragmatist learning style may begin with procedures. People having theorist learning style would look first at background information. All learning styles have to practice skill performance deliberately.

The analysis of the data from the reflective questionnaire showed that students benefited mostly from the possibility of getting background information, followed by getting procedures, techniques and tools. Getting examples was a problematic option.

A performance support system for educational purposes creates opportunities for structuring learning resources in a particular way, but it is up to the instructors to select concrete learning content and classify it as different categories (theories, examples, procedures and tools). The high scores on items such as availability of resources and flexibility of learning activities can be explained by the fact that these statements reflect the structure of components, built in the system. The scores on the statements related to the types of learning resources depend upon the contribution of the instructors. They decide what background information, procedure or examples to include. The same argumentation applies to the relatively moderate scores on feedback given and just-in-time help. It is the instructors who operationally provide feedback and just-in-time help.

The study identified some issues that need a further consideration. The performance support system, that was experimentally tested, did not promote at the required level the idea of performance. Performance was operationalised by proposing and involving students in solving authentic problems, creating opportunities for practicing these types of problems and applying adequate methods for performance assessment. According to the reflective questionnaire, students did not have feeling of dealing with real problems. They thought the tasks to solve were like learning exercises. From one hand, it is not a good idea to confront students with real-world problems, especially when they are at the beginning of their study, because it can increase the cognitive load, which has proved counterproductive in learning situations involving novices learners (Van Merriënboer and Sweller, 2005; van Merriënboer and Kirschner, 2007). From the other hand, learning tasks should be described in a meaningful real-life context. Another issue detected was that the students recognised knowledge and understanding as the levels of learning taxonomy they had reached, but it was not the case with reaching the level of applying knowledge and skills for solving real-world problems. Performance assessment and scaffolding of the support were not distinctive features of the evaluated PSSL as well. The issues with the successful operationalisation of performance should not be attributed to the idea of performance support for learning purposes itself but to its implementation in the software application. Another conclusion that can be drawn from the findings is that the system should integrate both a performance support system for instructors and a performance support system for learners. The performance support system for instructors helps them to design and develop content structured in a particular way for effective learning of students.

The study has some technical limitations regarding the organisation of the experiment. We designed an experiment, developed measurement instruments and gave an instruction to the university teachers how to conduct the experiment, but we did not have full control on what actually happened during the experimental sessions. The measurement instruments were far from perfect. We assumed that the instructors were content experts who had the needed knowledge and skills to make valid and reliable performance tests, but it might not be the case. Although these weaknesses, it is our belief that the study contributed to the efforts of finding better solutions of the issues related to performance support in higher education.

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