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Training troubleshooting skills with an anchored instruction module in an authentic computer based simulation environment

Abstract

To improve the application and transfer of troubleshooting skills when diagnosing faults in complex automated production units, we developed and implemented an “anchored instruction” learning module in the context of a computer based simulation environment. The effects of the instructional module were evaluated in a quasi-experimental evaluation study. During the study 42 mechatronic apprentices were trained in two parallel experimental groups with and without the anchored instruction module. We assessed success related training outcomes using measures of performance in several different transfer tasks. It could be shown that participants who trained with the anchored instruction module improved performance and strategic behavior especially in similar and new tasks in the learning environment.

Keywords: simulation based training, fault diagnosis, training evaluation, situated learning, anchored instruction

Störungsdiagnostetraining mithilfe eines Anchored Instruction Moduls im Rahmen einer computergestützten Simulationsumgebung

Zusammenfassung

Zur Vermittlung von Strategien zur Fehlersuche in automatisierten Produktionsanlagen wurde ein computergestütztes Simulationstraining mit einem Anchored-Instruction (AI)-Modul entwickelt. Das Training wurde bezüglich seiner Transferförderung mit 42 auszubildenden Mechatronikern evaluiert. Eine Experimentalgruppe bearbeitete das Training mit, die Kontrollgruppe ohne AI-Modul. Die Effekte der zwei Trainingsvarianten bezüglich des Diagnoseerfolgs wurden mithilfe von Diagnoseaufgaben auf drei Transferstufen erfasst. Die Ergebnisse zeigen, dass das Training mit AI die Fehlersuche nur teilweise gegenüber dem Simulationstraining mit kognitiver Modellierung verbessert. Beim nahen Transfer war die AI-Gruppe zwar signifikant überlegen, nicht jedoch beim Inhalts- und Kontexttransfer.

Schlüsselwörter: Störungsdiagnostetraining, computerbasiertes Simulationstraining, Trainings-evaluation, situiertes Lernen, Anchored Instruction

1 Introduction

Troubleshooting in industrial automation systems is a complex and demanding task, which requires well skilled staff. Up to now it is almost impossible to leave these diagnostic tasks, especially corrective maintenance, completely to technical systems (e.g. Madhavan, Wiegmann & Lacson, 2006). Mastering maintenance tasks requires the application of problem solving strategies as well as declarative knowledge (Kester, Kirschner & Merrienboer, 2006; Nickolaus, Abele & Gschwendtner, 2009), and expertise is of high economic relevance to minimize the costs of production downtimes. Owing to the variety of faults it is very important to support transfer of troubleshooting skills in novel situations (e.g. Kostopoulou & Duncan, 2001). Learning needs assessments indicate that technical staff should be especially supported to generate adequate mental models (Hoc & Carlier, 2000; Kontogiannis & Moustakis, 2002) and systematic strategies (Schaafstal, Schragen & Berlo, 2000; Schaper & Sonntag, 1998). Moreover, Ross and Orr (2009) state that troubleshooting skills include flexible and automatic application of these strategies in ill-structured problems.

1.1 Technology based learning environments

In order to train troubleshooting skills (Patrick, James & Friend, 1996), technology based learning environments are of great interest (Ronen & Eliahu, 2000). Several reasons suggest the use of simulations of diagnostic tasks: They enable risk less, potentially unlimited exploration and repeated practice of alternative strategies, even with rare tasks. A learning environment for this purpose should contain adequate learning tasks and adequate instruction methods in order to build mental models and to train problem-solving strategies.

Miscellaneous instructional approaches encourage the use of learning technologies to augment the teachers' activities and to structure learning processes (Moreno & Mayer, 2005). Technology based trainings, especially with simulation environments, could support complex instructional designs by presenting authentic problems including multiple perspectives and contexts (Chen & Toh, 2005). Additionally, technology-based learning environments should provide relevant information and instruction, which is needed for problem solving skills (Resnick, 1999).

Simulations enable the learner to train diagnostic procedures in a realistic way, understand complex systems, and also demand to act strategically. Research indicates that simulations could also support transfer of learning (Gopher, Weil & Bareket, 1994; Goettl, Yadrick et al., 1996). A simulation should have physical and conceptual fidelity to improve transfer of learning (Leplat, 1989). Advanced studies found that low fidelity simulations also work, if the relevant complex skills are trained adequately (Jentsch & Bowers, 1998). Diagnostic strategies should be practiced on concrete diagnostic actions in the system, like information inquiries, testing operations, exchange and recalibration of faulty components like in real world systems (e.g. Vasandani & Govindaraj, 1995). According to this recommendation, Ross and Orr (2009) also developed and evaluated a program to teach a troubleshooting method for information technology professionals named DECSAR. This is an acronym for six steps, which should be passed through in training: "Define the problem; Examine the situation;

consider the Causes; consider the Solution; Act and test; Review the troubleshooting”. Participants, who applied this methodology, could improve their troubleshooting success.

Additionally, technology-based learning environments could be enriched by the purposeful employment of audio-visual multimedia components, which provide authentic information about knowledge and skills in natural contexts. Effectiveness of technology-based instruction in occupational contexts for reaction, learning and transfer was evaluated in several studies reported in the review of Arthur et al. (2003), who found small to medium sized effects. De Rouin, Fritzsche and Salas (2005) state a general lack of theory driven implementation and evaluation of technology-based learning environments.

1.1 Principles of situated learning and anchored instruction

For the acquisition of complex skills and to foster expertise, especially in technology-based learning environments, instructional designs based on principles of situated or constructivist learning are often recommended, embedding learning in meaningful contexts (Arts, Gijsselaers & Segers, 2006). This rationale is well represented in approaches of situated learning, which propose natural learning situations, where learners can actively manipulate objects and reflect about the meaning of experiences and observations (Jonassen, 1999). Situated learning theories underline that the construction of knowledge is a continuous process of linking information with environment and actions. Therefore, knowledge and its retrieval are context-bound. Moreover, learning is a social activity: knowledge is acquired, mediated and applied in social context. Drawn from that, instructional approaches based on situated learning try to overcome the inertness of knowledge and cognitive skills taught in formal education by situated, collaborative and problem-based learning environments (Gijbels, VanDeWatering, Dochy & VanDenBossche, 2006). Well-known examples for these instructional approaches are cognitive apprenticeship (Collins, Brown & Newman, 1989) and anchored instruction (Michael, Klee, Bransford & Warren, 1993; Blumschein, 2004). However, investigations of training outcomes of these instructional approaches are rarely conducted and not always successful (Gulikers, Bastiaens & Martens, 2005).

In order to improve transfer of the learned skills effectively, approaches of instructional design propose problem based learning environments. In such problem based learning contexts learners should be enabled to engage in four different episodes of learning (Merrill 2001): Activation, demonstration, application and integration. Drawn from that, transfer oriented learning is encouraged under several conditions: A daily life problem or situation is presented to learners to activate the learned contents (activation). Problem solving is demonstrated in a real life context to the learners (demonstration). Learners can try out their own learned knowledge and skills in the learning context (application). Finally, they should be encouraged to reflect the learning and application process individually or discuss it in groups (integration).

There exist various approaches for constructive learning environments, which try to realize these design principles. They differ in their focus on specific instructional methods (Jonassen, 1999). Methods of cognitive apprenticeship (Collins, Brown & Newman, 1989) “re-integrate the learning of skills and knowledge in their social and functional context” in order to support

application and transfer as it is practiced in traditional apprenticeship. This approach contains three methods from the teacher's point of view (modeling, coaching, and scaffolding) and three methods from the learner's perspective (articulation, reflection, and exploration). Furthermore, it is suggested as a framework for instructional design in technology-based learning environments (Casey, 1996).

More recent research exists for “anchored instruction” as another important approach for the design of technology-based constructivist learning environments (e.g. Connell & Ruzic, 2001; Wang et al., 2005). This paradigm emphasizes that learning should take place in a context that allows learners to solve problems actively, which are relevant for the learner (Hendricks, 2001; Bransford & Stein, 1993). 'Anchoring' as a method and as a design principle means that contents of the learning environment should be presented in a realistic and comprehensive situation. It is further assumed, that in this way acquired knowledge and skills could be better transferred to similar situations (CTGV, 2000).

Learning is organized around so called macro contexts (anchors). They present interactive video sequences of problems in the application context (narrative format). Anchors also integrate all relevant information that is needed to solve the problem. Furthermore, the realistic environment and task should motivate learners to engage in active learning (e.g. Rieth, Bryant, Kinzer et al., 2003). Moreover, the content of anchors is complex and consists of several, interrelated problems, so that the students have to identify and formulate, which problem(s) exactly they want to solve (generative format). Finally, multiple scenarios and multiple perspectives on problems should especially enhance transfer of learning.

Therefore, the author's aim was to provide a situated, problem based e-learning environment of an industrial automation system to train troubleshooting skills step-by-step and to investigate the effects of an additional learning module based on principles of the anchored instruction approach. We expected that the anchored instruction module would additionally support learning and transfer of problem solving strategies for troubleshooting, enhancing the instructional effects of the already tested simulation environment in connection with a cognitive modeling module (Schaper, Hochholdinger & Sonntag, 2004).

2 Learning Environment

2.1 Simulation module

The e-learning environment “Diagnose-KIT” integrates problem based, situated learning in a simulation environment for fault diagnosis (Hochholdinger & Schaper, 2006). It is complemented with further instructional elements, based upon the principles of the cognitive apprenticeship approach (Collins, Brown & Newman, 1989).

The simulation module consists of 20 troubleshooting tasks in an authentic production unit, an automated double action press with 1160 connected components (see figure 1). It represents an existing production unit in automotive industry. Authenticity of the simulation was realized not only regarding the representation of the structural and physical characteristics of the technical system, but also regarding the interactions with the system. It was accomplished by

conducting precedent task analyses in maintenance jobs (Schaper & Sonntag, 1998) and working in an interdisciplinary team of psychologists, technicians, and software engineers to realize the learning environment.

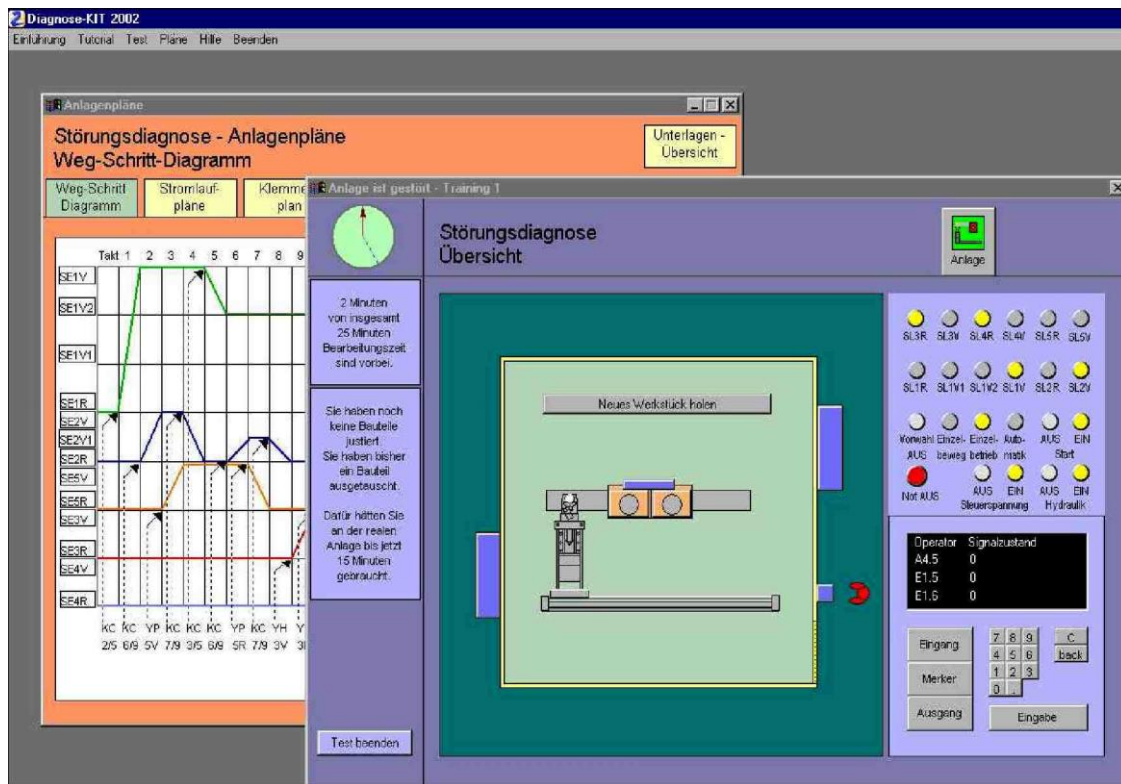


Fig. 1: Simulation screen of the e-learning environment Diagnose-KIT.

In order to facilitate exploration and to support generative problem solving processes the simulation module is equipped with a mouse controlled user interface that shows a two-dimensional view of the double action press and its components, like moving parts (grripper, cylinders, feeds), power supply, control elements, and PLC status display (Figure 1). The user's position is indicated by a red figure. It moves through the system initiated by the learner's mouse clicks on the button-like components. Arriving at the particular component the user can get more information and perform detailed operations. Technical documentation of the plant (e.g. circuit diagram, flow sheet, hydraulic diagram, PLC diagram) is available in a parallel menu and contains multiple perspectives of all functions. Additionally, the user is able to control the plant, to test functions and to request the status of PLC operands. These opportunities allow realistic, self-controlled and highly individualized troubleshooting.

In the e-learning environment the learner has to find several single faulty components like a maintenance worker in real life. For that purpose, one can test or calibrate components, for example voltage or pressure, examine their documentation and replace components. The troubleshooting tasks correspond to frequent operational faults of the original plant and cover four types of faults classified according to functions. We distinguished electrical input faults, electrical output faults, pneumatic and hydraulic faults due to one faulty component each.

Before starting the troubleshooting tasks two computer assisted instruction modules (CAI) are presented for preparation. The first CAI describes structure and function of the plant, and contains schematic representations connected with photos of the original plant. The second CAI module guides through the handling of the simulation, and illustrates the most important operations, like measurements and exchange of faulty units. Both CAI modules are mouse controlled. The troubleshooting tasks were administered over a common surface with a button for each task.

Complementary, the computer based simulation and the e-learning-environment are equipped with a modeling module based upon the cognitive apprenticeship approach (Collins, Brown & Newman, 1989). This instructional element focuses on the method of modeling, which means that an experienced person in the relevant domain demonstrates executing the target action process in an authentic task. By observing the model and reflecting on the observed actions learners can generate a mental model of the required action control processes and heuristics (Seel, 2001). The expert's externalization of usually internal processes and activities facilitates the comprehension of the action processes and transfer of learning (see also Schaper et al., 2004). The expert describes steps of problem solving and reduces thereby complexity for the learner. By that, the expert's behavior represents the training objectives.

The modeling module in Diagnose-KIT contains six problem-based video sequences, corresponding to six troubleshooting tasks in the simulation, which show an experienced maintenance worker solving troubleshooting tasks by employing diagnostic strategies at the original plant, on which the simulation is based. The shown strategic behavior is based upon findings on problem solving strategies comparing experts and novices (Schaper & Sonntag, 1998), and employs a taxonomy of problem solving strategies in troubleshooting tasks. A separate evaluation study has shown that the cognitive modeling module teaches effective strategic behavior to diagnose faults in the described computer based simulation environment (Schaper et al., 2004).

2.2 Anchored instruction module

In order to support especially transfer of the troubleshooting skills from the simulation towards real life production units principles of anchored instruction (Michael, Klee, Bransford & Warren, 1993; Blumschein, 2004) were adopted. The anchored instruction module provides information about two further production units, an automatic lathe and a transfer line. For each production unit two video based troubleshooting sequences exist (see figure 2). They are established as problem based illustrations of troubleshooting in a collaborative learning setting, whereas the video sequences in the modeling module complement individualized problem solving tasks in the simulation. This additional instructional module should provide further contexts and multiple perspectives of troubleshooting in order to improve the application of diagnostic strategies.

The development of the videos for the anchored instruction module was based on job analysis of experts in the field. For this, Schaper, Sonntag, Zink and Spenke (2000) analyzed fault finding strategies of experienced maintenance workers at both production units, using the PARI method of cognitive task analysis (Lesgold et al., 1998; Kieras et al., 2000). Results of

this analysis showed typical and successful fault finding strategies, relevant operation sequences and features of the production unit. These results were used for scripting and producing the videos (length about 5-10 minutes).

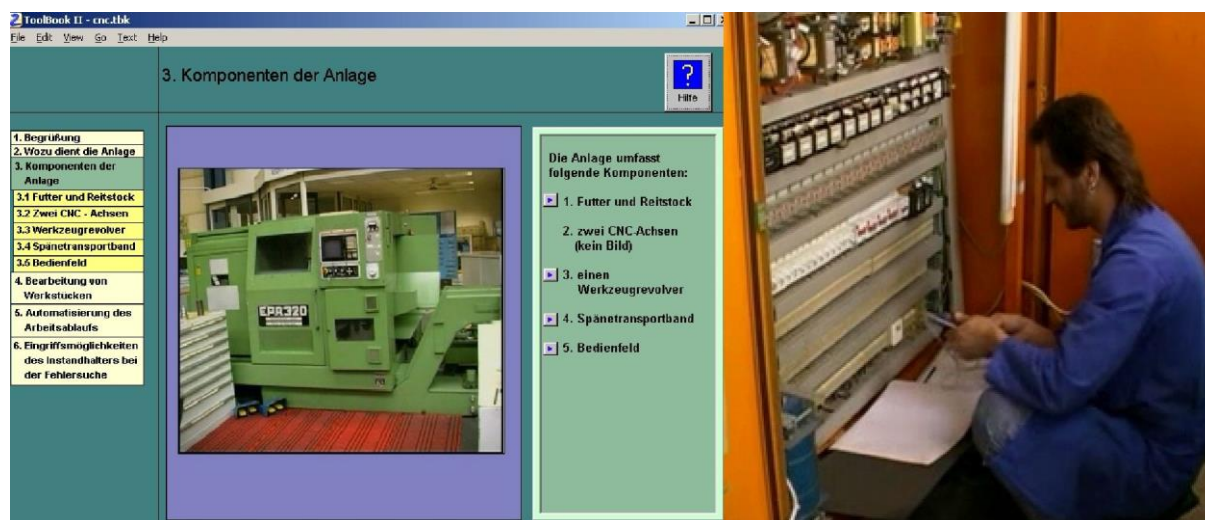


Fig. 2: Anchored instruction module: Computer based instruction and video sequence.

The anchored instruction module includes collaborative learning as suggested by Merrill 2001 which means, that the module was conducted in groups of about four to six learners. The instructional sequence comprises the following steps:

1. First, the learners receive a technically oriented, introductory CAI in two additional production units, including a video clip showing the faultless production units at work (video based format). Relevant operation sequences, components and functions were showed and explained.
2. In the next step a video sequence is presented where an experienced maintenance worker detects an operating failure (complex problem with embedded data). This is shown both visually and described verbally (narrative format).
3. At this point participants should take notes about the situation and plan next steps to diagnose the fault (generative format). Ideas are collected and discussed in the group. Leading questions are: What did you observe? Which type of fault do you assume? Which type of fault would you exclude at this point, and why? Which could be the next steps to find the fault?
4. In the next step a second video sequence is shown, where the experienced maintenance worker shows his solution successfully troubleshooting the fault accompanied by verbalizing objectives, procedures and internal processes of his actions.
5. Finally, participants take notes and reflect on their own diagnostic strategies and those of the expert. They also discuss required and available information and alternative procedures, following the presented questions: What caused the operation failure? How did the expert find the fault? Could you identify the steps to find it? Which diagnostic tools did the expert use? Are there other possible strategies?

3 Experiment

In a quasi-experimental evaluation study the author and his team investigated the additional effects of the anchored instruction module compared with a training resp. control group, which was only trained with the simulation environment and the cognitive apprenticeship instructional module. The effectiveness of the troubleshooting simulation environment (Diagnose-Kit) in combination with the cognitive modeling instructional module was successfully tested in a different study (Schaper et al., 2004). In this study, we tried to answer the question: How does anchored instruction affect the acquisition of troubleshooting skills measured by troubleshooting performance in diagnostic tasks at different transfer levels? Therefore, the already tested simulation was supplemented, which based on training with a cognitive modeling instructional module (control group) by two anchors with authentic, related problems in other contexts in the experimental condition. The author and his team expected that the experimental group would be more successful than the control group on all levels of transfer, especially in the tasks requiring context transfer.

3.1 Method

Concerning the evaluation of the additionally designed instructional module in a simulation based learning environment to train fault diagnosis, the question of interest was, how our anchored instruction module affects the troubleshooting performance at different transfer levels. Derived from Kirkpatrick's (1994) typology of training criteria we addressed learning and performance measures ordered by transfer distance. It was predicted that anchored instruction would improve troubleshooting outcomes for similar tasks in similar contexts (learning) as well as for new tasks in similar contexts and for similar tasks in new contexts (performance or near transfer sensu Laker, 1990).

3.1.1 Design

In order to examine the expectations concerning the instructional approaches training effectiveness of the anchored instruction module was explored. The effects of the additional anchored instruction module were analyzed in a quasi-experimental design with different pretest measures and posttest measures. The results of the pretest measures (success in troubleshooting tasks in the simulation and in a test of prior knowledge) were used to parallel two groups by aggregated matching, experimental group (anchored instruction) and control group (no anchored instruction). After the training period with or without anchored instruction the author and his team tested trouble-shooting performance on three levels of transfer (see also Schaper et al., 2004). Learning was tested with similar simulated trouble-shooting tasks as practiced in the learning environment before. So-called transfer of content was tested with new types of simulation tasks in the same simulation context. Transfer of context was tested with tasks of the same domain (i.e. similar troubleshooting tasks as in the first transfer level) but on a real production unit.

As experimental effects of anchored instruction posttest results were only analyzed, because pretest and posttest tasks were not identical. As suggested by Cook and Campbell (1979) the writer and his team relied on posttest measures a) because transfer tasks have to be new tasks

per definition and b) because the use of pretest-posttest discrepancy measures might be confounded by testing effects. In order to strengthen causal inferences of treatment effects the internal referencing strategy (Haccoun & Hamtiaux, 1994) was adopted and additionally tested changes of prior factual knowledge between pretest and posttest as irrelevant measure, which should be not affected by the variation of the training conditions. Knowledge was evaluated in the posttest again to control group differences in knowledge improvement as an irrelevant measure drawn from the internal referencing technique.

3.1.2 *Participants*

In order to examine the additional effects of anchored instruction on the acquisition and transfer of troubleshooting skills in a simulation based learning environment and at a real world production unit, 42 trainees of mechatronics were trained by the author and his team in their third year of apprenticeship. One woman and 41 men participated in this training. The average age was 19.2 years (SD 1.6). Participants were assigned to one of the two conditions by their pretest results to gain two comparable groups (so that each group included 21 persons).

3.1.3 *Procedure*

The simulation-based training was conducted as a four-day in-house training for apprentices of mechatronics in a globally-acting German technology company. The training served as a compulsive element of the curriculum for troubleshooting.

First, all participants received a computer-aided instruction (CAI) in the simulated production unit and the handling of the simulation as described above. In the pretest, all trainees had to solve three troubleshooting tasks in the learning environment: an electrical input fault, an electrical output fault, and a pneumatic fault. Additionally, they completed a knowledge test. After that, participants were allocated, depending on their pretest results to the experimental condition or the control group.

Both groups trained with a total of twelve troubleshooting tasks in the computer based training, four electric input faults, four electric output faults, and four pneumatic faults and the cognitive modeling module. The experimental group processed the anchored instruction modules supplementary. These participants obtained the anchored instruction module in three additional sections, each after the four training tasks of one domain. The first section contained the computer based introduction in the automatic lathe, a video presentation of the working lathe and one video based case for troubleshooting (electric input fault). The second section included the introduction in the transfer line, a video presentation of the working transfer line and one troubleshooting case (electric input fault). In the third section the participants solved two troubleshooting problems, one for each unit (pneumatic faults). The control group received work sheets on troubleshooting instead.

In the posttest the participants had to solve three troubleshooting tasks with similar content in the simulation environment: one electric input fault, one electric output fault and one pneumatic fault. As performance indicators requiring transfer of content they received two tasks in a new domain (hydraulic faults) but still in the same simulation environment. Finally, participants had to find an electrical input fault and a pneumatic fault at a real life production

unit, which was an automatic sorter. The results concerning this test task served as performance indicators requiring transfer of context. Functions and operations of the automatic sorter are analogous to the double action press in the simulation. It contains a PLC, electric and pneumatic components, and a sensor system. The sorter tests and sorts work pieces depending on size and material. Similar faults like in the simulation were implemented: One electric input fault and one pneumatic fault.

3.1.4 Measures

To test prior technical knowledge as pretest measure for paralleling groups and as training-irrelevant measure in the posttest an abbreviated version of a test for technical knowledge in mechatronics (Lohbeck, 1996) was used. It contains several open ended and closed questions on pneumatic, hydraulic and electric knowledge, being relevant for troubleshooting in mechatronic systems (Table 1).

Scale	Example	alpha
Knowledge	How much is the mean effective pressure of the hydraulic systems?	0.69
Understanding	Which position sensor is activated if the gripper is open?	0.75
Application	The pneumatic cylinder doesn't retract. You find working pressure at measuring point 5 of the pneumatic systems only. Which component could be faulty?	0.75

Tab. 1: Scales and exemplary items of the test for technical knowledge (Lohbeck, 1996).

The posttest measures captured training outcomes and strategic troubleshooting behavior (for the last measures see Hochholdinger & Schaper, 2008). Only the outcome measures were presented, which included the rate of successful findings of the faulty component in a given time (20 minutes) and the duration of the diagnostic search in minutes if the fault was found. Effective troubleshooting means that the training participants solved as many tasks as possible and found the faults as quickly as possible in the three posttest tasks in the simulation environment (near or within transfer), in two new domain tasks (middle or content transfer), and in two tasks at the real unit (far or context transfer).

3.2 Results

Participant troubleshooting performance measures and strategic behavior indicators were examined by using a t-Test for independent samples. Results were aggregated for the three tasks of near transfer, for the two tasks of content transfer and for the two tasks of context transfer. The average success rates were reported in percent for the experimental condition and the control condition, t-values, Cohen's effect size d as indices independent of sample size and p-values.

Performance indicator	Anchor	Control	T; df	d	p
Pretest knowledge test	14.12	13.86	0.24; 40	0.07	0.809
Pretest tasks	54%	52%	0.17; 40	0.05	0.746
Success rate near transfer tasks	56 %	30 %	2.92; 40	0.92	0.003*
Success rate content transfer	66 %	50 %	1.38; 40	0.44	0.088
Success rate context transfer	47 %	38 %	0.78; 40	0.25	0.218
Time for near transfer tasks	15.6 min	17.2 min	-1.71; 39	-0.55	0.047*
Time for content transfer tasks	14.5 min	15.6 min	-0.93; 39	-0.30	0.177
Time for context transfer tasks	15.6 min	16.4 min	-0.57; 40	-0.18	0.285
Posttest knowledge test	15.88	15.32	0.53; 38	0.17	0.600
Difference knowledge test	1.76	1.71	0.06; 38	0.02	0.952

* $p < 0.05$

Tab. 2: Pretest and posttest training outcomes: Average scores in the knowledge test, average percentage of solution and average time to solution for the modeling condition and control.

The results for outcome measures in the posttest are summarized in Table 2, also for pretest measures. Concerning the success rates for troubleshooting in the near transfer tasks the experimental group with the additional anchored instruction module performed significantly better than the control group. In contrast, no significant differences were found for troubleshooting success rate in content and in context transfer. Similarly, the experimental group solved the tasks requiring near transfer significantly faster, which represents a more effective troubleshooting. In contrast to that, the difference was not significant for the other tasks. According to Cohen (1988) the author and his team found small to medium effect sizes except for the success rate in context transfer. They consider these - though mixed - results for training outcomes still as positive effects of anchored instruction.

In order to control the found group differences against experimental biases, the knowledge improvement as an irrelevant measure drawn from the internal referencing technique was investigated. No differences were observed in the knowledge test as training irrelevant posttest measure, which strengthens the interpretation of the training relevant differences as effects of anchored instruction. However, both groups improved their technical knowledge significantly to the same extent, due to the practiced simulation tasks. The improvement is considered as a side effect of the simulation based e-learning environment and the absence of a group effect as control against experimental biases like demand characteristics.

4 Discussion

The results of this evaluation experiment show that the employment of the anchored instruction module seems to have a positive impact on the success of diagnostic skills especially in the near transfer and content transfer task environment. A slight advantage of the experimental group (small to medium effect sizes) was also found in transfer tasks with fault diagnosis tasks at the authentic production unit. So, the expectations, concerning the training success of the additional anchored instruction module, could only be fulfilled partially. How can these mixed results be explained? Considering the results, it first has to be kept in mind that the control group received already a carefully conceptualized problem based training, which proved already its effectiveness on the same outcome measures (Schaper et al., 2004). So the author and his team think that it was not easy to outperform this “basic” training with further instructional modules. Nevertheless, the anchored instruction module showed at least small to medium additional benefits in this context. At a second glance on the results, though, they were a little bit astonished about the small effects concerning the content and context transfer compared with the larger effects in the near transfer tasks. One would have expected the opposite, because the design of the anchored instruction module rather intended to support middle and far transfer skills than near transfer competences. The results though suggest that working on the anchored instruction module was more helpful to consolidate the diagnostic skills, which had been acquired in the simulation environment. But it was only slightly successful to support the transfer of the skills to new contents or in new application contexts.

One reason for these rather disappointing effects concerning the middle and far transfer might be that the transfer of the skills was not exercised resp. practiced often enough. Finally, under a methodological perspective, it has to be admitted that the experimental design suffered a little bit under the relative small sample sizes. Due to the small sample size power it was not possible resp. very difficult to test the effects against a p-value of 0.05. The conclusion is that the transfer of strategies is only partially successful, but could be supported through additional exercise units.

5 Conclusion

The results of the evaluation indicate that providing computer based training with a situated instruction module drawn from the anchored instruction approach improves troubleshooting

performance at least partially. To examine transfer of learning outcome measures for performance tasks on three levels of transfer were considered.

As expected, the additional employment of the anchored instruction module for the experimental group had positive effects on tasks requiring transfer. However, the clearest effects were found in near transfer tasks, and the weakest (small to medium sized) effects were seen in tasks, requiring context transfer. Effects of anchored instruction were controlled against experimental biases by the internal referencing technique.

One important implication of the results might also be that it is necessary to integrate Diagnose-Kit into extended learning arrangements, in order to successfully foster transfer of training. Further steps in the project will focus on the development and comparative evaluation of additional tutorial modules, such as the employment of context-sensitive instruction according to the coaching and scaffolding elements of the cognitive apprenticeship approach (Collins et al., 1989). Apart from the extension of the training, the troubleshooting behavior should be diagnosed more exactly on the process level, in order to draw more differentiated conclusions how far transfer succeeds.

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