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Student-oriented versus teacher-centred: The effect of learning at workstations about birds and bird flight on cognitive achievement and motivation

Abstract

The study investigated cognitive and motivational effects of two educational interventions, a conventional versus a student-oriented approach. We monitored the impact on the cognitive achievement outcome and the motivation of students. Both approaches dealt with the subject of birds and bird flight; the student-oriented approach consisted of a unit based on workstations, the conventional one was taught in a more teacher-centred manner. 326 secondary school pupils of the highest stratification level participated in this study. By using a pre-, post- and retention-test design, both approaches were evaluated with the same empirical batteries (by applying a cognitive item set and the 'Intrinsic Motivation Inventory'). The conventional approach provided higher achievement scores whereas the student-oriented approach showed a higher motivational rating. Comparing the student-oriented approach with and without introduction, the group with introduction attained higher achievement scores. The results are discussed in terms of general expectations about the cognitive outcome in open learning environments and self-determination theory. Educational implications are drawn concerning the implementation of learning at workstations in school curricula.

Introduction

Student-oriented[1] teaching at school is very often given priority by teacher in contrast to more teacher-centred lessons (e.g. Von Secker & Lissitz, 1999). Conventional, teacher-centred instruction generally is seen as an information transfer from the teacher to the learner (Bonk & Cunningham, 1998; Kember & Gow, 1994). The desks are arranged in rows and most of the time students face in front of a board a teacher talking and questioning students while instructions are addressed to all learners (Cuban, 1983). Students simultaneously work on tasks by following a teacher's direction (Daniels, Kalkman, & McCombs, 2001). In a student-oriented approach, the focus of the teacher and instruction moves to the student (Schuh, 2004). A lesson consists of more frequent student talks, of varied instructional materials, of student choices towards a subject matter and of cooperative or group working scenarios (Cuban).

In an effort to sustain the vision of student-oriented teaching, we developed distinctive workstations on a standard middle school subject. Learning at workstations is an educational approach, where students work cooperatively and autonomously in small groups at various workstations. After a task of any workstation is completed, the individual group shifts to another workstation. Instructional materials and description of hands-on activities are provided at each workstation or given in workbooks leading the group members. The specific value of learning at workstations is that the students could work self-guided and on their own pace; they could choose the order of the workstations and the duration of engaging with a single workstation according to their interest (Hepp, 1996, 1999; Schaal & Bogner, 2005). Originally, the idea of workstations derived of the subject of physical education: The 'circuit training' consists of stations with different physical activity-tasks (Hepp, 1999). In science

[1] In this study, the term 'student-oriented' is used synonymously for 'student-centered' (Cuban, 1983) and 'learner-centered' (Schuh, 2004)

lessons, the workstations may consist of any tasks which include hands-on, experiments; the objective is self-guided study of a subject matter. Learning at workstations can be seen as one form of an open learning environment in terms of the method of instruction (Bauer, 2003; Hepp, 1999). Other aspects include the content (subject matter) and the 'institutional openness', both provided by the design of this study. Open learning environments can generally be regarded as highly student-oriented (Bauer, 2003).

Mainstream research in science education has largely focused on cooperative learning environments while few studies have investigated learning effects and motivational aspects of learning at workstations. Most studies on cooperative and open learning environments reported an overall positive outcome: A meta-analysis of Lord (2001) reported for a mere 8% of 300 articles negative results of cooperative learning environments. In the main, students scored significantly higher in cooperative learning classes (Lord, 1997) and they are psychologically and physically healthier than students taught in competitive classrooms (Johnson & Johnson, 1989; Slavin 1990; in Lord, 2001). Similarly, Iwon (1992) found for students in learner-centred lessons higher achievement scores compared to teacher-centred lessons. Beside cognitive effects, many studies also demonstrate affective outcomes of student-oriented learning environments. For instance, learner-centred approaches provide a significantly higher 'well-being' than teacher-centred approaches (Randler & Bogner, 2006; Schaal & Bogner, 2005); a similar result is obtained for the perceived value of the biological content's personal meaningfulness (Schaal & Bogner, 2005). Additionally, social skills and social competences were more easily trained in student-oriented lessons than in cooperative learning environments (Lord, 2001). Chang and Fisher (2001) found that the perception of an affirmative, favourable and fulfilling learning environment tends to lead towards increased achievement scores.

Student-oriented approaches give learners a central focus and thus the acting force. This requires motivated and self-directed learners (Lee, 2000). According to self-determination theory, motivation can be enhanced by autonomous support, by a feeling of competence and social relatedness (e.g. Deci & Ryan, 1993; Grolnick & Ryan, 1989; Williams & Deci, 1996). Thus, the learning environment should maximise these three psychological needs. Learning at workstations might enhance autonomy, perceived competence and social relatedness: students work in self-directed and autonomous fashion in small groups on learning stations (Bauer, 2003) and teachers shift their role from 'instructors' to 'supporters' of a learning process (Schaal & Bogner, 2005). From a logistic point of view, workstations are useful if media used in biological lessons exist only in one copy, which is often the case for models (models and hands-on activities are seen as a motivating factor in the learning process [Berck, 2001; p. 57]). Thus, learning at workstations might enhance students' motivation and interest and might increase their cognitive achievement, as outlined above. However, recent studies have linked student-oriented learning environments not necessarily to an overall higher cognitive learning outcome but rather to conventional approaches (Randler & Bogner, 2002; Schaal & Bogner, 2005). Potential reasons for those unexpected results could lie in the lack of experience in hands-on activities as well as open or learner-centred approaches which as unfamiliar environments may cause anxiety and thus inhibit learning success (Kagan & Fasan, 1988; Bohl, 2001; Randler & Bogner, 2002). Any specific introduction to the new learning environment may reduce this 'novelty factor' (Kubota & Olstad, 1991; Orion & Hofstein, 1994). This could consist of a prior lesson about the subject matter to create basic knowledge about the specific subject. To prepare the students to the specific type of learning environment, a short explanation of the learning situation may help to reduce the unfamiliar feeling. Subsequent regular practice in student-oriented curricula might then help to extinguish the 'novelty factor' and to train self-directed learning and social competences.

Many comparison studies of teacher-centred versus student-oriented learning environments have produced controversial results with no consistency in the explanation of effects of different learning environments with regard to achievement and motivation scores. This study does not intend to add to this controversy, but to maintain the ongoing discussion on the importance of the integration of student-oriented learning environments into conventional syllabi. Our educational approach dealt with the subject of bird flight. Usually, bird issues are taught in teacher-centred approaches with a few demonstrated experiments but without any hands-on activities. However, theory of how 'lift' is produced is difficult to understand: A common and simple explanation still builds on the Bernoulli-principle which does not correctly explain it in all aspects (Anderson & Eberhardt, 2001; for other explanations see e.g. Anderson & Eberhardt; Weltner, 2001). Niermann (1989) found a widespread usage of the Bernoulli-principle in schoolbooks and by teachers, and even Physics students comprise false understandings of this phenomenon. Although we do not claim to cover all possible conceptions of students about this phenomenon, hands-on experiments might awake the interest and favour further engagement in this subject compared to conventional approaches with experimental demonstrations. In the present study, workstations with hands-on choices showing the preconditions of bird flight are implemented (see Appendix B for details). Before conducting the learning at workstations, the students attended a preliminary lesson about bird's anatomies and specific preconditions for flying. To date no investigation has examined whether learning at workstations about bird flight may lead to a better understanding of this difficult topic, as compared to traditional approaches. Additionally, it is not known whether an introduction of the workbook guiding through the workstations has any influence on the learning and motivation of students. Thus, the objectives of our study were to investigate (1) the cognitive outcome and the motivation of the students following a student-oriented in comparison to a teacher-centred educational approach and (2) the impact of a specific introduction phase into the 'new' learning environment by comparing the student-oriented approach with and without such an introduction. We hypothesised that (i) a student-oriented approach (learning at workstations and hands-on activities) would enhance cognitive achievement and motivation scores; and (ii) that higher cognitive effects would be reached when an introduction phase is included.

Methodology

326 secondary 6th graders of Bavarian schools participated in this study. They were students of a variety of secondary schools (highest stratification level: 'Gymnasium'), in total 12 classes. The average age of the participants was 12.48 years (±0.50 SD). The study followed a quasi-experimental design (Table 1): Complete classes followed a specific instruction. Two out of the three instructions dealt with learning at workstations, the third was a conventional teacher-centred approach; one group served as a control group for the test assessment and other potential external influences (Lienert & Raatz, 1998).

[Insert Table 1 about here]

In all three instructional interventions, the classes attended a regular classroom lesson on basic issues about birds: the anatomy of birds and their specific adaptations for flying (see Appendix A). This 'pre'-lesson gave an introduction to this previously to 6th graders unknown subject. To prevent differences in the subject to be taught in the 'pre'-lesson, the Biology teacher followed exactly the learning goals given by the researchers. The following lesson differed for the three treatment groups: In instruction-1 (G-1, n = 176), the students worked in groups of three to five for 90 minutes at the workstations in the classroom, guided by a workbook. The groups assembled by free choice. In total, eight workstations were developed (Appendix B), including three optional stations for fast working groups. At the workstations, the students had to raise hypotheses, conduct and observe experiments, discuss the results and record them in the workbook. The workbook consisted of one 'chapter' for each workstation: first, the workstation is shortly described, followed by tasks and questions on the appropriate workstation. Generally, the students first had to raise hypotheses, then conduct an experiment and record the data or observations, and, finally, discuss the results (see Appendix C for an example). Thus, the workbook is guiding the students through the stations without any further instruction. Participating pupils received the workbooks immediately before starting with the workstations. Additional information was available on a designated 'information desk', if needed (the students signed this up in their workbook, if used). Instruction-2 (G-2, *n* = 30) was similar to G-1 except for an additional introduction of the workbook: Subsequent to the initial lesson, the students could familiarise themselves for 15 minutes with the workbook. After that, the workbooks were collected by the teacher. The procedure for learning at the workstations followed the G-1 model (as described before). In instruction-3 (G-3, *n* = 93), the Biology teacher taught the content of the workstations for 90 minutes using a conventional approach. All teachers of G-3 followed the same curriculum as was the case in the learning at workstations. Guidelines and materials of the workstations were made available to teachers thus permitting a similar procedure to that of G-1 and G-2: The students had to raise hypotheses, observe the experiments done by the teacher and explain the results. The only difference to G-1 and G-2 consisted in the teacher's role as a guide for the learning process.

Due to organisational reasons of the participating schools, the sample sizes of G-1, G-2 and G-3 differ. However, in our quasi-experimental design we may compare the groups due to the same age-group, grade and level.

A knowledge questionnaire and a motivation assessment battery were administered. The knowledge questionnaire consisted of 17 multiple choice questions (see Appendix D) and one semi-open question. All items specifically covered the lesson's contents about bird flight. Although an identical knowledge test was applied three times, potential resultant bias was avoided by different orders of the questions; additionally, the students were unaware that the test would be repeated (e.g. Bogner, 1999). The pre-test (T-1) was implemented one week before the introductory lesson to assess the previously existing knowledge of the students; the post-test (T-2) was applied immediately after the 90-minutes implementation; a retention-test (T-3) was administered six weeks after the post-test to measure the long-term learning effect of the intervention (Bogner, 1998). The students were aware that responses to our questionnaires would have no effect on their marks.

Four subscales of the 'Intrinsic Motivation Inventory' (IMI), namely 'Interest & Enjoyment', 'Perceived Competence', 'Perceived Choice' and 'Value / Usefulness' have been employed (e.g., Deci *et al*., 1994; Ryan *et al*., 1991). In all items the original phrase 'this activity' was substituted by either 'the working on learning stations' (G-1 and G-2), or 'the lesson about bird flight' (G-3). We used the German version of the IMI which was previously applied successfully, for instance, by Girwidz *et al*. (2006). A 5-point Likert response scale was used. The motivation test was implemented immediately after the knowledge post-test to assess the actual motivational situation of the students after the interventional phase.

A control group (*n* = 27) with no instruction was included to take any test effects into account. All questionnaires (except the motivation scale) were applied in the same time frame as the experimental groups (G-1, G-2 and G-3). They received no teaching in the subject of birds and bird flight before or during the test assessment.

The statistic analyses were conducted with SPSS 14.0. The multiple choice questions as well as the semi-open question were analysed with correct answers scored unity, incorrect ones zero. The range of item difficulty (= % of correct answers, Bortz & Döring, 2001) was normal distributed for the pre-, post- and retention-test (Shapiro-Wilk, $p_{pre} = .27$; $p_{post} = .73$; $p_{retention} = .88$). Reliability analyses revealed low scores for the knowledge tests (Cronbach's $\alpha_{pre} = 0.38$; $\alpha_{post} = 0.58$; $\alpha_{retention} = 0.52$). However, knowledge tests are in principle difficult to test for reliability (Lienert & Raatz, 1998, [p. 214]). Though, reliability coefficients less than 0.6 can be used for differentiating groups (Lienert & Raatz, [p. 213]). Content validity of the knowledge test is given due to the curriculum based subject. Furthermore, all knowledge items were constructed according to the learning goals of the intervention. Also, criterion validity is fulfilled: According to the participating teachers, the content of the intervention and the knowledge test is representative for the curriculum. The reliability of the motivation battery showed a Cronbach's α of 0.94.

Since the sum scores over the knowledge items were not normally distributed (Kolmogorov-Smirnov with Lilliefors Significance Correction, $p < 0.001$, in T-1, T-2 and T-3), we used non-parametric tests and box plots as graphic output. We presume that the different sample sizes and the quasi-experimental design of the study affected the not-normal distributed data. For investigating the first objective, the knowledge and motivation data of G-1 was compared with G-3; the second objective was to investigate the influence of an introduction phase into the workbook by comparing G-1 and G-2.

Results

No statistically significant group differences were found in the pre-test achievement scores (Kruskal-Wallis-Test[2], Chi-Square[3] $_{(T-1)} = 2.867$; df = 3; $p = 0.413$), but different gains in the

[2] H-test of Kruskal-Wallis is used for the comparison of more than two independent samples. For not normally distributed data, it substitutes ANOVA and ANCOVA (Zöfel, 2002, [p. 114]). The Kruskal-Wallis test was applied to test first if any differences exist in the pre-test results. For further pair-wise analyses, the U-test of Mann-Whitney for not normally distributed data was used (Zöfel, [p. 103]).

post- and retention-test (Kruskal-Wallis-Test (KS), Chi-Square$_{(T-2)}$ = 83.089 and Chi-Square$_{(T-3)}$ = 66.026; df = 3; $p < 0.001$, in all cases). A post-hoc test (e.g. Bonferroni correction) was not applied because of Bender and Lange (2001 [p. 1238]): 'If the global null hypothesis is rejected proceed with level α tests for the (...) pair-wise comparison'. Subsequent pair-wise analyses of the groups (Figure 1; Table 2) showed for teacher-centred lessons (G-3) significantly higher scores in the post- and the retention-test compared to G-1. G-3 and G-2 differed not significantly in the retention-rest results. Obviously, both treatments led to the same long-term learning effect. Comparing the two groups that worked at the learning stations without an introduction (G-1), or with introduction (G-2), group G-2 scored higher both in the post- and the retention-test than G-1. Apparently, the group G-2 (with an introduction in the workbook) learnt more than G-1.

[Insert Figure 1 about here]

[Insert Table 2 about here]

As expected, no significant differences were found within the control group in achievement scores in all three test assessments (Table 3; Figure 1). Thus, repeated item battery application did not provide any change in the test results. However, all treatment groups (G-1, G-2, G-3) showed a significant short-term learning outcome which is in all three treatment groups the students learnt something. Comparing the post-test with the retention-test in G-2 and G-3, the scores do not differ. An unexpected outcome is a significant increase of achieved scores in the retention-test in G-1, compared to the post-test within this group (see discussion).

[Insert Table 3 about here]

[3] Chi-Square value is reported in addition when computing the Kruskal-Wallis test with SPSS 14.0.

The 'Intrinsic Motivation Inventory' (Figure 2; Table 4) revealed between-groups differences in the subscales 'Interest / Enjoyment' (KS[4], Chi-Square = 29.516; df = 2; $p <$ 0.001), 'Perceived Choice' (KS, Chi-Square = 35.395; df = 2; $p < 0.001$) and in the subscale 'Value / Usefulness' (Chi-Square = 21.821; df = 2; $p < 0.001$). No significant difference was found in the subscale 'Perceived Competence' (KS, Chi-Square = 1.861; df = 2; $p = 0.394$).

[Insert Figure 2 about here]

[Insert Table 4 about here]

Discussion

The main outcomes of this present study were: (1) students learnt more in teacher-centred lessons (traditional approach) than at the workstations although in the latter they stated higher motivation scores during their work; (2) students attending a preliminary introduction into the workbook scored higher in the cognitive achievement test than those without an introduction phase.

In all three treatment groups we observed a substantial learning effect, while the students of the teacher-centred lesson achieved significantly better than the others. This contradicts many studies comparing teacher-centred and student-oriented learning environments, as for instance in a study of Randler and Bogner (2002) involving bird identification skills no significant difference in the hands-on compared to the conventional approach was found. In a follow-up study of Randler and Bogner (2006) using the same subject set the students of the hands-on approach scored higher in the post- and the retention-test compared to the students of the conventional approach when a reduced number of bird

[4] Before conducting pair-wise analyses with the Mann-Whitney U-test, H-test of Kruskal-Wallis was applied to test if any differences at all exist between the three groups.

species had to be identified. Thus, it may provide an advantage to reduce the total amount of subject matter of workstations. As regards on this study, a reason for the significantly lower achievement scores of the workstation groups may lie in the mere number of learning stations – according to the principle 'less is more' (slogan in Benchmarks for Science Literacy, AAAS, 1993 [p. 320]). The students might have been too stressed to accomplish all the stations and thus, insufficiently concentrated on single stations to ensure successful learning. Another reason could lie in an desire of students of rushing through the different learning stations in order to accomplish all learning stations within a minimum of time and to 'be free' for the remaining time. Furthermore, demands upon students' cognition could have been excessive within such learning at workstations by posing hypotheses, dealing with the experiments and explaining the results (Schaal & Bogner, 2005) without any guidance on the part of the teacher. Hence, they learnt less than in the teacher-centred approach.

No difference existed in the long-term learning effect between the teacher-centred group and the group with a specific introduction into the learning stations. This contrasts with other studies (e.g. Schaal & Bogner, 2005; Scharfenberg, Bogner & Klautke, 2007). It seems that an introduction into a 'new' learning environment leads to a similar long-term cognitive outcome as a teacher-centred approach although the actual short-term outcome was lower in a student-oriented approach. Surprisingly, the students of G-2 and G-3 did not forget anything, as a comparison of post- and the retention-test scores demonstrate. This is an unexpected result when we consider that normally not all information gained is transferred from working memory (or 'short-term memory') into long-term memory (Driscoll, 2005 [p. 75]). Loss of information from working memory and the process of transfer into long-term memory can be reduced by 'rehearsal' and 'encoding' of the information (Driscoll [p. 88]). It could be that the experimentation and the hands-on activities at the learning stations provided the 'rehearsal' and the 'encoding' of the subject; and the teachers of the conventional approach might be 'good' teachers with a high student-learning success.

Although the students working on learning stations learnt less, they reported a higher overall motivation than the students attending the traditional approach. In detail, the students scored the interest and enjoyment higher; they perceived the learning at workstations as valuable and useful; and they reported a higher perceived choice compared to the teacher-centred curriculum. This result is not surprising given the fact that open learning environments, such as learning at workstations, may provide an overall positive and self-determined learning situation if a learner's autonomy is supported (Black & Deci, 2000). In this study, the students conducting the workstations could work autonomously and self-directed in a social atmosphere: they could choose the order of the stations and the pace, and discuss the experiments with group members. According to Hofstein and Lunetta (2003), laboratory work (they define 'science laboratory work' as learning experiences in which students interact with materials and/or with models to observe and understand the natural world) is an important medium to stimulate and to increase interest and enjoyment and to motivate students to learn science.

We found no significant differences in the subscale 'perceived competence' in either of the treatment groups. The groups who worked on the learning stations did not feel more competent than the students of the teachers-centred approach. One reason could be that learning at workstations is still an uncommon learning environment, as the students are preoccupied with technical and manipulative details, with handling the experiments and hands-on activities (Hofstein & Lunetta, 2003). As a consequence, this 'pre-occupation' could lead only to an average of the 'perceived competence' and, in addition, prevent meaningful learning.

Finally, the huge variance within the mean scores in G-3 (Figure3) just may reflect a normal classroom situation where a few students show very high as well as very low motivation scores and the majority ranges somewhere in the middle (all scores appear from 1 to 5). An argument for this interpretation delivers the distribution of G-1 and G-2 where the variance does not spread over the whole scale: Even lowest indications rank higher than 1 (the lowest possible score) which is that learning at workstations apparently motivates better.

The second objective of this study was to examine whether an introduction into the learning stations could enhance the cognitive achievement. Therefore, one group (G-2) was allowed to familiarize itself with the workbook for up to 15 minutes in an initial lesson. As a result, the group with such an introduction (G-2) outscored the one without (G-1). Although the sample size of G-2 was low, the better achievement might be explained by the familiarizing phase. Since the subject of bird flight within the learning stations was new to all participating students, a 'novel environment' (e.g. Orion & Hofstein, 1994) may distract students from the subject itself because of the cognitive novelty, the geographical novelty (e.g. during a field trip) and the psychological novelty (Orion & Hofstein 1996). Hofstein and Rosenfeld (1996) found that proper preparation could maximize familiarity and thus facilitate meaningful learning during a field trip. Nonetheless, we must exercise some caution in explaining this result as a reduced 'novelty effect' because of the preliminary introduction into the workbook. However, it seems reasonable to prepare students for any activities which go beyond the traditional classroom approaches.

Another unexpected outcome lied in the group G-1 scoring which was higher in the retention-test compared to the post-test. This result might simply reason in a hidden intervention by one specific teacher (Scharfenberg *et al.*, 2007). An argument for this may the analysis of the group G-1 with regard to a class-level where two classes raised the retention-test achievement scores over the significant level. By excluding those specific classes, the significant difference between retention-test and post-test in G-1 disappeared (G-1: $n = 117$; Wilcoxon-test: $Z = -0.154$; $p = .877$). Furthermore, those two specific classes derived from the same school taught by the very same teacher. As the retention-test was handed out six weeks after the post-test, this specific teacher could have added an additional repetition of some aspects of birds and bird flight. Thus, although we prepared the teachers and claimed the importance to follow the specific guidelines, one can never prevent some participants of a study from ignoring and/or disregarding the instructions of the researchers.

Considering our initial research questions, we can only partially accept the first hypothesis. Whereas the overall motivation was higher in the student-oriented approach, the short-term learning outcome was lower than in the teacher-centred approach. However, an introduction into the student-oriented approach leads to a similar long-term learning effect than in the traditional approach. The second hypothesis could be fully accepted within the frame of this study. Future prospects comprise qualitative analyses of the workbooks in terms of changes in concept learning of students about bird issues.

Educational Implications

Student-oriented learning environments are perceived to be more interesting, enjoyable and valuable than teacher-centred approaches. Although the students actually learnt less in terms of a short-term learning effect, an introduction into the 'new' learning approach leads to similar long-term learning outcomes as it does the traditional approach. Hence, it is worthwhile to include student-oriented approaches and open learning environments in the curriculum. According to Killermann (1998), one never can expect to achieve best results in all areas with only one single 'method'. He suggests a 'mixture of methods' may realise optimal effects in terms of the performance and in terms of the attitude and interest in the subject.

Learning as an active process of construction (Greeno *et al*., 1996) should include inquiry-based components (Häußler *et al*, 1998 [p.155]). In this sense, 'inquiry' is used (1) as *content understanding* and (2) as *abilities* (Bybee, 2000, in Hofstein, 2001). Whereas the content *understanding focuses* on the subject matter, the *abilities* include scientific skills like raising questions and hypotheses, designing and conducting experiments, explaining and reflecting the results (Bybee, 2000). These skills might be realised by self-conducted experiments (e.g., Finn, 2002; Wright, 1992). Beside scientific skills, laboratory activities may enhance social skills or key competences as well (for definition of 'laboratory activities' see above) (Hofstein & Lunetta, 1982; Lazarowitz & Tamir, 1994). However, Bohl (2001) found only slight propagation of 'modern' forms of teaching in south-western Germany. In addition, he reports a lack of training in learner-centred and 'open' instructional concepts. Often, teachers claim excessive time consumption, inadequacy of space and equipment, or difficulties in performing assessments (Angeli, 2002). Therefore, we suggest frequent training in student-oriented learning environments, in particular in the use of workstations. Not only students but teachers too may adapt to the implementation of learner-centred teaching and thus reduce the perceived inadequacies. Active learning and support of a student's autonomy may enhance students' achievement and psychological development (Black & Deci, 2000).

Based on our results (and in accordance with the literature) various aspects should be regarded before, during and after the implementation of a student-oriented learning environment:

- A limitation of topics taught but doing this in depth and with care might exceed a learning success compared to a rather large number of topics (Hofstein, 2003). For instance, learning stations should consist of just a few but meaningful stations rather than of a large number of stations.

- Prior knowledge in the subject matter could awaken and maintain interest (e.g. Csikszentmihalyi, 1987). As regards on the learning at workstations, it could be worthwhile to conduct a 'pre'-lesson about the topic and then consolidate the acquired knowledge in the learning stations.
- As reasoned above, a mixture of methods as well as variation and diversity of tasks are more likely to facilitate an interest in learning a certain subject (Ames, 1992). For example, one learning station may involve experiments whereas another learning station consists of processing a text. Variation in tasks might also be obtained by altering e.g. the auditory and the visual channel at single learning stations.
- Also, Van den Akker (1998) suggests that experimentation should be intertwined with reflection to increase understanding and competence. It might be difficult to interrupt the learning at workstations for reflection on some topics because of the different progress of the groups. However, a 'post processing' of the learning stations might consolidate the outcome. This could be, for example, a presentation of the results of the groups, a discussion or the correction of the workbook.

To give a detailed list of all features which should be considered when working with learning stations would go beyond this study. However, we suggest conveying the theory and practice of the implementation of learning stations to 'Pre-service teachers' as well as to 'In-service teachers', e.g. in vocational trainings for teachers.

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Appendix A. Content of the pre-lesson.

The adaptations of birds on their habitat: the air

- Feathers, wings
- Special morphology of the sternum
- Special anatomy of the lungs
- Reduction of weight: Air-filled bones and reduction of inner organs:
  - ⇒ Female birds have only one ovary
  - ⇒ No bladder but a cloacae
  - ⇒ No teeth

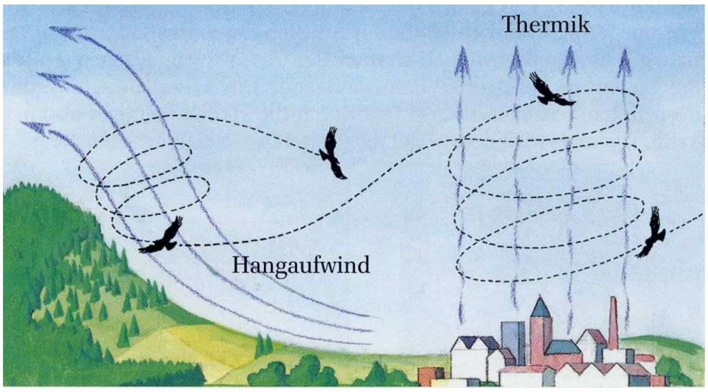
***Appendix B.** The learning stations and the expected learning outcome (the learning stations F, G and H are optional).*

Short description:	**Focused outcome:**
A) Comparison of wing profiles and the 'postcard experiment'	A) All wings are arched
B) Experiments with an aerofoil model	B) How is lift produced
C) Experiments with an air-track model	C) Aerodynamic differences of different formed bodies
D) Experiments with cold and warm air	D) Warm air is raising
E) Description of one bird	E) Focused view on one bird
F) Investigating a feather	*F) Morphology of a feather*
G) The flying ability of paper-airplanes	*G) An air stream is the precondition to produce lift*
H) The comparison of bones of birds and mammals	*H) Different anatomy of the bones*

Appendix C. *Example of one 'chapter' in the workbook (experiment with warm air).*

Station D: Gliding of birds

In addition to the active form of flying, birds also fly in a passive mode by using natural aerodynamic winds for lift. Gliding is a energy-saving type of flying, because the bird hardly has to flap with the wings. Nevertheless, gliding is not always possible: Certain preconditions have to be fulfilled!



V

1. Drop a down through the glass tube! (The candle is not lit, yet)

____

____

2. Lit the candle. Now, drop the down again through the glass tube!

____

____

3. Try to explain the result:

____

____

Appendix D. Test item examples.

I) A common feature of the wings of all birds is:

- ☐ They have no thumbs.
- ☐ They cannot be stretched completely.
- ☐ They have a wide wing panel.
- ☐ The cross section is narrow.
- ☐ The cross section is arched. [correct]

II) On the picture above you can see an aerofoil model. Inside are movable balls. What do you think will happen, if the air generator is turned on?

- ☐ The balls will be lifted mainly because on of an overpressure.
- ☐ The balls will be lifted mainly because on of a negative pressure. [correct]
- ☐ The air-stream presses the balls bottom-up.
- ☐ The balls won‘t move, because the aerofoil is not flapping like a bird.
- ☐ The balls will float in the middle of the wholes.

III) One of the following statements is wrong. Mark it with a cross!

For gliding, birds need ...

- ☐ … warm, ascending air
- ☐ … ascending air at mountainsides
- ☐ … huge wings
- ☐ … plenty of energy [correct]
- ☐ … the tail feathers for navigation

Table 1. The experimental design (the external control group is not shown).

	Instruction-1 (G-1)	Instruction-2 (G-2)	Instruction-3 (G-3)
45 min	'Pre'-lesson	'Pre'-lesson + introduction into the workbook	'Pre'-lesson
90 min	Learning at working stations with workbook	Learning at working stations with workbook	Teacher-centred lesson (contents of the working stations)

Table 2. *Between-groups comparison of knowledge scores in the post- and the retention-test (Mann-Whitney U-Test, asympt. sig., 2-tailed).*

Groups*	G2		G3		Control	
	Z	*p*	*Z*	*p*	*Z*	*p*
			Post-test			
G1	-2.129	0.033	-7.578	0.000	-3.759	0.000
G2	–		-3.416	0.001	-4.424	0.000
G3			–		-6.752	0.000
			Retention-test			
G1	-2.176	0.030	-5.339	0.000	-5.352	0.000
G2	–		-1.547	ns	-4.940	0.000
G3			–		-6.764	0.000

* $n_{G1} = 176$, $n_{G2} = 30$, $n_{G3} = 93$, $n_{control} = 27$

Table 3. *In-group comparison of the knowledge scores (Wilcoxon-Test, asympt. sig., 2-tailed).*

	Pre-test vs. Post-test		Post-test vs. Retention-test		Pre-test vs. Retention-test	
	Z	*p*	*Z*	*p*	*Z*	*p*
G1 (*n* = 176)	-9.266	0.000	-2.746	0.006	-10.027	0.000
G2 (*n* = 30)	-4.495	0.000	-0.556	ns	-4.560	0.000
G3 (*n* = 93)	-8.280	0.000	-1.873	ns	-8.143	0.000
Control (*n* = 27)	-1.090	ns	-0.691	ns	-0.053	ns

Table 4. *Between-groups comparison of subscales of the 'Intrinsic Motivation Inventory' (Mann-Whitney U-Test, asympt. sig., 2-tailed).*

	Interest / Enjoyment		Perceived Choice		Value / Usefulness		Perceived Competence	
Group-wise comparison	*Z*	*p*	*Z*	*p*	*Z*	*p*	*Z*	*p*
G1 vs. G2	-1.166	ns	-0.131	ns	-0.899	ns	-0.763	ns
G1 vs. G3	-5.055	0.000	-5.655	0.000	-4.629	0.000	-1.267	ns
G2 vs. G3	-3.692	0.000	-4.012	0.000	-2.193	0.028	-0.221	ns

FIGURE CAPTIONS

Figure 1. *Knowledge test results of all experimental groups and the external control group.*

Figure 2. *'Intrinsic Motivation Inventory' test results.*

FIGURE 1

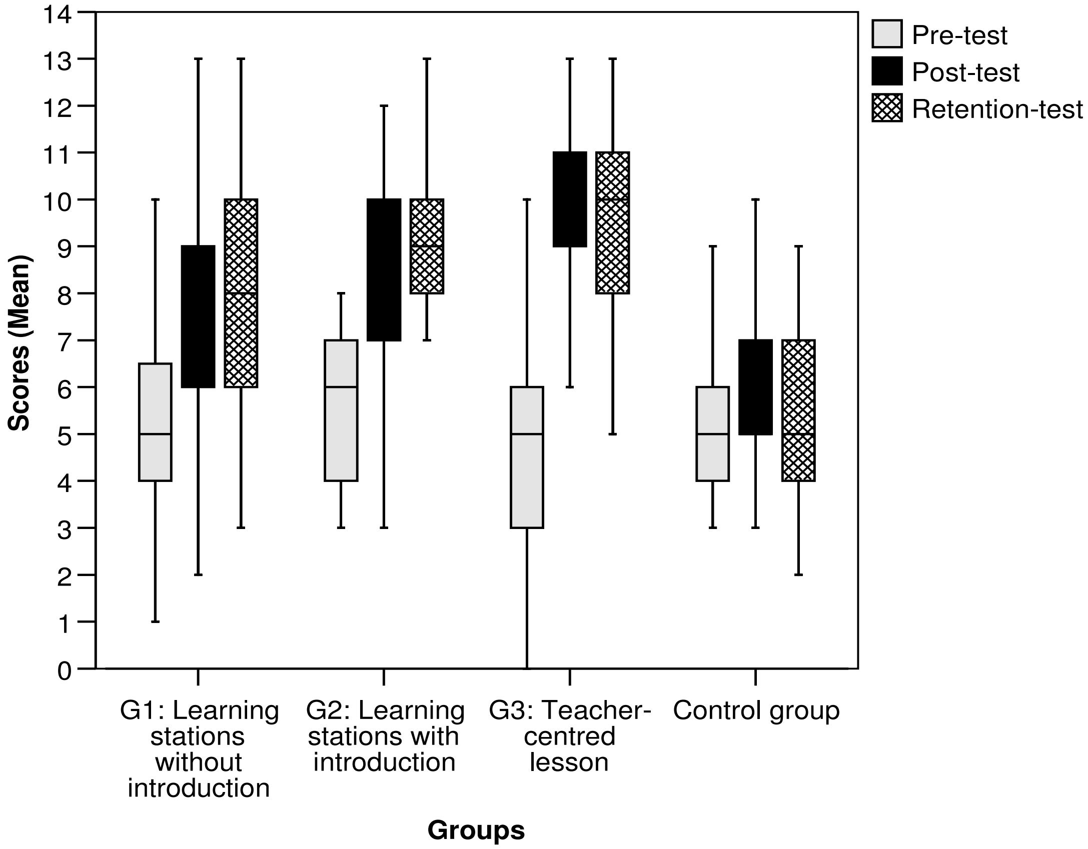
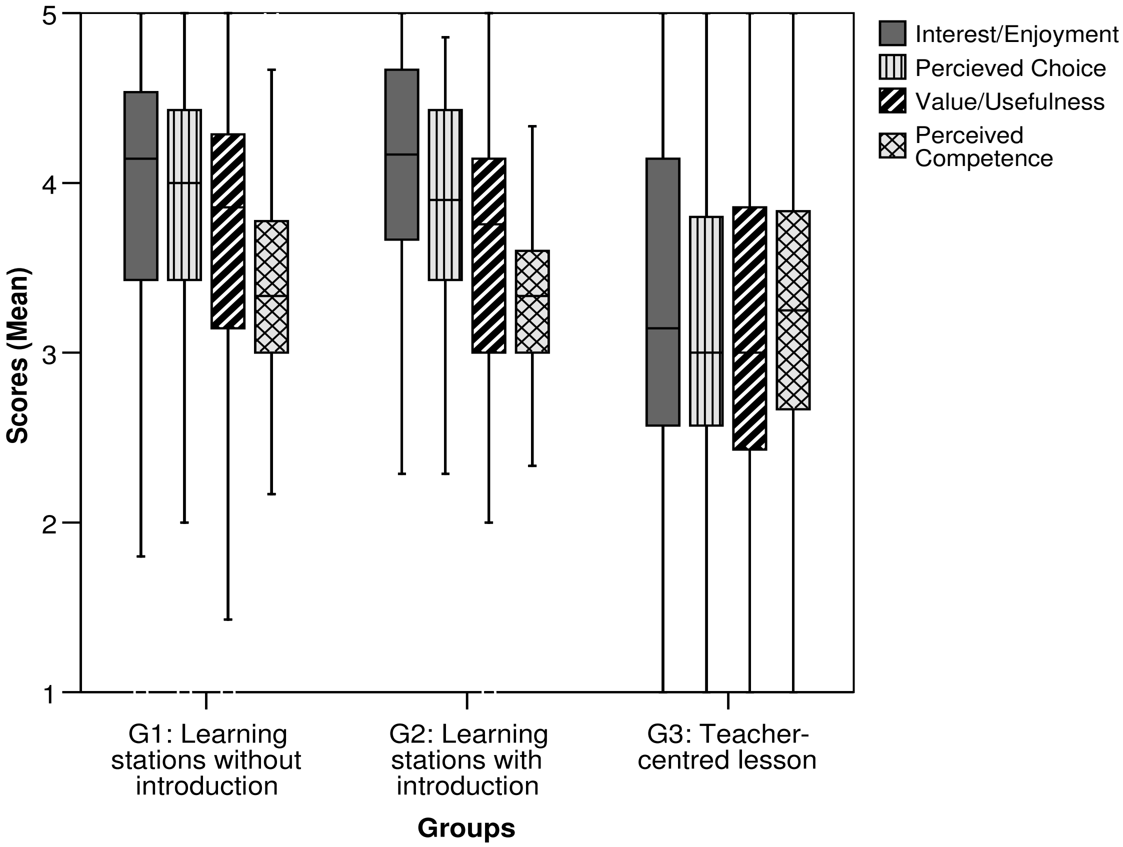

Scores (Mean)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Pre-test
Post-test
Retention-test
G1: Learning stations without introduction
G2: Learning stations with introduction
G3: Teacher-centred lesson
Control group
Groups

FIGURE 2


5
4
3
2
1
Scores (Mean)
Interest/Enjoyment
Percieved Choice
Value/Usefulness
Perceived Competence
G1: Learning stations without introduction
G2: Learning stations with introduction
G3: Teacher-centred lesson
Groups

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