

## A category-based video-analysis of students' activities in an out-of-school hands-on gene technology lesson

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**A category-based video-analysis of students' activities in an out-of-school hands-on gene technology lesson**

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**Title:**

**A category-based video-analysis of students' activities in an out-of-school hands-on gene technology lesson**

Running head:

Category-based video-analysis of students' lab activities in a gene-technology lab-lesson

Keywords:

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## TITLE

A category-based video-analysis of students' activities in an out-of-school hands-on gene technology lesson

## ABSTRACT

Our research objectives focussed on monitoring (i) students' activities during experimental teaching phases in an out-of-school gene technology lab; (ii) potential relationships with variables such as work group size and cognitive achievement. Altogether, we videotaped 20 work groups of A-level 12<sup>th</sup> graders (N = 67), by continuous recording of their lab-work phases. Subsequent analysis revealed nine categories characterizing the students' most relevant activities. Intra- and inter-observer objectivity as well as reliability scores confirmed the good fit of this categorization. Based on the individual time budgets generated, we extracted four clusters derived from students' prevalent activities. A cross-tabulation of two cluster analysis methods independently used showed a high level of agreement. Clusters were labelled as (i) 'all-rounders' (members of which applied similar portions of time to the main activities), (ii) 'observers' (members' dominating activity focussed on in-group observation of the lab-work), (iii) 'high-experimenters' (members predominantly engaged in specific hands-on activities), and (iv) 'passive students' (members mainly engaged in activities with no experimental relation). Particularly, we found members of clusters 1 and 2 in four-person work groups while members of clusters 3 and 4 were prevalent in three-person groups. During the educational intervention, students of all clusters improved their cognitive achievement on a short-term and a long-term schedule. However, only the 'all-rounders' revealed a high level of persistent (long-term) knowledge with no decrease rate at all. We draw conclusions with respect to work group sizes as well as to organisational aspects of experimental lessons.

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## INTRODUCTION

Hand-on experiments at school are generally regarded as important for facilitating any learning in science education by providing experiences to students otherwise unavailable in learning science (Hofstein & Lunetta, 2004). On the other hand, experiments in classrooms differ from those in real science. They typically show less variability as well as time and resource limitations (e.g. Füller, 1992). Additionally, in the context of gene technology, legal frameworks may prevent experimentation at school: In Germany, as the law stands, for instance, working with recombinant DNA is usually not allowed in school labs. Universities, museums, science centres, or industrial companies therefore provide dedicated educational laboratories in the field of molecular biology. They typically offer experimental workshops as out-of-school opportunities for hands-on experience (e.g. Maxton-Küchenmeister & Herrmann, 2003). Science education in those labs may also provide authentic hands-on experiences without the typical shortcomings of the classroom (e.g. Markowitz, 2004). In this context, authentic experiments are seen as activities representing 'ordinary day-to-day actions of the community of the practioners' (Hodson, 1998, p. 118). Nevertheless, the gain of such out-of-school experimental lessons is a topic on the current agenda in science education research, although effectiveness of lab work itself frequently has been investigated (e.g. Harlen, 1999; Hofstein & Lunetta, 2004). Additionally, in contrast to physics education where variables such as students' cognitive achievement have been assessed (e.g. Heard, Divall & Johnson, 2000; Semper, 1990) comparable studies of gene technology laboratories do not yet exist.

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Based on this rationale, we offered a daylong teaching unit with experiments conformant with the current syllabus of 12<sup>th</sup> grade A-level in biology (Bavaria, Germany). Our specific module 'marker genes in bacteria' consisted of a sequence of four experiments:

- (a) transformation of bacteria using a recombinant plasmid coding for the green fluorescent protein (GFP, Tsien, 1998) commonly used as marker protein in molecular biology (e.g. Tromans, 2004);
- (b) isolation of the plasmid transformed,
- (c) restriction analysis of the plasmid with selected enzymes and
- (d) visualisation of students' own results by agarose gel electrophoresis.

All experiments were authentic and followed the criteria of 'authentic inquiry' (Chinn & Malhotra, 2002, p. 118). For instance, students carried out relatively complex controls by testing the survival rates of host bacteria during transformation.

We evaluated our experimental module with regard to cognitive achievement (published elsewhere: Authors, 2006). However, any complete evaluation study also requires 'information and insight about what is really happening when students engage in laboratory activities' (Hofstein & Lunetta, 2004, p. 38). Videotaping is generally seen as an appropriate tool to monitor students' activities during the experimental phases of a teaching unit. (e.g. Seidel, 2005)

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Any lab-work in gene technology education generates new as well as complex situations for the students involved. In a lesson-phase prior to hands-on activities, students have to make predictions about potential experimental results, and after experimentation, they have to match the results to their previously formulated hypotheses. During the experimental phase, they have to read instructions and to operate equipment unknown to them (e.g. variable micropipettes or table centrifuges). Any lack of basic experimental skills might prevent successful lab-work (Bryce & Robertson, 1985) and, in consequence, might decrease any learning outcome. According to authors such as Dunn and Boud (1986), Hodson (1998), and Lunetta (1998), we included a controlled pre-lab exercise in order to assure such basic skills. The pre-lab phase (45 min) consisted of an introduction to the working place by the teacher

1  
2 coupled with students' handling of all relevant equipment. Furthermore, in hands-on phases  
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4 students generally have to interact and to cooperate within the peer groups accepting specific  
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6 role requirements within the group work. At least, they have to discuss the procedures to be  
7  
8 done and their progress in work. In consequence, experimentation together with others is  
9  
10 regarded as a form of cooperative learning (CL) in science teaching (e.g. Tanner, Chatman &  
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12 Allen, 2003). CL has the potential to provide a framework for promoting scientific process  
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14 skills (Sherman, 1994). Additionally, better awareness of the objectives to be reached by  
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16 experimentation may be achieved (Stamovlasis, Dimos & Tsaparlis, 2006). Therefore,  
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18 according to Johnson, Johnson and Smith (1991) we included some of the important  
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20 components of CL in the experimental phases:

- 21  
22 (a) all resources of a working place had to be shared;  
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25 (b) the experimental tasks were generally too difficult to be done individually;  
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28 (c) the pre-lab phase gave the group members opportunities to accustom themselves to  
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30 collaboration, independently of the later tasks ;  
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33 (d) we requested participants to change places at the shared working table in order to  
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35 facilitate learning opportunities to all group members;  
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38 (e) we included a variety of pauses in our module, which allowed time for reflection  
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40 on the processes within the working group.

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42 Any analyses of lab-work phases are challenging due to their complexity (Niedderer,  
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44 et al., 2002). Any research going beyond this has to apply questionnaires or to observe  
45  
46 students directly. Just a few scales have dealt with the context of social interactions, for  
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48 instance, the Laboratory Interaction Categories (Ogunniyi, 1983) and the Science Laboratory  
49  
50 Interaction Categories (Kyle, Penick & Shymansky 1979; Okebukola, 1985). Similarly, a few  
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52 have dealt with the experimental lesson as a whole, for instance, the Laboratory Analysis  
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54 Inventory (e.g. Tamir, 1989) originally developed for the analysis of laboratory manuals  
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(Tamir & Lunetta, 1978) and the Laboratory Program Variables Inventory (Abraham, 1982). Nevertheless, authors have reported three major limitations by using questionnaires (Stigler, Gonzales, Kawanaka, Knoll & Serrano, 1999): (a) different perceptions of complex situations by different persons; (b) low accuracy of questions with regard to given time restrictions; (c) proximity of questionnaires to just a specific set of responses. Direct observations might overcome some of those limitations (e.g. Stigler, et al., 1999). For instance, they might take into account the processes in the learning environment independently of the test persons. Nowadays the state of the art focuses on video surveys including both qualitative and quantitative data collection (Jacobs, et al., 2003). For example, Niedderer et al. (2002) provided a Category-Based Analysis of Videotapes for analysing lab work in physics education. Nevertheless, any categorisation with regard to students' experimentation in the area of gene technology is lacking.

The objectives of our video study were

- (a) to categorise students' activities during the experimental phases of a teaching unit;
- (b) to explore potential relations of their activity pattern to variables such as prior experiences in experimentation, prior achievement in biology, interest in gene technology, and work group sizes as well as cognitive achievement.

## METHODOLOGY

### Sample and videotaping

Altogether, 67 secondary schools students (12<sup>th</sup> grade, highest stratification level ['Gymnasium']) participated in our video study. All (24 boys, 43 girls, average age 18.0) were enrolled in a regular A-level Biology classroom course ('Leistungskurs'). The sample represents a sub-sample of a main study in our educational laboratory ([Scharfenberg, Bogner & Klautke, 2006](#)). All students had already successfully completed a regular half-year A-level

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1 genetics course before participating in our lab-lesson. The videotaped students formed one 2-  
2 person, eleven 3-person, and eight 4-person work groups by their own choice. We videotaped  
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4  
5 all 20 groups in a continuous recording (average duration 51.7 min,  $SD = 9.9$ ) by focal  
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8 sampling during their experimental phases of the lab-lesson (Martin & Bateson, 1986).  
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### 10 **Categorisation**

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12 We categorized the observed activities of each student during his/her lab-work phases and  
13 analysed the individual time budgets (e.g. Figure 1). In principal, our categorisation followed  
14 the criteria of content analysis (Bos & Tarnai, 1999), but we partially adopted also relevant  
15 results of physics education (e.g. Niedderer, et al. 2002; Seidel, 2005). We employed nine  
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21 categories for a complete description of the observed activities (Table 1).

22 [Insert Table 1 here]

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24  
25 We pre-trained two observers in the use of our categorization system, using the  
26 software Videograph (Rimmele, 2002). We assessed intra-observer and inter-observer  
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28  
29 objectivity (Martin & Bateson, 1986) as well as intra-observer and inter-observer reliability  
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31  
32 (Jacobs, et al., 2003). We randomly selected 3-minutes periods for a second categorization of  
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35 each videotaped working group. We choose the first period with the lack of the category  
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38 "activity not visible" for re-categorization by the first observer as well as by the second one.  
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41 For the objectivity test, we performed a scan sampling every 30 s and compared the chosen  
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44 categories of the first and the second categorization. As value for intra- and inter-observer  
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46  
47 objectivity, we computed Cohen's Kappa coefficient (Cohen, 1968; Table 2). According to  
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49  
50 the criteria of the Video Study within the Third International Mathematics and Science Study  
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52  
53 1999 (Jacobs, et al., 2003), we assessed intra- and inter-observer reliability (Table 2).  
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47 [Insert table 2 here]

49 [Insert figure 1 here]

### 51 **Cluster analysis**

We used the individual time budgets (e.g. Figure 1) for clustering students based upon similar activity patterns. We extracted a four-cluster solution by an agglomerative hierarchical cluster analysis applying Ward's method (Norusis, 1993). For determining students' cluster membership, we used the K-Means Cluster Analysis procedure (Anderberg, 1973) specifying the cluster number as four. We validated this analysis by a cluster-wise cross-tabulation of the two methods used (Figure 2), revealing a high level of agreement.

[Insert figure 2 here]

According to Bacher (1994), clusters are homogeneous if standard deviations of each variable within each cluster are lower than the corresponding values in the sample as a whole. Almost all our within-cluster values fulfilled this criterion (Table 3).

[Insert table 3 here]

### Relations to input and output variables

The procedure of data collection is described elsewhere in detail ([Scharfenberg, 2005](#); [Scharfenberg et al., 2006](#)). Prior experiences in experimentation were measured as sum of self-assessment in physics, chemistry, and biology with five categories for specialist assessment due to each science: 0 = *never*, 1 = *seldom*, 2 = *occasional*, 3 = *often*, 4 = *always*; according to Bortz and Döring (1995), this verbal rating has been validated as equidistant. Prior achievement in biology was given as standard of school work in written form. Epistemic interest (Krapp, 2002) in gene technology was rated according to Todt and Götz (2000, nine item scale rated from 0 = *not at all* to 5 = *extraordinary*, Cronbachs Alpha .64). In order to test for students' cognitive achievement at the output side, we applied three different test schedules, a pre-test (T-1) before participation, a post-test (T-2) immediately after the intervention and a retention test (T-3) about six weeks later. We applied nonparametric methods due to existing partially non-normal distribution of variables (Kolmogorov-Smirnov tests (Lilliefors modification): T-1  $p = .012$ ; T-2  $p = .040$ ; T-3  $p = .200$ ,  $N = 54$ ), and, in

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2 consequence, present our results as Boxplots. Changes within all three tests were analyzed  
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4 with the Friedman test in combination with a pair-wise analysis from T-1 to T-2 and T-3 and  
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6 from T-2 to T-3 by using Wilcoxon signed-rank test. According to authors such as Bender and  
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8 Lange (2001), Zöfel (2002), and Diehl and Arbinger (2001), we did not apply possible  
9  
10 Bonferroni correction: 'If the global null hypothesis is rejected proceed with 'level  $\alpha$  tests for  
11  
12 the (...) pair-wise comparison' (Bender & Lange, 2001, p. 1238). Potential differences  
13  
14 between the clusters were analysed by the Kruskal-Wallis test.

## 15 RESULTS

### 16 Cluster analysis

17  
18 We identified and labelled four clusters with regard to students' prevalent activities: (1) 'all-  
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20 rounders' ( $n = 21$ ), (2) 'observers' ( $n = 17$ ), (3) 'high-experimenters' ( $n = 15$ ), and (4)  
21  
22 'passive students' ( $n = 14$ , Figure 3).  
23  
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26 [Insert figure 3 here]  
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28  
29 Individual clusters were analysed with regard to single category importance by  
30  
31 analysis of variance (ANOVA; Table 4). However, we used the  $F$  tests for descriptive  
32  
33 purposes only, since the clusters have been chosen to maximize the differences among cases  
34  
35 within the four clusters (usually, computed  $p$ -values are not corrected for this). Thus, we do  
36  
37 not interpret the  $p$ -values as tests of hypotheses that the cluster means are equal (Norusis,  
38  
39 1993). For the purpose of a further cluster description, we applied Tuckey tests as post-hoc  
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41 tests in the cases of significant  $p$ -values due to the different sample sizes.

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43 [Insert table 4 here]  
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46 We labelled cluster-1 as 'all-rounders': whose members distributed their time equally  
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48 over all relevant activities, 20.2 % for observing purposes, 22.2 % for reading the instruction,  
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50 21.2 % for hands-on activities (preparing or reworking as well as experimental steps), and  
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52 22.3 % for the different forms of interaction (see Table 4 for details). Especially, their  
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category “activity not visible” dominated all other clusters (Tukey tests:  $p \leq .003$  in each case). Cluster-2 was labelled as ‘observers’, clearly dominating the other clusters by “in-group observing of lab-work” (Tukey tests:  $p < .001$  in each case, see Figure 3). Cluster-3 represented the ‘high-experimenters’, dominating the other clusters their hands-on activities (“preparing or reworking steps” as well as “experimental step”, Tukey tests:  $p \leq .001$  in each case, see Figure 3). [Members of cluster-4](#) [were](#) labelled as ‘passive students’ characterized by following attributes (see Figure 3): (a) a high proportion of “no experimental relation” (Tukey tests:  $p < .001$  in each case); (b) a less one of “reading instruction” and “advising interactions” compared to the ‘all-rounders’ cluster (Tukey tests:  $p = .003$  and  $p < .001$ ); (c) less “out-group interactions” than the ‘all-rounders’ as well as the ‘observers’ cluster (Tukey tests:  $p < .001$  in both cases).

#### Relations to input and output variables

Additionally, we analyzed students’ cluster assignment with regard to variables of potential influence on activities during experimental phases: (a) prior experiences with experimentation at school; (b) prior achievement in biology at school; (c) epistemic interest in gene technology, and (d) work group size.

Analysis of variance showed no effect of the first three variables: (a) prior experiences at school, neither with student experiments ( $F = 1.107, p = .355, N = 50$  nor with experiments demonstrated by teachers ( $F = 0.921, p = .438, N = 52$ ), (b) prior achievement at school ( $F = 0.691, p = .562, N = 52$ ), and (c) interest in gene technology ( $F = 0.709, p = .551, N = 52$ ).

Cross-tabulating of group size (d) and cluster assignment revealed a significant relation between these variables (Figure 4). ‘All-rounders’ and ‘observers’ dominated the 4-person workgroup while ‘high-experimenters’ and ‘passive students’ were prevalent in the 3-person groups. As expected, participants of the only 2-person group were ‘high-experimenting

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2 students' performing the same hands-on activities as the 3- or 4-person groups as group of  
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4 two.

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6 [Insert figure 4 here]  
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8  
9 Students of all clusters improved their cognitive achievement (T-1 to T-2, Table 5 and  
10 Figure 5). In the long-term (T-3), all scores dropped except the 'all-rounders' ones, but never  
11 back to the previous levels (T-1). However, we found statistical significance only in the 'high-  
12 experimenters' cluster. The lack of significance in the 'observers' and the 'passive students'  
13 cluster might originate from the low sample size because the similar change in the sample as a  
14 whole was significant (Table 5). Thus, the cluster did not differ in prior knowledge at T-1  
15 (Kruskal-Wallis test  $\chi^2 = 2.737$ ,  $df = 3$ ,  $p = .434$ ).  
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18  
19 [Insert table 5 here]  
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23 [Insert figure 5 here]  
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## 25 26 DISCUSSION

27  
28 We focussed in our study on the categorization of students' activities during the experimental  
29 phases of a science unit teaching gene technology in a dedicated out-of-school lab.

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30  
31 Additionally, we explored students' activity patterns in relation to potential influences such as  
32 (at the input side) prior experiences in experimentation, prior achievement at school,  
33 epistemic interest in gene technology, and the work group size, or (at the output side)  
34 cognitive achievement after the intervention. Our category system extracted specific students'  
35 activity patterns in the experimental phases. According to individual students' time budgets  
36 four activity types were revealed: 'all-rounders', 'observers', 'high-experimenters', and  
37 'passive students'. 'All-rounders' evenly distributed their time to different types of activities.  
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41 Their higher value of the category 'activity not visible' is not explainable in detail: Perhaps,  
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44 'all-rounder' students were more active compared to the other students thereby obscuring  
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47 their activities at a higher level. Nevertheless, we do not know what they really did in this part  
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2 of their time (ca. 10 %). It might be possible that someone of this cluster would be assigned to  
3 another cluster if his/her activities had been visible. 'Observers' and 'high-experimenters'  
4 were clearly characterised by the categories used for labelling. The same is true of the  
5 'passive students' cluster which was primarily labelled as 'passive' because of students' high  
6 level of the category 'no experimental relation'. However, [we see different explanations for](#)  
7 [this passive behaviour](#). They might have had a high level of prior experimental experiences,  
8 but we did not find any differences between the clusters with regard to prior experiences in  
9 experimentation. With regard to the cognitive level, 'passive students' might represent low  
10 achievers for whom the content taught was too complex. However, they also might represent  
11 high achievers for whom the content taught was previously known and did not challenge them  
12 at all. This explanation might fit the critics of CL as failing to benefit low achievers as well  
13 high achievers (Slavin, 1984). Nevertheless, we have to take into consideration both that prior  
14 achievement at school and specific prior knowledge did not differ in any cluster. Another  
15 possible explanation might rise from the social level: 'Passive students' might act just as  
16 outsider in their work-groups. However, the cluster did not differ in the level of 'in-group  
17 interaction' (Table 4). At least, 'passive students' might have a low level of interest. Although  
18 we did not monitor differences in the epistemic interest in gene technology between the four  
19 clusters, an object of interest may not only be associated with the content but also with the  
20 context and the kinds of activities involved (Hoffmann, 2002). Beside the over-all epistemic  
21 part, a lower level of these dimensions may have caused passivity: (i) interest in the specific  
22 content of our authentic experiments (as the particular context of the gene technology content  
23 generally taught); (ii) interest in the experimentation itself (as the particular activities  
24 connected; Gardner, 1985; Hoffmann, 2002). A low level of the categories 'reading  
25 instruction' and 'advising interactions' in the 'passive students' cluster (Table 4) may support  
26 this hypothesis. Another aspect may rise from the specific effect of the work group size.  
27 'Passive students' dominated the 3-person groups (as well as 'high experimenter' students)

**Deleted:** these students might generally be regarded as problematic targets of science education

1  
2 and were not found in 4-person groups (Figure 4). Thus, social interactions as well as other  
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4 cooperative effects within a 4-person group may hinder the 'passive' activity pattern (and  
5  
6 reduce the probability of the 'high-experimenter' pattern, too). The specific situation in a gene  
7  
8 technology lab may be corroborated by previous and more general results in CL research that  
9  
10 'team formation is most effective when four students work together' (Sherman, 1994, p. 227).  
11

12 Some researchers have previously assigned roles to students in CL situations.  
13  
14 O'Donnell, Dansereau, and Rocklin (1991), for instance, described a 'performer' role (as an  
15  
16 active member performing the claimed activity) and a 'listener' role (providing only feedback  
17  
18 for his/her partner) within dyads. Horn, Collier, Oxford, Bond, and Dansereau (1998)  
19  
20 specifically described a 'learner' and a 'learner facilitator'; the first emerging from a dyad's  
21  
22 performer recalls and/or processes information needed for the CL activity; the latter serves as  
23  
24 explainer as well as provider of supportive material. Additionally, Wenzel (2000) described  
25  
26 the 'leadership' role. Such a student takes initiatives for answering and/or explanations  
27  
28 thereby leading interactions (Stamovlasis, Dimos & Tsarpalis, 2006), but he/she may  
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30 occasionally monopolise work and lead to dysfunctional results of CL (Wenzel, 2000).  
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32 Nevertheless, only the latter role of leadership might fit to one of the four clusters given by  
33  
34 our experimental situation. The 'high-experimenter' students clearly dominated their work  
35  
36 group's hands-on activities thus resembling a leading function, and maybe monopolising  
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38 hands-on activities, too. Stamovlasis et al. (2006, p. 562) assigned three roles, an 'active  
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40 member', a 'very active member', and a 'spectator' based on utterance analysis as measure of  
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42 individual student's involvement in CL interactions. The 'active member' may comply the  
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44 'all-rounder' found in our study. The 'very active member' is characterised by a higher  
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46 contribution to the 'total number of utterances' than the average and the 'spectator' by a lower  
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48 contribution to the 'total number of utterances'. The 'very active member' may comply with  
49  
50 our 'high-experimenter' while the 'spectator' may comply with our 'passive student' in our  
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52 hands-on situation. In contrast to the both active members, the 'spectators' are 'did not profit  
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2 from CL (...) as a result of non-participation in the process of CL' (p. 567). A match with our  
3  
4 active 'observer' failed to emerge; perhaps such behaviour may just emerge only in real  
5  
6 hands-on settings. All three roles showed a decrease in the long term knowledge (Stamovlasis  
7  
8 et al. 2006) while our 'all-rounders' did not loose their acquired knowledge again, maybe  
9  
10 caused by the more active situation in our hands-on setting. Thus, an 'all-rounder'  
11  
12 contributing his/her time more or less equally to the different activities during  
13  
14 experimentation may learn best in a hands-on group work.

15  
16 A limitation of our video study is the lack of a transcription analysis with regard to  
17  
18 students' verbalising. Although such an analysis might be ideal as an additional step in  
19  
20 science education research, our aim only was the analysis on the level of activities. Further  
21  
22 research may connect this level with the level of the specific talks during experimentation.  
23

## 24 CONCLUSIONS

25  
26 With regard to experimentation embedded in a complex content, our video study may indicate  
27  
28 advantages for teaching: (i) Portioning the time available in similar fashion to hands-on  
29  
30 activities might benefit students at the cognitive level. (ii) Assigning students to 4-person  
31  
32 work groups might be useful in order to prevent a potential 'passive' behaviour.  
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35 Teacher might guide their students towards 'all-rounder' behaviour. A consistent  
36  
37 movement at the working place rather than sitting as in the classroom may provide a  
38  
39 supportive environment. A single request for that at the beginning of a module (as we did)  
40  
41 seems to be insufficient. Furthermore, the teacher might especially address the desired 'all-  
42  
43 rounder' behaviour type to the students. Prior to the experimentation phase, he/she might  
44  
45 request an equal distribution of the given activities to all students of the work group. A more  
46  
47 convincing method for the students might be the use of cooperation scripts. They clearly  
48  
49 describe what has to be done coupled with personal addressing of the working steps. The  
50  
51 purpose of such socio-cognitive scripts has already been shown in e-learning settings (e.g.  
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2 Ertl, Fischer & Mandl, 2006; Reynolds, Patterson, Skaggs & Danserau, 1991). These scripts  
3  
4 resemble to a specific role assignment prior to the activities. However, Chang and Lederman  
5  
6 (1994, p.169) tested the effect of a preliminary assignment of more global roles (in this case,  
7  
8 'manager, investigator, and recorder') to the students in laboratory classes and found no  
9  
10 significant effect on their achievement. Assigning students to 4-person groups might be [an](#)  
11  
12 uncomplicated [solution](#). Especially in complex hands-on situation in an out-of-school learning  
13  
14 environment, one might convince class teachers to employ this work group size. Further  
15  
16 research will possibly reveal potential advantages of using the described cooperative scripts in  
17  
18 hands-on science education. Another approach we follow is [the request of](#) more content  
19  
20 specific interactions within the work group. We intend to introduce a group discussion phase  
21  
22 prior to the hands-on phase coupled with writing down students' content specific ideas. We  
23  
24 expect thus to reduce the amount of 'passive' behaviour.

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36 664/5-1 and BO 944/4-2).

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TABLE 1: Categories for the description of students' observed activities during their lab-work phases

<i>Category</i>	<i>Description</i>	<i>Example</i>
Activity not visible	S's activity cannot be seen because he/she is hidden behind another person or by equipment or he/she has left the working place.	The teacher stands in front of S.
No experimental relation <sup>a</sup>	S shows an activity not related to the experimental phase.	S phones with his/her mobile.
Out-group interaction <sup>b</sup>	S contacts a S of another workgroup.	S turns to S of the workgroup behind.
Advising interaction <sup>b</sup>	S contacts an adviser either the lab teacher or his/her present own teacher or the present assistant.	S asks the assistant.
In-group interaction <sup>b</sup>	S contacts S of his/her own workgroup.	S talks to S beside.
In-group observing of lab-work <sup>c</sup>	S looks at experimental steps as well as preparing or reworking steps done by S of his/her own workgroup by visible turning towards and without doing anything else.	S looks at S beside doing a lab-work step.
Reading instruction <sup>d</sup>	S reads the written instruction.	S looks at his instruction
Preparing or reworking steps <sup>e</sup>	S prepares an experimental step or finishes it by a reworking step.	S adjusts a graduated pipette.
Experimental step <sup>f</sup>	S performs an experimental step written in the instruction.	S pipettes a given volume.

Note: Abbreviations used in following tables and figures: <sup>a</sup>No exper. relation; <sup>b</sup>interact.; <sup>c</sup>In-group observ.; <sup>d</sup>Read. instruction; <sup>e</sup>Prepar. or rework.; <sup>f</sup>Exper. steps.

TABLE 2: Intra- and inter-observer objectivity and reliability of categorization

Observer	Objectivity (Cohens Kappa <sup>a</sup> )		Reliability (Percentage of concordant coded phases <sup>b</sup> )	
	Intra-observer	Inter-observer	Intra-observer	Inter-observer
1	.82	.71	.88	.83
2	.80	.69	.88	.75

Notes: <sup>a</sup> Wolf (1997, p. 964) assesses kappa values between .41 and .60 as 'moderate', between .61 and .80 as 'substantial' and > .80 as 'almost perfect'.

<sup>b</sup> We rated every matching in-point and out-point of a coding interval within a phase of maximally ten seconds as well as every concordantly coded phase between these points as consistently coded time phase (Jacobs, et al., 2003).



TABLE 3: Analysis of cluster homogeneity by comparison of the standard deviations of each variable within the clusters with the values in the sample as a whole<sup>a</sup>

Category	Cluster (N)				All (N)
	1	2	3	4	
	(21)	(17)	(15)	(14)	(67)
Activity not visible	4,61 <sup>a</sup>	2,59	3,59	3,80	4,44
No experimental relation	2,96	6,32	4,25	5,48	9,61
Out-group interaction	3,25	4,61	2,57	1,93	4,78
Advising interaction	1,92 <sup>a</sup>	1,30	1,39	1,58	1,80
In-group interaction	2,45	3,92	5,67 <sup>a</sup>	3,73	4,09
In-group observing of lab-work	3,53	3,85	4,06	3,66	8,10
Reading instruction	5,68	5,74	5,12	5,50	5,96
Preparing or reworking steps	3,50	2,79	6,75	4,12	6,94
Experimental steps	2,95	3,22	3,17	3,09	3,85

Note: <sup>a</sup> Only three (of 36, grey background) within-cluster values showed a higher level as the corresponding values in the sample as a whole.

TABLE 4: Cluster specific ANOVA of the observed activities

Category	Percentage	of time	budget	(M)	ANOVA	
	Cluster	(N)			F	p
	All-rounders	Observers	High-experimenters	Passive students		
	(21)	(17)	(15)	(14)		
Activity not visible	10.2	5.7	5.0	4.3	9.38	<.001
No experimental relation	3.8	6.2	10.3	26.1	66.71	<.001
Out-group interaction	7.8	10.1	2.4	1.7	24.73	<.001
Advising interaction	4.9	4.3	3.8	2.5	6.88	<.001
In-group interaction	9.6	7.3	10.5	7.9	2.31	.085
In-group observing of lab-work	20.2	31.0	11.0	16.4	81.02	<.001
Reading instruction	22.2	18.5	19.5	15.2	4.51	.006
Preparing or reworking steps	13.2	11.4	25.5	18.7	33.34	<.001
Experimental steps	8.0	5.4	12.1	7.3	12.95	<.001

Note: ANOVA was performed based on following prerequisites: Variables were normally distributed (Kolmogorov-Smirnov tests [Lilliefors modification]:  $p > .051$  in each case,  $N = 67$ ). Homogeneity of variance was given for six variables (Levene tests:  $p > .073$  in each case). Nevertheless, we accepted the three significant values (Levene tests:  $p < .029$  in each case) by adjusting the  $p$ -value for significance for the analysis of variance to .01 (Zöfel 2002).

TABLE 5: Changes in scoring of knowledge in the four clusters as well as in the sample as a whole

Test dates	Changes of medians (grouped)				
	All-rounders (N=17)	Observers (N=16)	High-experimenters (N=10)	Passive students (N=11)	All (N=54)
T-1 / T-2	6.0 to 9.8 ***	4.4 to 9.3 **	4.5 to 10.8 **	5.5 to 10.0 **	5.0 to 10.0 ***
T-2 / T-3 <sup>a</sup>	9.8 to 9.7	9.3 to 6.8	10.8 to 8.0 *	10.0 to 8.2	10.0 to 8.2 ***

Notes: significant differences \*  $p < .05$ , \*\*  $p < .01$ ; \*\*\*  $p < .001$  (for statistical tests see Appendix).

<sup>a</sup> All changes from T-1 to T-3 were significant, too (see Appendix).

## FIGURE CAPTIONS

FIGURE 1: Example of a student's individual time budget showing his/her categorised activities during the experimental phases.

FIGURE 2: Validation of the cluster analysis by cluster-wise cross-tabulation of both methods used: Ward's method and K-Means procedure (coefficient of contingency  $C = .83$  with  $C_{\max} = .87$ ,  $N = 67$ ,  $p < .001$ ).

FIGURE 3: Characterization of the four clusters identified with regard to students' activities during the experimental phases (see text for details).

FIGURE 4: Significant relation between work group size and cluster assignment (coefficient of contingency  $C = .64$  with estimated  $C_{\max} = .85$ ,  $N = 67$  and  $p < .001$ ).

FIGURE 5: Changes in knowledge scores in the four clusters over the three test schedules.

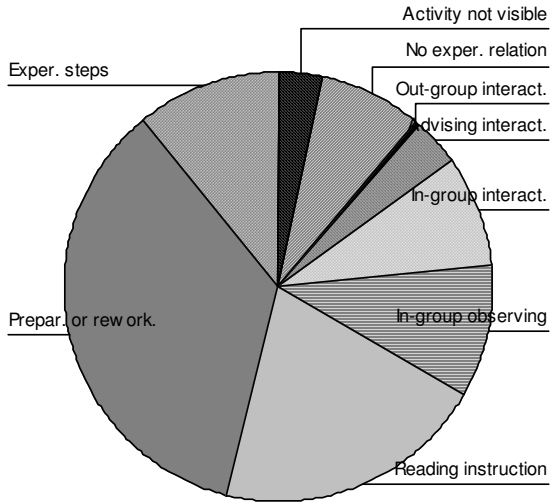


FIGURE 1

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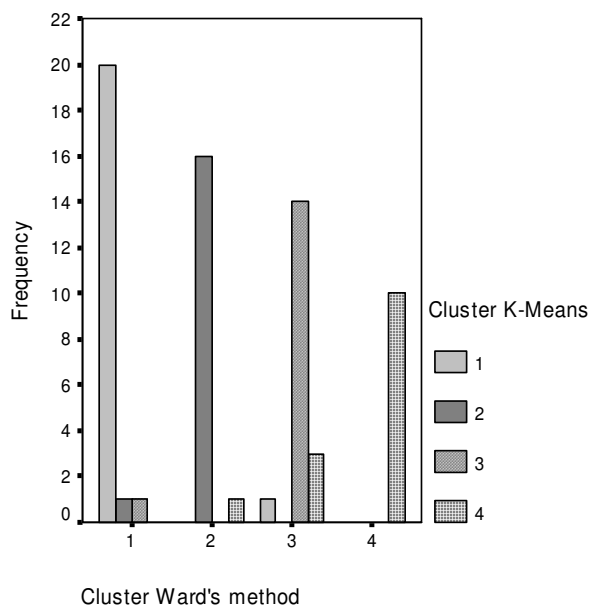


FIGURE 2

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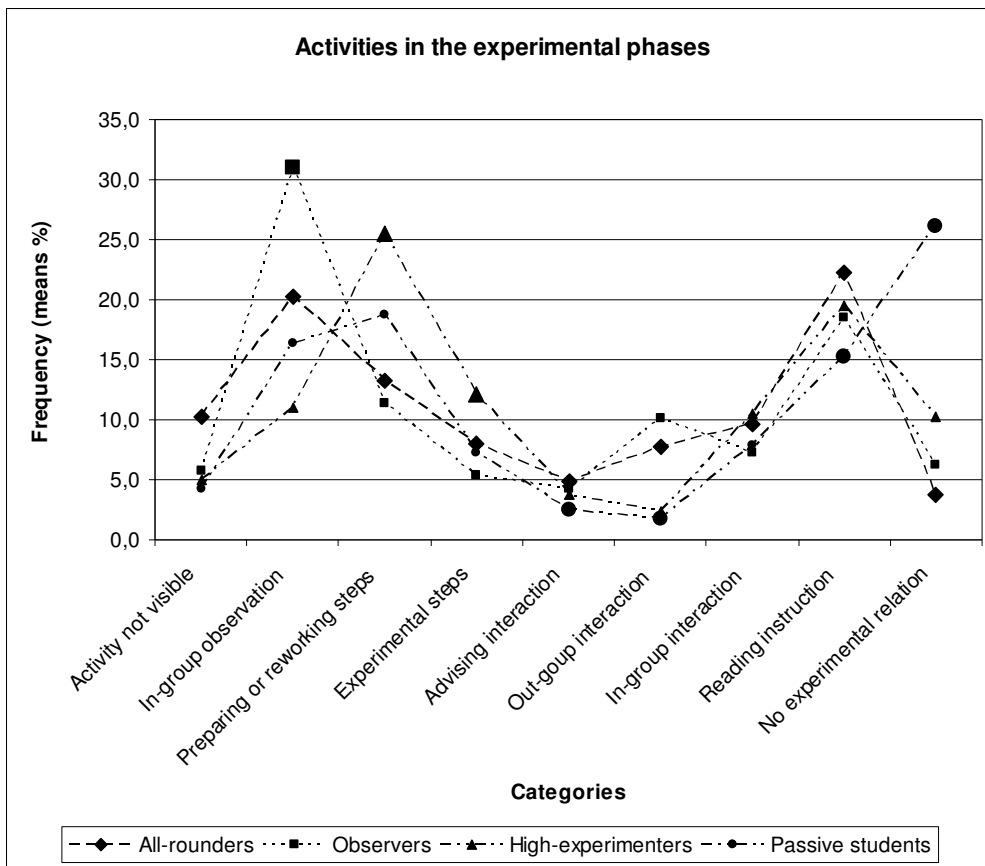


FIGURE 3

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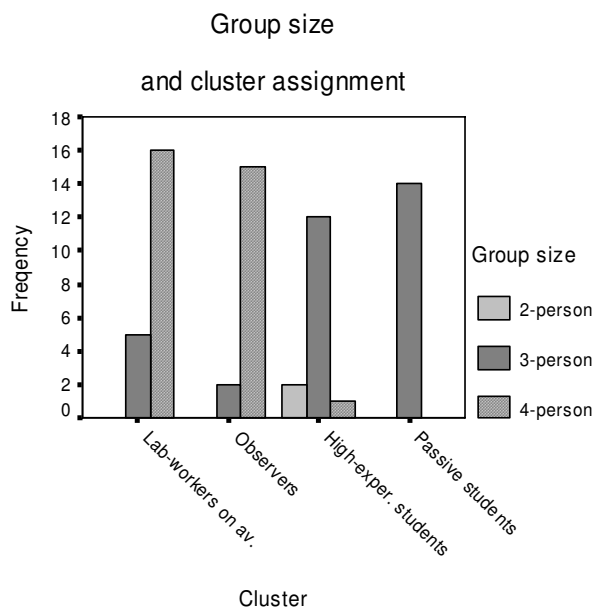


FIGURE 4

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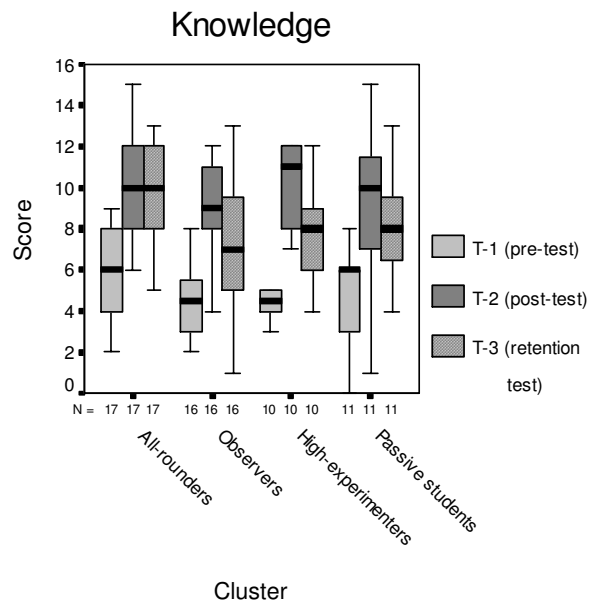


FIGURE 5

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APPENDIX: Friedman tests (in any case  $df=2$ ) and subsequent pair-wise Wilcoxon tests demonstrate cognitive achievement in the students' sample as a whole ( $N=54$ ) as well as specific results of the four clusters

Group	Friedman test			Wilcoxon signed-rank test					
	N	Chi-Square	<i>p</i>	T-1 / T-2		T-2 / T-3		T-1 / T-3	
				Z	<i>p</i>	Z	<i>p</i>	Z	<i>p</i>
Whole sample	54	72.07	<.001	-6.27	<.001	-3.59	<.001	-5.91	<.001
Cluster-1 <sup>a</sup>	17	24.29	<.001	-3.63	<.001	-1.42	.153	-3.20	.001
Cluster-2 <sup>b</sup>	16	16.26	<.001	-3.32	.001	-1.82	.068	-3.08	.002
Cluster-3 <sup>c</sup>	10	14.7	.001	-2.81	.005	-2.31	.020	-2.56	.01
Cluster-4 <sup>d</sup>	11	18.42	<.001	-2.82	.005	-1.83	.067	-2.95	.003

Note: <sup>a</sup>All-rounders'; <sup>b</sup>observers'; <sup>c</sup>high-experimenters'; <sup>d</sup>passive students'.