

**Higher Education in Environmental Sciences:
The Effects of Incorporating Expert Information in Group Discussions of a
Transdisciplinary Case Study**

by

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Introduction

In 1987, the curriculum of Environmental Sciences was introduced at Swiss Federal Institute of Technology Zurich ([Eidgenössische Technische Hochschule Zurich], ETHZ). The curriculum was motivated by demands and pressures that characterize our post-industrial age, particularly the necessity to understand complex environmental problems and assess their long term impacts from an interdisciplinary natural science perspective (Gigon, 1997). Environmental problems and catastrophes, such as the nuclear power plant accident at Chernobyl, the dioxin contamination at Seveso, and the chemical industry's accidental contamination of the River Rhine, which all occurred in the 80's, contributed to this motivation (Frischknecht & Imboden, 1995; Gigon, 1997; Scholz & Tietje, 2002).

The Environmental Sciences curriculum at ETHZ connects the idea of a general natural science education to that of a specialist in the analysis of diverse environmental systems. The aim of the curriculum is to prepare students for practical scientific work in the environmental area and, at the same time, to open up the possibility of qualified research (Frischknecht & Imboden, 1995; Scholz, Steiner, & Hansmann, 2004). In addition to the basic natural science knowledge that is necessary to understand environmental problems on a theoretical scientific level, practical experience in environmental problem solving appears important for the development of the corresponding expertise (Kolb, 1984; Mieg, 2001; Woschnack & Mieg, 2002, 2003). Thus, already since its

inception in 1987 the curriculum of Environmental Sciences at ETH Zurich has included the compulsory participation in an environmental case study of comparably large scale, which is organized by the ETH Natural Science Social Science Interface Chair (UNS). These case studies involve cooperation with scientists, municipal authorities, citizens, professionals, and representatives from various companies (e.g. Mieg, 1996, 2000; Scholz, Bösch, Mieg, & Stünzi, 1997; Scholz & Tietje, 2002). Combining practical application of knowledge, collaboration with experts, research, and teaching, the ETH-UNS case studies have set forth a new type of *instructional design* (Gagne & Briggs, 1974; Reigeluth, 1983) and are denoted as *transdisciplinary* projects (Häberli, Scholz, Bill, & Welti, 2000), which means that they cross the usual boundaries of sciences by involving non-scientific experts and the people directly affected by environmental problems.

The Environmental Sciences students at ETHZ usually spend their eighth semester participating in the transdisciplinary case study. By this time the students should have acquired the necessary prerequisite knowledge and skills (Kaufman & Thiagarajan, 1987) to cope with a complex, multi-layered, and ill-defined environmental real-world problem. The educational aim of the case study is to improve the environmental problem-solving ability of the students (Scholz, Flückiger et. al., 1997), to enhance their cognitive competence when it comes to mastering complexity, to improve their ability to cooperate in teams, and to enlarge their practical experience in transdisciplinary work (Mieg, 1996, 2000; Oswald & Scholz, 1999; Scholz, Mieg, & Weber, 1997; Scholz & Tietje, 2002). However, the ETH UNS case studies serve more than an educational purpose. They also support the ecological problem-solving process within the specific *case*, and thus, promote sustainable development. At the end of each case study a report on the environmental system that has been analyzed is produced (e.g. Mieg, Hübner, Stauffacher, Balmer, & Bösch, 2001; Scholz, Bösch, Stauffacher, & Oswald, 2000) to serve as an informative decision aid for the administrators involved in the corresponding planning processes. This practical relevance is connected to motivating effects for the students to engage in the case study work and learning.

The field experiment presented in this article was conducted within the ETH UNS case study 1998 (see Scholz, Bösch, Carlucci, & Oswald, 1999), which concerned problems of the socio-economical and environmental development in Klettgau, a rural region straddling the Swiss-German border, serving as an important groundwater reservoir. The goal of the experiment was to examine how information on expert opinions can influence learning effects because of participation in a transdisciplinary environmental case study. Therefore, the learning effects of two different formats of group discussions, namely of usual group discussions (Hansmann, 2001; McGrath, 1984; Witte, 1998, 2001) and of group discussions including the preliminary information of the discussants concerning the opinions of experts (Mieg, 2001) were compared to each other in an experimental design. The purpose of this experiment was to obtain information useful for a refinement of the

instructional design of the group discussions, which inherently play a crucial role within transdisciplinary environmental case studies.

Judgment Validity as an Indicator of Learning Effects

Environmental Problem Solving (Scholz, Flückiger et al., 1997) entails the construction and evaluation of projects for future, and thus uncertain and changing, environmental systems. In general, environmental problems are complex and *ill-defined*, i.e. problems where the initial state cannot be precisely described, the target or goal state is not sufficiently known, and the types of barriers to be passed for a successful transformation are not known (Scholz & Tietje, 2002, pp. 26). In environmental problem-solving, it is necessary to understand the impacts that particular variables in an environmental system have on each other.

To measure the environmental problem-solving ability of students is, of course, difficult. However, an improvement in the quality of students' judgments concerning major impacts within an environmental system indicates a better understanding of the system and thus corresponds to an improved *environmental problem-solving ability*. Accordingly, in the present study, the validity of students' judgments will be used as a criterion for the analysis of learning effects due to the participation in a case study. Changes in judgment validity will also be used as a criterion for the comparison between the learning effects of two different group discussion formats. However, the judgmental tasks that were used in the experiment do not have exact solutions that are objectively correct. Therefore, the judgments of experts will serve as the point of reference for the validity of students' judgments (Connolly, Arkes, & Hammond, 2000; Jacoby & Gonzales, 1991; McGrath, 1984, p. 62).

Our hypotheses with respect to the learning effects of case study participation, and of group discussions of the two different formats, are explained in the following.

Expert Information and Case Study Participation

On the background of the explanations given in the Introduction, it was expected that during case study participation, the students would gain a better, more elaborate, understanding of the socio-ecological situation in the Klettgau region, i.e. of the specific case, which had been selected. Therefore, we formulated **Hypothesis 1**: *The validity of students' judgments concerning major impacts within the socio-ecological system of Klettgau will increase during case study participation.*

In all scientific case studies, the selected cases are unique, but also only one among many and therefore always related to something general (Stake, 1995). Thus, consistent with the general principles of case study learning, it is assumed that an enhanced understanding of the interrelationships within the specific environmental system also indicates a general improvement of the environmental problem-solving ability of the students (Oswald & Scholz, 1999; Scholz, Flückiger et al., 1997; Scholz & Tietje, 2002).

In transdisciplinary case studies, we find several types of experts (Mieg, 2000, 2001): (a) scientific experts, (b) professionals, and (c) "local experts." Local experts are very familiar with the case and provide particular information on the case and its history; local experts can be farmers or persons who have been serving a local public function for a long time. Local experts are experts from within the case and are therefore also called "system experts." Whereas the contribution of local experts can be reduced to providing information and contact, professionals (e.g. self-employed environmental engineers or urban traffic planners) have an interest in conducting a project according to their particular professional standards. However, the ETH UNS case study has its own methodology. Local experts and scientific experts from academia by far prevail in ETH UNS case studies (Mieg, 2000). This is also due to the fact that environmental problem-solving in the ETH UNS case study is based on group work and collective reasoning. In this context, the function of experts is to contribute to the collective problem-solving process by providing information or other scientific input. This function of experts, in a nutshell, is not professional process management, but "social validation" (Stasser, Stewart, & Wittenbaum, 1995; Stewart & Stasser, 1995; Mieg, 2001).

The cooperation with experts is an important aspect of transdisciplinary case studies, and the knowledge of expert opinions should generally enhance the students understanding of a case. Thus, we formulated **Hypothesis 2:** *During case study participation, the validity of students' judgments concerning major impacts within the socio-ecological system of Klettgau will increase more if the corresponding expert opinions are disclosed than if they are not disclosed.*

Group Discussions With Versus Without Information on Expert Judgments

Group discussions represent a common setting in processes of environmental planning. Therefore, it appears important to enable students to gain practical experience in corresponding environmental group discussions. The importance of group decisions in environmental planning results from the complexity and transdisciplinarity of environmental problem-solving processes, as well as from the multiplicity of stake holders and interest groups that are affected by the decisions. Group discussions are a valuable means for the integration of information. This integration can

comprise the exchange of knowledge from different disciplines, as well as information exchanges concerning different interests or preferences (*distributed reasoning*, cf. Dunbar, 1999, 2000). Thus, *mutual learning* (Scholz, 2000) takes place through the exchange of information during group discussion (Stasser, 1992; Stasser, Taylor, & Hanna, 1989; Winquist & Larson, 1998). During group discussions students can acquire knowledge from different sources in an integrative way. One possibility of learning within group discussions consists of a process of each group member teaching his knowledge to all other group members. If the discussants exchange their information fully, this process can result in an even distribution of knowledge within the group, on a higher level than before the group process. In addition, process gains adding to the total knowledge of the group can be reached, for example, if the group members elaborate on their knowledge together, or if they inspire each other to reach creative solutions (Hackman & Morris, 1975; Jung, 2001; Kurtzberg & Amabile, 2001; Osborn, 1957; Paulus, Larey, & Dzindolet, 2001; Rogelberg & O'Connor, 1998; Witte, 1998, 2001).

There are two main sources of influence that determine the opinion formation process in group discussions, namely *normative influence* and *informative influence* (e.g., Crott, Grotzer, Hansmann, Mieg, & Scholz, 1999; Crott, Werner, & Hoffmann, 1996; Deutsch & Gerard, 1955; Stasser & Davis, 1981). Normative influence includes, among other aspects, conformity pressure, social desirability, and social comparison processes (e.g., Asch, 1956; Crott & Werner, 1994; Goethals & Zanna, 1979; Stasser, Kerr, & Davis, 1989). Informative influence is also effective during opinion formation processes. It is connected to the exchange of arguments and task relevant information that takes place within group discussions (Burnstein & Vinokur, 1973, 1975, 1977; Vinokur & Burnstein, 1974). Thus, group members who support the correct solution for an *intellective task* (McGrath, 1984) are often more influential than advocates of a wrong solution (Crott, Giesel, & Hoffmann, 1998; Hansmann, 2001; Laughlin, 1980; Laughlin & Ellis, 1986).

The group discussions in this field experiment concerned judgmental tasks. Previous studies have shown that, in a variety of tasks, group judgments are on average more accurate than individual pre-discussion judgments, and improvements in accuracy have also been observed from individual pre-discussion to individual post-discussion judgments (see, Gigone & Hastie, 1997; Hastie, 1986; Sniezek & Henry, 1990). Accordingly, we formulated **Hypothesis 3**: *The validity of the individual judgments will increase during the group discussions, even in those groups where the expert judgments were not disclosed to the students.*

Psychological research has shown that the assignment of expert roles in a group has a great impact on the exchange of information within group discussions. Group members primarily

exchange, and thus acquire, the knowledge of assigned experts (Stasser et al., 1995; Stewart & Stasser, 1995). Moreover, previous research showed that the influence of communication on opinions largely depends on the credibility of the communicator (e.g., Aronson, Turner, Carlsmith, & Merrill, 1963; Hovland & Weiss, 1951; Jain & Posavac, 2001; Shore & Tashchian, 2002), and it can well be assumed that experts in general possess high credibility (Mieg, 2001). Therefore, it was expected that, if the discussants were informed directly on the judgment of experts, they would tend to markedly change their judgments into the direction of the expert judgment. This corresponds to our **Hypothesis 4**: *During the group discussions the validity of the individual judgments (as measured by their congruence with the expert judgments) will increase more strongly in those groups where the expert judgments have been disclosed to the students, as compared to the groups of the control condition.*

However, there exist different ways of *how* the information on expert judgments might cause the students to change their own judgments:

One possibility is an adoption of the expert judgments within a process of social orientation (Asch, 1956; Goethals & Zanna, 1979; Festinger, 1954; Sherif, 1935; Hansmann, 2001) or *social validation* (Stewart & Stasser, 1995). Social orientation might cause the students to revise their own judgments due to the high credibility of the expert judgments. The group members might believe that the experts have greater competence to make accurate judgments than they have themselves. Consequently, they might presume the expert judgments to be more accurate than their own judgments and accordingly adopt these judgments. Hence, in this case, informative considerations are the basis for conformity with the expert judgments.

A second possibility corresponds with normative conformity influence (Asch, 1956; Crott & Werner, 1994; Deutsch & Gerard, 1955) and the connected group think phenomena (Janis, 1972, 1997). Group members might hesitate to express judgments or arguments that differ from the expert judgments if they feared that such arguments or judgments would be evaluated negatively by others. Moreover, it might appear to be socially desirable to support the expert judgments verbally. Hence, the exchange of information during the discussions might be systematically biased.

A third possibility of how the information on expert judgments might promote corresponding changes of students' estimates corresponds with purely informational influence. The possibility to influence the generation of arguments via feedback on the opinions of other persons has been confirmed in an experiment of Burnstein and Vinokur (1975). They concluded: "...that knowledge about others' preferences can be a sufficient condition for revising preferences to the extent that it

leads one to think of arguments in support of the courses of action others have selected, arguments which previously had not come to mind (p. 423)." The disclosure of expert judgments might accordingly enhance the search for information that is consistent with them. If a student prefers a judgment that differs from the expert judgment he might experience cognitive dissonance. On the one hand, he might have trust in the competence of the experts, and consequently in the correctness of the expert judgment. On the other hand, his information and arguments support a different judgment. This comprises a cognitive contradiction. Hence, according to Festinger (1957), the student will try to obtain cognitive consonance to balance his cognitive system. In this case there exists no possibility to change the expert judgment. Hence, cognitive consonance can only be reached by changes within the cognitive system of the students. It can be achieved, for example, by the search for new information and by the generation of new arguments in favor of the expert judgment, or by devaluating arguments objecting to the expert judgment (see Festinger, 1964). Analogously, the expert judgment can be viewed as evidence that contradicts the considerations and assumptions of the students. From the perspective of Gestalt psychology, such contradictions can stimulate productive thought (Duncker, 1935; Wertheimer, 1944, 1945). Expert information seems to induce changes to the cognitive *hypothesis space* (Klahr & Dunbar, 1988; van Joolingen & de Jong, 1997) of the students. Particularly, attention to unexpected information, and the subsequently reinforced search for alternative explanations can foster scientific discovery and the formation of scientific thinking (Dunbar, 1999, 2000).

It has to be kept in mind that, considering Hypotheses 2 and 4, the correspondence between increases in judgment accuracy and the development of components of the environmental problem-solving ability might greatly depend on *how* the information on expert judgments might cause the students to change their own judgments.

Method

Experimental Task

The experiment was part of the ETH-UNS case study 1998 (Scholz et al., 1999) that focused on regional development in the Swiss-German border-straddling region of Klettgau. To establish an integral perspective on the problems of the Klettgau region, the students worked in four different *synthesis groups* (Mieg, 2000) that investigated the socio-ecological situation in Klettgau from the perspective of mobility, protection of the environment, settlement planning, and economy. These four synthesis groups worked quite independently from each other during the case study. However, in the final stage of the case study process, a synthesis of their perspectives was intended.

The experimental task for the students was to judge the strength of the impact that certain environmental and socio-economical variables exerted on other variables.¹ They were told that their estimates should refer to the situation in the Klettgau region. The following four impact relations (IR) had to be judged:

IR 1 = the impact of nature protection on the Swiss-German coordination of regional development planning,

IR 2 = the impact of support for local economy on local nature protection,

IR 3 = the impact of nature protection on the regions' attractiveness for tourism, and

IR 4 = the impact of the Swiss-German coordination of regional development planning on the regions' economic situation.

These IRs were selected out of a larger list of potential impact variables, which was compiled in collaboration with environmental scientists. Only four IRs were chosen because time constraints restricted the duration of the experimental sessions to one hour. In accordance with previous experiences (Crott et al., 1999), the timing with four IRs seemed to be appropriate to ensure that important information could be exchanged during the discussions. Two criteria formed the basis for the selection of the IRs for the experiment. There is supposed to be some variation in the strength of the four impacts, and they had to leave room for controversial argumentation. The IRs selected for the experiment have not been the focus of any planned instruction during the case study.

Expert estimates for the four IRs were obtained from three independent experts who were familiar with the situation in the Klettgau region. None of these experts was directly involved in the case study. For each impact, the mean of the three estimates was considered as the *expert estimate* which served to determine the validity of the students' estimates. The experts gave the following mean judgments (M_{Exp}) for the impacts on a five point rating scale reaching from 1 = *very low impact* to 5 = *very strong impact*:

- $M_{Exp}(\text{IR 1, impact of nature protection on the Swiss-German coordination of regional development planning}) = 1.7, SD_{Exp} = 0.58;$

¹ In environmental planning, identification of powerful impact variables and determination of influences these variables exert on other variables can serve as the basis for the performance of a computational *scenario analysis*. Scenario analysis is a means for strategic planning that was developed by Rand Corporation in the 1950's and 1960's (Kahn & Wiener, 1967). It is a prominent technique for environmental planning in ETH-UNS case studies because it achieves knowledge integration via fast data aggregation and, thus, allows for the modeling of complex processes (Scholz & Tietje, 2002). Scenario analysis is also used in other domains, e.g., for traffic planning (Forschungsverbund Lebensraum Stadt, 1994) and for predicting climate change (Houghton, Jenkins, & Ephraums, 1990). The experimental task was connected to a scenario analysis within the ETH-UNS Case Study 1998.

- $M_{\text{Exp}}(\text{IR 2, impact of support for local economy on local nature protection}) = 2.3$, $SD_{\text{Exp}} = 1.53$;
- $M_{\text{Exp}}(\text{IR 3, impact of nature protection on the regions' attractiveness for tourism}) = 3.3$, $SD_{\text{Exp}} = 1.15$;
- $M_{\text{Exp}}(\text{IR 4, impact of the Swiss-German coordination of regional development planning on the regions' economic situation}) = 1.7$, $SD_{\text{Exp}} = 0.58$.

Participants, Procedure and Experimental Design

Altogether, 80 male and female students of Environmental Science at ETH Zurich in their eighth semester participated in the study. These students were working together in the transdisciplinary case study project that was part of their study curriculum.

The experiment as a whole consisted of two experimental runs. The basic experimental procedure was identical for the two runs. The first run of the experiment was conducted when the students started to work on the case study. The second run of the experiment was conducted about four months later, shortly before the end of the case study. In the two experimental runs, 16 (*in run 1*) and 12 (*in run 2*) five-person groups discussed the selected impacts. The groups were randomly formed in the first experimental run, as well as in the second one. Therefore, the groups of both runs were considered independent groups, though they were formed from the same pool of persons. In both runs of the experiment, the groups had to discuss each of the four IRs. At the end of each discussion, a joint group estimate for the IR under consideration had to be formed. Table 1 shows the experimental design. In both runs an experimental variation was included that consisted of the disclosure of the expert judgment for two of the four IRs in half of the groups. In the corresponding groups, the expert judgments were revealed before the beginning of the group discussion on the task, but after each group member had already noted the individual pre-discussion judgment on his or her experimental sheet.

Table 1: Design of the overall study including 4 months of participation in the case study (longitudinal analysis) and two runs of group discussions with an experimental variation of the disclosure of expert judgments.

Formation of groups, $n_{Gr} = 16$			
Control condition, $n_{Gr} = 8$		Experimental condition, $n_{Gr} = 8$	
Disclosure of expert judgments before group discussion			Run 1: Discussion of the 4 Impact Relations
IR 1	No	No	IR 1, IR 2, IR 3, IR 4
and 2:	No	Yes	
IR 3			
and 4:			
4 months of participation in the case study			
Formation of new groups, $n_{Gr} = 12$			
Control condition, $n_{Gr} = 6$		Experimental condition, $n_{Gr} = 6$	
Disclosure of expert judgments before group discussion			Run 2: Discussion of the 4 Impact Relations
IR 1	No	Yes	IR 1, IR 2, IR 3, IR 4
and 2:	Yes	Yes	
3 and 4:			

Note. IR 1 = Impact of Nature protection on the Swiss-German coordination of regional development planning; IR 2 = Impact of Support for local economy on local nature protection; IR 3 = impact of nature protection on the regions' attractiveness for tourism; IR 4 = impact of the Swiss-German coordination of regional development planning on the regions' economic situation; n_{Gr} = number of five-person groups.

As Table 1 shows, there was no disclosure of the expert judgments for IR 1 and IR 2 in the first run of the experiment. In run 1, the expert judgments were only disclosed in half of the groups

for IR 3 and IR 4. In run 2, the expert judgments for IR 1 and IR 2 were disclosed in half of the groups, whereas the expert judgments for IR 3 and IR 4 were disclosed to *all* groups at the beginning of the discussions. In both runs, IR 1 and 2 were always discussed prior to IR 3 and 4. This sequence was determined to avoid irritations that might have resulted if participants would have received the expert estimates for the first two IRs, but would not have received these judgments for the following IRs that they had to discuss. Therefore, only the sequence of discussions on IR 1 versus IR 2 and IR 3 versus IR 4 was balanced within the experiment.

In each run of the experiment, the participants were assigned randomly to the different conditions. There were four experimental sessions in run 1, and three experimental sessions in run 2. In every experimental session, four groups worked parallel, in separate rooms. The experimental sessions of each run were conducted on one single day. At each experimental session 20 persons participated. They were randomly assigned to four five-person groups that were guided to separate rooms by an experimenter. The experimenter read aloud the instructions and then presented the first IR to the group. Before the group discussion of an IR, the group members were given 2 minutes to individually judge the strength of the impact under consideration. Group members were supposed to mark their private pre-discussion estimate on a rating scale (1 = *very low impact*, 2 = *low impact*, 3 = *medium impact*, 4 = *strong impact*, 5 = *very strong impact*). In this period of individual work on the task, participants also had to allocate 100 *confidence points* on the five possible impact levels. They should distribute these points according to how likely they thought that each of these levels might represent the true impact level of the impact under consideration. All 100 points had to be distributed over the five alternative impact levels which were proposed by the five step rating scale. Hence, the points that a person allocated to his or her own judgment can be interpreted as a measure of the confidence in its correctness (Sniezek, 1992). After denoting the individual pre-discussion judgment and allocating the 100 confidence points, the group members began to discuss the strength of the IR. The discussion time was 6 minutes for each impact.

During the discussion, an acoustic signal sounded every 90 seconds. This signal requested that the group members mark, on a five point rating scale, the impact estimate that they most favored at this point in time, and distribute 100 points of confidence among the five alternatives. The participants were instructed not to let themselves be irritated by these signals. Instead, they were told to continue the group discussion while denoting their current opinions.² At the end of 6

² Introducing this procedure of periodic opinion documentation was necessary for a detailed analysis of the opinion formation processes. Previous studies, in which the effects of similar procedures that required the participants to document their opinions periodically were analyzed, showed no substantial influence of these procedures on the resulting opinions (Crott & Werner, 1994; Kerr, 1981, 1982; Werner, 1992). Nevertheless, corresponding effects cannot be excluded.

discussion minutes, the group members denoted their final estimates, and once more distributed 100 points of confidence among the five alternatives. Then, the group was asked to formulate a joint group judgment for the strength of the impact under consideration. This group estimate finished the work on the first task. The experimenter then presented the next IR to the group.

The basic experimental procedure was the same for all four tasks and for both experimental runs. If, according to the experimental plan, the expert judgment for a task had to be disclosed to the group, the experimenter additionally informed the participants about the mean judgment that independent experts had made for the task. The participants received this information after they had denoted their private pre-discussion judgment for the task, but prior to the beginning of the group discussion on a task. When the fourth task was finished, the experimenter answered any questions about the purpose of the research, and thanked the students for their participation. Figure 1 gives a schematic description of the experimental procedure.

Results

Firstly, a longitudinal analysis focuses on how the validity of the students' individual estimates changes during the time of their case study participation. The analysis hence examines whether the students' understanding of the environmental impacts within the *Klettgau Case* has increased during their participation in the case study. Secondly, an experimental analysis of the opinion formation process during the group discussions in the experimental versus control condition examines how the disclosure of expert judgments influences the process of judgment formation. Here, a first ANOVA examines the judgment validity in the two conditions, and a second ANOVA addresses the subjective confidence of the students in the correctness of their estimates.

Validity of Students' Judgments at the Beginning and End of Case Study Participation (Longitudinal Analysis)

The students participated in two group discussions on each IR. As described previously the first discussion took place at the beginning of the case study (run 1), and the second discussion at the end (run 2). In both experimental runs, the students individually estimated each IR before the start, and at the end of the group discussion of that IR. The resulting four times of measurement (M 1 to M 4) are represented in this analysis by the two repeated measurement variables *discussion* (2 levels: before vs. at the end of the group discussion) and *case study* (2 levels: at the beginning vs. at the end of the case study). The absolute deviation of students' judgments from the expert judgment for a task will be considered as a measure of judgment (in-)accuracy. As was mentioned in the method section, the students were divided into four synthesis groups during their case study work. The students within each synthesis group cooperated closely during the case study. Hence, a statistical analysis on the basis of the group means of the synthesis groups was performed to obtain (partly) independent observations. However, complete independence of observations could not be obtained.

The mean deviation of the individual judgments of the students in each synthesis group from the expert judgments will be the basis of this longitudinal analysis. This deviation was calculated for each task at the four different points of measurement M 1 to M 4:

M 1 = Immediately before the start of the group discussion at the beginning of the case study,

M 2 = At the end of the group discussion at the beginning of the case study,

M 3 = After four months of work in the case study, immediately before the start of the group discussion at the end of the case study,

M 4 = At the end of the group discussion at the end of the case study.

For IR 1 and IR 2 the expert judgments were not disclosed in any group in the first experimental run at the beginning of the case study. The expert judgments for these two IRs were only disclosed in half of the groups during the discussions in the second run. This means that only for M 4 students' judgments exist for IR 1 and IR 2 that are influenced by the disclosure of the expert judgments. Therefore, the judgments in M 4 that are influenced by the disclosure of expert judgments will not be considered here. Accordingly, with respect to IR 1 or IR 2 this longitudinal analysis only considers group discussions where no expert judgments were disclosed. Complementary, for IR 3 and IR 4, the discussions of the first run which were *not* influenced by the disclosure of expert judgments immediately after M 1 will not be included in this analysis. Accordingly, the disclosure of expert judgments at the beginning of the discussions (yes vs. no) is totally confounded with the use of different tasks (IR 3 and IR 4 vs. IR 1 and IR 2) in this analysis. Yet, as a consequence there is no confounding between the variable case study (before vs. after) and the disclosure of expert judgments for IR 1 and IR 2. This allows for a proper examination of the effects of case study participation itself, which is the focus of this longitudinal analysis.

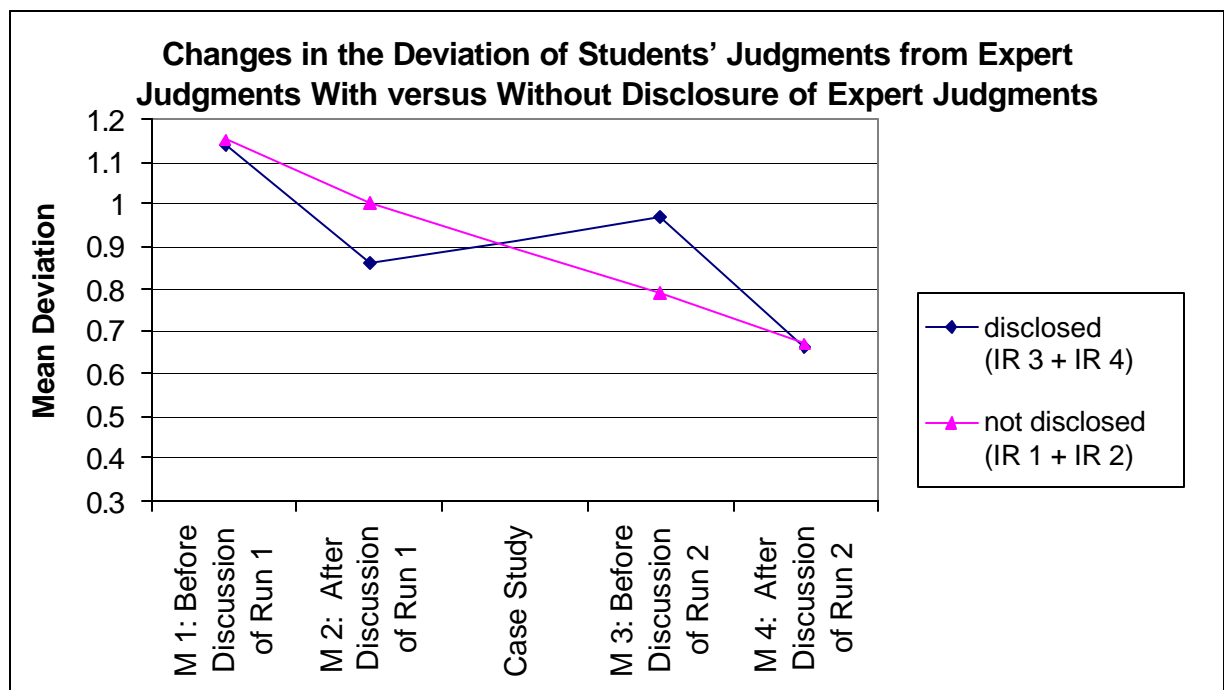


Figure 2: Development of the mean deviation of students' judgments from expert judgments in the 4 measurements M1 = before group discussion at beginning of case study, M 2 = at the end of the group discussion of run 1, M 3 = before group discussions at the end of the case study, and M 4 = at the end of the group discussion of run 2. The expert judgments for the IRs 3 and 4 were disclosed to the students at the beginning of all discussions included in this figure. Expert judgments for IR 1 and IR 2 were not disclosed in any of the discussions included in this figure.

The ANOVA was performed with the repeated measurement variables *case study* (2 levels: beginning vs. at the end of the case study), *discussion* (2 levels: before vs. at the end of the discussion), *disclosure of expert judgment* (2 levels: yes vs. no, this variable is confounded with the two tasks IR 3 and IR 4 vs. IR 1 and IR 2), *task number* (2 levels: high vs. low number, this variable distinguishes IR 3 vs. IR 4 on the *yes* level of the variable disclosure of expert judgment, and IR 1 vs. IR 2 on the *no* level). The dependent variable was the mean deviation (DE) of the students' judgments in each synthesis group from the expert judgments.

There was a significant main effect for the variable case study, $F(1, 3) = 19.41, p < .05$. The students' judgments at the end of the case study were significantly more appropriate than the judgments at the beginning of the case study. Hypothesis 1 was thus confirmed by the data. In addition, there was a significant main effect of discussion, $F(1, 3) = 12.21, p < .05$. At the end of the discussions the students' judgments were significantly more accurate compared to the beginning of the discussions. Figure 2 depicts the development of the mean deviation of the students' judgments from the expert judgments over the four pre- and post-discussion measurements M 1 to M 4 for a special selection of groups. Corresponding to the experimental design as depicted in Table 1, for IR 1 and 2 only the groups *without* disclosure of expert judgments are included ($M_{DE_M1} = 1.15, M_{DE_M2} = 1.00, M_{DE_M3} = 0.79, M_{DE_M4} = 0.67$), whereas for IR 3 and IR 4 only the group discussions *with* disclosure of the expert judgments are included ($M_{DE_M1} = 1.14, M_{DE_M2} = 0.86, M_{DE_M3} = 0.97, M_{DE_M4} = 0.66$). According to Figure 2, there was no difference between the two IRs for which the expert judgments were disclosed, and the other two IRs in the overall tendency of the individual judgments to approach the expert judgments. Hypothesis 2 was thus not confirmed by the data. It is difficult to interpret this result, because differences of the IRs may play a role here. Nevertheless, this result shows that the information on the opinions of external experts was not a prerequisite for improvements of judgment accuracy during case study participation. Figure 2 indicates that the processes of case study participation, simple group discussions, and group discussions with disclosure of expert judgments point into the same direction. However, the figure also shows an apparent rebound effect of diminishing judgment validity during case study participation for the IRs 3 and 4, where the expert judgments have been disclosed in the discussions of run 1. A plausible explanation for this effect could be that the students tended to forget the disclosed expert judgments during the case study. This might well have caused the students to revert to some extent to their pre-discussion judgments of run 1.

Influence of the Disclosure of Expert Judgments on Opinion Formation during the Discussions

The process of opinion formation in the experimental group discussions was analyzed with respect to changes in the validity of the students' judgments, and with respect to the level of confidence that the students had in their judgments. The experimental design only includes the group discussions on IR 3 and IR 4 in run 1 and the discussions on IR 1 and IR 2 in run 2. For these discussions the disclosure of the expert judgments was experimentally varied, that is, only, in half of the groups the expert judgments were revealed to the discussants at the beginning of the group discussions.

As in the previous analysis, the absolute deviation of the students' judgments from the expert judgment for a task was used as the measure for judgment (in-)accuracy. The units of this analysis were the five-person groups. The group mean, of the absolute deviation (DE) of the individual judgments from the expert judgment served as the dependent variable. The individual judgments for each IR were assessed five times during the discussion. Accordingly, an ANOVA with the repeated measurement variables *assessment* (5 levels: individual judgments 1 to 5) and *task number* (2 levels that represent IR 3 vs. IR 4 in run 1, and IR 1 vs. IR 2 in run 2) was performed. The two independent variables were the *disclosure of expert judgment* (2 levels: yes vs. no), and *experimental run* (2 levels: run 1 vs. run 2).

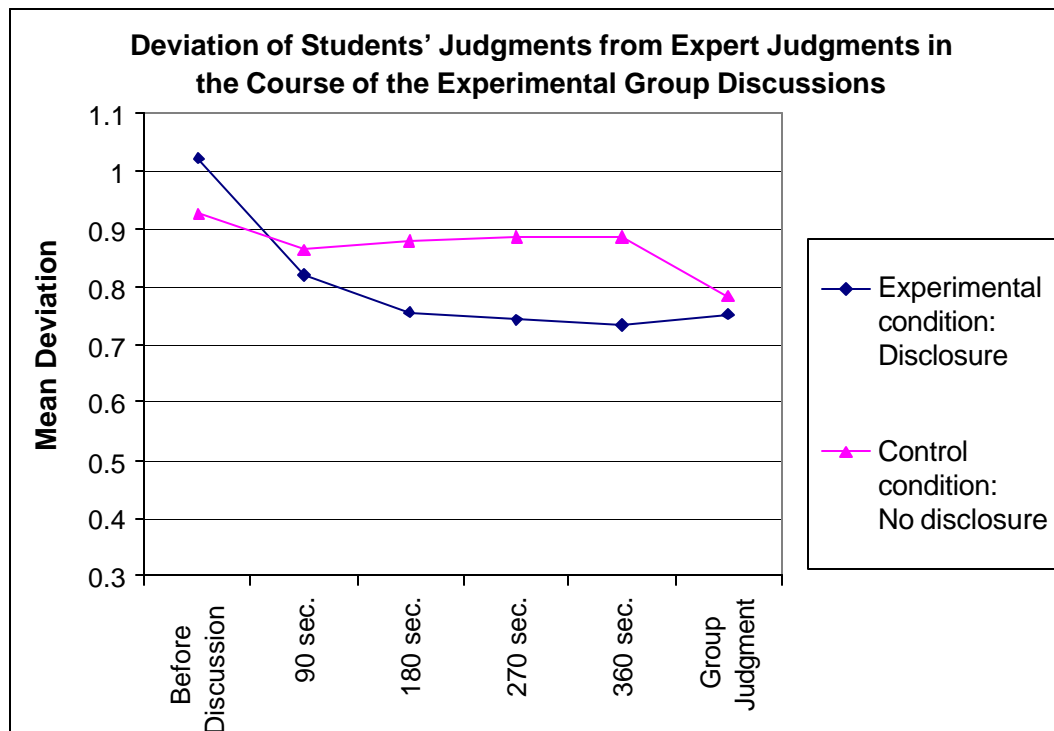


Figure 3: Mean deviation of students' judgments from expert judgments at the individual assessments before the discussions and during the discussions, and for the group judgments, separated for the experimental groups *with* versus control groups *without disclosure of the expert judgments*. In the disclosure condition the students were informed about the expert judgments immediately after the individual assessment before the discussions.

The ANOVA showed a highly significant main effect of assessment, $F(2.98, 71.52) = 10.96, p < .001$ ($\epsilon = .75$).³ This effect reflects that the inaccuracy of the judgments continuously decreased from $M_{DE_1} = 0.96$ at the beginning of the discussions to $M_{DE_5} = 0.81$ at the end of the discussions.

The Hypothesis 3 was hence confirmed in this analysis as well as by the previous longitudinal analysis. Additionally there was a highly significant interaction effect between the independent variable disclosure of expert judgment and the repeated measurement variable assessment, $F(2.98, 71.52) = 6.11, p < .001$ ($\epsilon = .75$). Confirming Hypothesis 4, this effect shows that the students' individual estimates in the groups where the expert judgments were disclosed, approached the expert judgments more strongly than in the control groups (see Figure 3).

The joint group judgments were not included in the analysis, because individual learning is the main focus in the present context. However, a corresponding, additional ANOVA revealed no difference between the validity of the group judgments in the experimental condition and in the control groups (see Figure 3). This was due to a marginally significant increase in accuracy from the last individual judgments to the joint group judgments in the control groups ($p < .1$), which was not observed in the experimental condition.

The subjective confidence (C) of the students in their judgments was analyzed within an ANOVA that was analogous to the analysis of the validity of the students' individual judgments. The group mean of the confidence points that each group member allocated to his or her own judgment served as the dependent variable.

The analysis showed a significant main effect of assessment, $F(3.40, 81.54) = 3.61, p < .05$ ($\epsilon = .85$). Before the discussions the mean confidence level was $M_C = 58.16$, after 90 seconds of discussion the mean confidence level was reduced to $M_C = 57.15$, subsequently the confidence level increased continuously to $M_C = 59.67$ at the end of the discussions. The *disclosure X assessment*

³ Because of a significant violation of the sphericity assumption (Mauchly Sphericity Test, $p < .001$), the degrees of freedom were corrected according to the Huynh-Feldt-Epsilon ($\epsilon = .745$). A similar procedure was necessary in some of the following analyses. Values of Huynh-Feldt-Epsilon are presented in parentheses after the level of significance.

interaction was marginally significant, $F(3.40, 81.54) = 2.13, p < .1$ ($\epsilon = .85$). There was a tendency that the reduction in confidence that was observed in the first phase of the discussions was stronger in those groups where the expert judgments were disclosed and a descriptive overall increase in confidence was only observed in the control condition.

Discussion

This field experiment analyzed the effects of incorporating the opinions of external experts into a transdisciplinary environmental case study on the validity of students' judgments of the relationship between environmental impact variables within the environmental system of the case. Therefore, two different group discussion formats, namely usual group discussions, versus group discussions including the preliminary disclosure of expert judgments were experimentally compared. The point of reference for the evaluation of students' judgment validity was defined by the mean judgments of independent experts. Changes in the appropriateness of students' judgments on environmental impacts, as measured by changes in the deviation of these estimates from the expert judgments, were interpreted as an indicator for learning effects. The ETH-UNS case study 1998 in Klettgau presented the context for the analyses.

Case Study Participation and Expert Information

The longitudinal analysis revealed a significant effect of case study participation on judgment validity. This increase in the validity of the students' judgments can be interpreted as an indicator for an improved system understanding, which is basic for environmental problem-solving. However, this interpretation has to be regarded with some caution, because judgment validity as measured in the present experiment represents a very specific and narrow indicator of environmental problem-solving ability. Moreover, the collaboration with experts during the project work in the case study can be connected to the reception and superficial adoption of expert judgments on relevant aspects of the problem under consideration. This is true even though the IRs that were selected for the experiment have not been the focus of any planned instruction during the case study, and even though the external experts, whose estimates served as the standard of excellence for the students' judgments, did not take part in the case study. There was no difference in the tendency of the students' judgments to approach the expert judgments between the two IRs where the expert opinions were disclosed to the students, and the two IRs where these estimates were not disclosed (see Figure 2). This shows that additional information provided by external experts is not absolutely necessary for the students to achieve a profound understanding of relevant impact relations within a case. However, it would be preemptive to conclude that the information on the opinions of external

experts generally has no positive effect on the improvement of judgment accuracy due to case study participation. A study that uses a larger pool of IRs, which are randomly assigned to the disclosure and non-disclosure condition, would be necessary to allow for such a conclusion. Moreover, we do not know the effect participation in the case study would have had on the experts. Perhaps the external experts would have changed or differentiated their judgments. As local and scientific, the selected experts had particular knowledge about the case, but they were unfamiliar with the transdisciplinary case study and the kind of integrated knowledge such studies produce.

Group Discussions With Versus Without the Disclosure of Expert Opinions

The experimental sub-design compared the process of collective judgment formation in groups where the expert judgments were disclosed at the beginning of the group discussions versus in groups where no such disclosure took place. The net effect to reduce the deviation of the students' judgments from the expert judgments was significantly stronger in the discussions where the expert judgments had been disclosed to the students. However, there was no significant difference between the validity of the common group judgments of the experimental versus control groups. This suggests that the integration of the individual knowledge and information of the group members into a joint group decision might have effects similar to the integration of external expert information. In the groups where no expert information was given, the group judgments tended to be more accurate than the individual judgments immediately preceding the group decision. This was not observed in the experimental condition. The higher accuracy of the group judgments as compared to the individual judgments, which were assessed immediately before the group decisions were made, might have been connected to learning processes and increases in judgment accuracy on the individual level. The result might, however, also be due to the aggregation of the individual judgments into one group decision, e.g. via averaging the individual judgments (e.g. Crott, Szilvas, & Zuber, 1991; Crott, Zuber, & Schermer, 1986). If the first explanation would be valid, this would suggest that the formulation of a group decision is a didactically very important part of group discussions, which should be included in instructional group discussions because of its potential to enhance individual judgments - in particular, if the students have no access to external (expert) information that can resolve the issues of the group discussion. Considering further experiments, the results suggest that it is important to also assess the individual judgments of the group members after the group decision is formulated, in spite of the fact that unambiguous results with respect to the processes underlying the changes of individual judgments subsequent to a group discussion are very difficult to obtain. For example, there are manifold possibilities that might account for the (possible) accommodation of individual judgments to the group judgment, e.g. reduction of dissonance, normative pressure or the facilitation of collective action (e.g. Festinger, 1954, 1957, 1964; Zuber, Crott, & Werner, 1992). The challenge would be to experimentally identify which of these processes are operative and to conceptually relate these processes to individual learning.

The analysis concerning the confidence of the students in their judgments showed that, in the disclosure condition, the subjective confidence that the students had in their judgments did not increase during the discussions, whereas there was such an increase in the control groups. This might seem surprising. Experts generally possess a high credibility, which is what we have assumed to be one reason for the strong influence that the expert judgments exerted on the students' judgments. It might well have been expected that the disclosure of information from a highly credible source would be connected to a high confidence of the students in their own adapted judgments. However, the experts could not contribute arguments to support their judgments. Supposedly, corresponding arguments can increase the confidence of students who adopt the position of experts, in particular if the students cognitively integrate them via *central* as opposed to *peripheral information processing* (see Petty & Cacioppo, 1986).

On the one hand, the missing gains in confidence in the disclosure groups indicate that the students did not fully comprehend the expert judgments they were informed of. On the other hand, the lack of significant confidence gains indicates that the students did not adopt the expert judgments in an overconfident, uncritical manner. In both conditions, individual confidence decreased in the first phase of the discussion, i.e. subsequent to the presentation of the expert judgments and to hearing about the judgments of the other group members, respectively. Considering the experimental groups, one explanation for the decrease in confidence might be that the students adopted the expert opinions without seeking personal understanding of the judgments. However, the observed reduction of confidence might also be due to a cognitive conflict raised by the differences between their own pre-discussion viewpoint and the expert judgments. Thus, no definite conclusion can be drawn as to what extent the students really understood the expert judgments that had been disclosed to them, and to what extent they simply adopted the expert judgments superficially, e.g. because of their high credibility. Therefore, even though there was a stronger net effect on individual judgment validity in the disclosure groups, as compared to the control groups, it is not possible to determine which of the two discussion formats obtains a stronger learning effect with respect to the students' environmental problem-solving ability. For the practical design of group discussions in higher environmental education there exists, however, the possibility to combine the two formats. The group discussion could begin *without* the disclosure of expert opinions. This first part of the instructional group discussion could increase the validity of students' individual judgments, without the help of external experts. In this phase, the students are required to generate arguments and to form their own opinion. Subsequently, the expert judgments could be disclosed to the students as an additional informational basis. In this second part, a further increase in the congruence of the students' estimates with the expert estimates might be obtained. Moreover, during the second part, the reasoning and the arguments of the experts for their judgments can also be unveiled to the students. This would enable the students to better comprehend the expert judgments, to gain confidence in these judgments, and to subsequently form a group judgment on a more elaborate informational

basis. Accordingly, the students first get the opportunity to construct their own viewpoint, and subsequently additional information is presented to enhance their environmental understanding.

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