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# Preventing undesirable effects of mutual trust and the development of skepticism in virtual groups by applying the knowledge and information awareness approach

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**Abstract** Empirical studies have proven the effectiveness of the knowledge and information awareness approach of Engelmann and colleagues for improving collaboration and collaborative problem-solving performance of spatially distributed group members. This approach informs group members about both their collaborators' knowledge structures and their collaborators' information. In the current study, we investigated whether this implicit approach reduces undesirable effects of mutual trust and mutual skepticism. Trust is an important influencing factor with regard to behavior and performance of groups. High mutual trust can have a negative impact on group effectiveness because it reduces mutual control and, as a result, the detection of the others' mistakes. In an empirical study, 20 triads collaborating with the knowledge and information awareness approach were compared with 20 triads collaborating without this approach. The members of a triad were spatially distributed and participated in a computer-supported collaboration. The results demonstrated that the availability of the knowledge and information awareness approach overrides the negative impact of too much mutual trust and counteracts the development of mutual skepticism. This study contributes to further clarifying the impact of trust on effectiveness and efficiency of virtual groups depending upon different situational contexts.

**Keywords** Computer-supported collaborative problem solving · Group awareness · Knowledge and information awareness · Mutual skepticism · Mutual trust

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## Introduction

Different lines of research (e.g., Nickerson 1999; Wegner 1986) highlight the importance of knowing what collaborators know in order to communicate and collaborate effectively. However, the process of acquiring such knowledge is prone to errors (e.g., Nickerson 1999) and the acquisition of such knowledge needs time (Wegner 1986). Engelmann and colleagues have developed a solution for this problem: Their knowledge and information awareness approach (KIA approach) assists spatially distributed group members in acquiring knowledge about their collaborators' knowledge structures and the information underlying these structures in an effective and efficient way (e.g., Engelmann and Hesse 2010; Engelmann et al. 2010). Therefore, they define knowledge and information awareness (KIA) as being informed about the collaboration partners' knowledge structures and about the partners' information underlying these structures (e.g., Engelmann et al. 2010). The acquisition of KIA is enhanced by digital concept maps that visualize both the collaborators' knowledge structures and the information underlying these structures (see Fig. 1). These concept maps are provided to the group members while they are participating in a computer-supported collaboration.

Concept maps are a well-proven kind of knowledge visualization consisting of hierarchically ordered labeled nodes and labeled links between these nodes (Novak and Gowin 1984). Digital concept maps moreover allow for adding hyperlinks for accessing further information (e.g., Alpert 2005).

The studies by Engelmann and colleagues demonstrated that this KIA approach not only improves collaborative problem solving of virtual groups – that is, groups with spatially distributed group members – but also can help to overcome several collaboration barriers (e.g., Engelmann and Hesse 2011; Engelmann and Kolodziej 2012; Schreiber and Engelmann 2010).

Another collaboration barrier refers to the concept of mutual trust. Trust is an important influencing factor with regard to behavior and performance of groups (Salas et al. 2005). According to Mayer et al. (1995) trust refers to "the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party" (p. 712); that is, one group member has to believe that another group member will perform the needed activity in order to accomplish a common task.



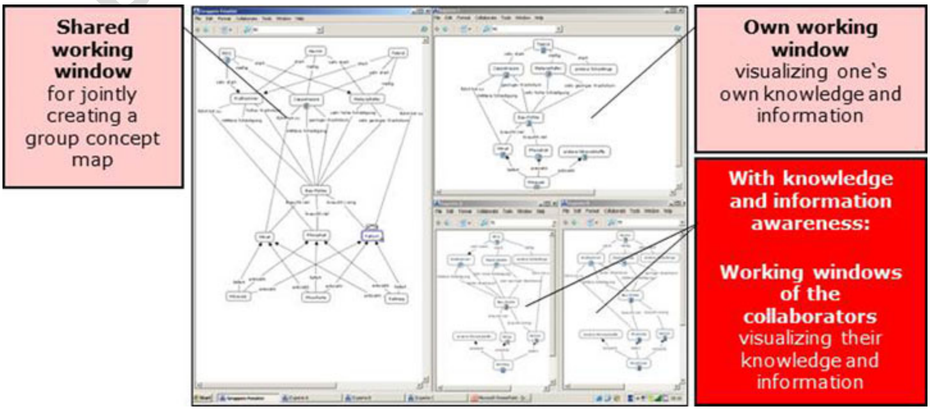


**Fig. 1** Computer screen of the experimental condition with a KIA approach Q5

Imagine a situation in which several people, having different domain expertises, were ordered to solve an acute environmental pollution problem: They are highly busy and work at different institutions. Therefore, they have to collaborate via computers. In addition, they do not know each other and thus do not know what the others know – a problem that could be solved with the KIA approach. Moreover, all experts differ in the amount of general trust they have in others, also called trust propensity (trust as a trait) (e.g., Colquitt et al. 2007). Thus trust is likely to affect the collaboration. In addition, mutual trust can be developed through collaboration (trust as a state) (cf. Aubert and Kelsey 2003).

Our current study addressed group situations like the one described and investigated the impact of mutual trust in virtual groups on group performance depending on whether the KIA approach is available or not (trust as a predictor). In addition, it investigated whether – depending on the availability of the KIA approach – differences in the amount of collaboration quality have an impact on the developed trust after the collaboration phase (trust as criterion).

In this paper, we will start by highlighting the challenges of computer-supported collaboration, especially the need for fostering the acquisition of knowing what collaborators know. We will then explain how the KIA approach solves this problem and why it is able to help to overcome several collaboration barriers, especially the barrier with regard to mutual trust. Subsequently, we will present our experimental study . The paper ends with a discussion as well as with explicating implications.

## Challenges of computer-supported collaboration

The need for collaboration, especially between persons in different fields, is ever rising in our information age, and certainly the geographical dispersion of different experts can be overcome by using, for example, specialized groupware. Groupware can also address the social element of computer-supported collaborative learning (CSCL) such as explicating thoughts, actively discussing views, and coordinating actions (Kirschner and Erkens 2013). To bridge the research gap between computer-supported cooperative work (CSCW) and CSCL, Fransen et al. (2013) summarized variables mediating group effectiveness and applied these findings from CSCW research to the field of CSCL. While there are differences between working- and learning-teams, many similarities make knowledge gained in a CSCW setting applicable to a CSCL setting and vice versa.

There are several advantages of computer-supported collaboration (cf. Engelmann et al. 2009; Janssen and Bodemer 2013; Kirschner and Erkens 2013), but it is not easily achieved in an effective way. Interaction problems, especially regarding communication and coordination may occur (Janssen et al. 2007): For example, a reduced amount of communication channels may hinder coordination (e.g., Smith et al. 2011), provided communication capabilities may be rarely used (Lambropoulos et al. 2012) or misused (Baker et al. 2012). According to Kirschner et al. (2008) learning often does not take place in CSCL settings, because the tasks are not suited for collaboration, the computer-supported environment is not suited to support learning, or the social conditions that are necessary for good collaboration do not exist. In this current paper, we refer to the last reason: A difficulty for virtual groups is that often the members do not know each other before they have to collaborate on a common task, and therefore, they do not know what their collaborators know. However, different lines of research have demonstrated the importance of knowing what collaborators know (cf. Engelmann and Hesse 2010): Research on *Audience Design* (e.g., Dehler-Zufferey et al. 2011) gives evidence that individuals adapt their texts depending upon the addressee. According to the *Knowledge Imputing* approach (Nickerson 1999), effective communication requires a sufficient amount of correct knowledge about the communication partner's knowledge. If one overestimates the partner's knowledge, the partner might not be able to understand the statements anymore (Nickerson 1999). This is also highlighted by Beers et al. (2005) who pointed out that members of a multidisciplinary group "need to find some kind of commonality between their different perspectives in order to benefit from each other" (p. 624). Studies on the *Theory of Transactive Memory System* (Wegner 1986) confirm that the groups whose members know who is an expert on which topics achieve more in-group tasks (e.g., Liang et al. 1995).

Prior research has shown that it is not easy to acquire correct knowledge about the collaboration partner's knowledge: During this process, a lot of perception or evaluation mistakes can slip in (Nickerson 1999). In addition, according to the theory of transactive memory system (Wegner 1986) sufficient common time is required to acquire this knowledge. Furthermore, there are situations in which the possibilities of acquiring knowledge about the partners' knowledge are strongly restricted (Engelmann and Hesse 2010), for example a CSCL setting with a reduced amount of communication channels (cf. Baker et al. 2012; Lambropoulos et al. 2012).

## The approach for fostering knowledge and information awareness

In order to find a solution to the need for and the problem of acquiring knowledge about the collaboration partners'knowledge in computer-supported collaborative settings, Engelmann (née Keller) and colleagues developed their KIA approach (Keller et al. 2006). It provides, as mentioned above, the spatially distributed group members with their collaborators' knowledge structures and their collaborators' information underlying these structures, both visualized by means of digital concept maps (e.g., Engelmann and Hesse 2010).

Empirical studies confirmed that this approach not only leads to an easy and quick acquisition of KIA, but also to an improvement of collaborative problem solving (e.g., Engelmann and Hesse 2010). Because it has been proven that collaborative problem solving fosters learning (e.g., Hausmann et al. 2004), one can expect that this approach also increases learning. This was tested in a recent study by Lechner and Engelmann in which the KIA approach was applied in a school setting to improve learning in biology. This data is being analyzed at the moment.

That knowledge awareness increases learning has been also confirmed by studies using other approaches: For example, Bodemer's (2011) knowledge awareness approach marginally improved individual learning gains as well as collaborative learning performance. In his experimental condition a learner was provided with his own solution together with the learning partner's solutions in the context of a multiple external representation task, while in his control condition the dyad members only saw their own solutions. In the study by Nückles and Stürz (2006) self-ratings regarding the expertise of laypersons were provided to the experts. As a result, the communication between the expert and the layperson was more efficient, compared to a condition without this knowledge awareness tool. This improved communication led to laypersons acquiring more procedural and declarative knowledge.

Empirical results demonstrated that the KIA approach may also assist in overcoming collaboration barriers: With the study by Engelmann and Hesse (2011) evidence was provided showing that the KIA approach fostered sharing and cognitively processing of unshared information. In the study by Schreiber and Engelmann (2010), it was shown that this approach fostered the development of a transactive memory system. Further effects of knowledge awareness approaches in CSCL are summarized by Janssen and Bodemer (2013). In the current paper, we focus on investigating a collaboration barrier having to do with the concept of mutual trust.

**The impact of mutual trust on behavior and performance of groups**

Trust is an important influencing factor regarding behavior and performance of groups (Salas et al. 2005). It can lead to more helping behaviors in CSCL groups (Hsu et al. 2011) and is seen as a crucial part of CSCL by Kirschner and Erkens (2013). Changes in the situation can have an impact on the role of trust in groups (e.g., Kramer 1999). For example, the role of trust is dependent on the degree of structure in the situation (Dirks and Ferrin 2001; Jarvenpaa et al. 2004), that is, the degree of freedom regarding the group members' activities: In situations with a low degree of structure, trust has a direct effect on group variables. In such situations, it is difficult to interpret others' behaviors. Therefore, their behavior is interpreted depending on the amount of trust the group members have with each other. In situations with a moderate degree of structure, trust is a moderating factor. Factors for interpreting others' behaviors are given; however, trust influences how these factors are interpreted. In situations with high structure, others' behaviors can be directly evaluated. Trust is not used to interpret others' behaviors and, therefore, does not have any impact on group measurements.

In situations, in which trust has an effect on group variables, the following relations are to be expected: In numerous publications (e.g., Jarvenpaa et al. 1998), it is argued that mutual trust is an important influencing factor for group effectiveness. This was also confirmed by several empirical studies (e.g., Colquitt et al. 2007; Kanawattanachai and Yoo 2002; Paul and McDaniel 2004). Further empirical studies, for instance by Aubert and Kelsey (2003) as well as Jarvenpaa et al. (2004), have shown that trust has an effect on group efficiency, but not on group effectiveness.

These contradictory results could possibly be explained by another influencing factor, namely, correctness of individual performances: If group members with *high mutual trust* work without mistakes, this should result – according to Aubert and Kelsey (2003) as well as Jarvenpaa et al. (2004) – in a faster and, therefore, more efficient collaboration, since it is to be expected that high mutual trust reduces mutual control. When free from errors, high mutual trust should not have an impact on group effectiveness. If group members with high mutual trust make mistakes, these mistakes might not be discovered due to the reduced mutual control caused by having high mutual trust. This should lead to reduced group effectiveness (cf., Jarvenpaa et al. 2004; Dirks and Ferrin 2001). Due to the fact that efficiency is defined as effectiveness per time, the time saved while performing the task has to be very high in order to obtain good efficiency with low effectiveness. Therefore, it is expected that low effectiveness will lead to poor efficiency (see Fig. 2, left side).

Contrarily, *low mutual trust* should increase mutual control and, therefore, the needed time; that is, it should reduce group efficiency. *Low mutual trust* has already been shown to lead to more relationship conflicts and task conflicts as well as to reduce the time of constructive collaboration (Peterson and Behfar 2003). However, there is a good chance that the mistakes of the collaboration partners will be discovered. As a consequence, higher group effectiveness can be expected (see Fig. 2, right side).

Due to the fact that, compared to face-to-face collaboration, computer-supported collaboration is often accompanied by various difficulties (e.g., Janssen and Bodemer 2013), it is most likely that the group members will make mistakes. Therefore, the following argumentation refers only to collaborations in which mistakes appeared.

In computer-supported environments, the ability for mutual control is often more limited compared to face-to-face settings. Therefore, it is to assume that in computer-supported environments mutual control is very effortful.

One research goal of this study was to investigate the impact of mutual trust in virtual groups on group performance depending on whether the KIA approach was available or not. (Mutual trust is a predictor here.)

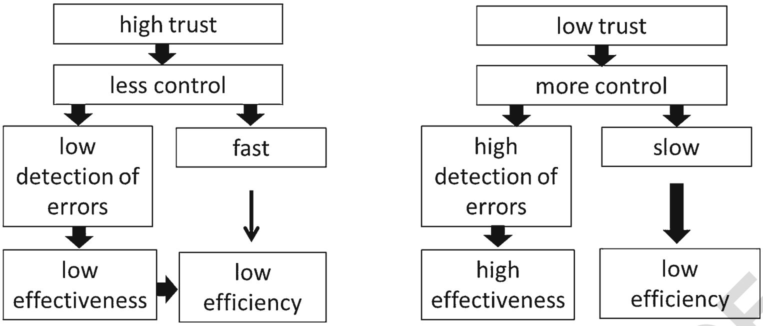


**Fig. 2** The impact of high trust (*left side*) and high trust (*right side*) on group effectiveness and group efficiency

The amount of mutual trust also varies depending on prior group experience in a concrete group (Aubert and Kelsey 2003). As a consequence, depending on the amount of collaboration quality in the group, a different amount of trust should develop.

Another research goal of this study was to clarify the question of whether – depending on the availability of the KIA approach – differences in the amount of collaboration quality have an impact on the development of trust after the collaboration. (Mutual trust is the criterion here.)

## Experimental study

With regard to these two research goals the following expectations were postulated.

### Expectations

*Postulated effects of the interaction between initial trust and condition on group performance (trust as predictor)* Without being provided with the KIA approach (control condition), it was to be expected that trust will affect group effectiveness: As explained above, if mutual trust is high, it was to be expected that there was low mutual control and, therefore, mistakes would not be detected. This should decrease group effectiveness (cf., Jarvenpaa et al. 2004; Dirks and Ferrin 2001) and – because of its relation to effectiveness – efficiency. However, low trust should lead to mutual control, even if mutual control was effortful in computer-supported settings. This should reduce efficiency, while effectiveness should be increased. (However, due to the mutual control difficulties in virtual groups, it was to be expected that not all mistakes would be detected.).

In addition, it was expected that by direct access to the collaborators' knowledge and information, the availability of the KIA approach (experimental condition) would facilitate mutual control. The ability for easy mutual control can therefore be given also in virtual groups. In prior studies (e.g., Engelmann and Hesse 2010), it was confirmed that the KIA approach is used if it is available. This means that even though the group members were not explicitly instructed to cognitively process the maps depicting their collaborators' knowledge structures and information, when these maps were provided, cognitive processing of the maps did take place. Therefore, there should not be an impact of mutual trust on mutual control; that is, there should be mutual control independent of the amount of mutual trust. Consequently, it was to be expected that the amount of mutual trust would not have an impact on group effectiveness and group efficiency.

Due to the fact that first, the collaborators' work would be checked over and, therefore, their mistakes would be detected, and second, because the process costs of mutual control are low, an effective and efficient group performance was to be expected, compared to groups that collaborate without the KIA approach.

To sum up, we hypothesized – under the assumption of the existence of individual mistakes in virtual groups – the following effects:

*Hypothesis 1:* Regarding *group effectiveness* as criterion, we expected a significant interaction between initial mutual trust and condition. In more detail, we expected that (1.1) in the experimental condition, initial trust would not have an impact on group effectiveness, while (1.2) in the control condition, high initial trust would reduce effectiveness because of less mutual control and, therefore, less mutual corrections of mistakes.

*Hypothesis 2:* Regarding *group efficiency* as the criterion, we only expected a main effect for condition in favor of the experimental condition; that is, (2.1) the experimental condition would be more efficient compared to the control condition. We expected (2.2) neither a main effect for trust nor an interaction of trust and condition on group efficiency.

*Postulated effects of the interaction between the quality of performance within the group and condition on the development of mutual trust (trust as criterion)* The amount of mutual trust varies also, for example, depending on the experiences in a concrete group (Aubert and Kelsey 2003). Therefore, depending on the amount of collaboration quality of the groups, a different amount of trust should be developed.

It was assumed that in the control condition, poor collaboration quality of the group will lead to low mutual trust and high mutual skepticism, respectively. The difficult mutual control in virtual groups should lead to the following: The group members should attribute poor collaboration quality to their collaborators, because they were not able to check the others' work completely. In the experimental condition, however, it was to be expected that the group members check each other's work due to the easy opportunities provided by the KIA approach. Poor collaboration quality of the group should, therefore, not be attributed to the collaborators whose work has been checked, but to external factors such as task difficulties.

*Hypothesis 3:* We expected a significant interaction between condition and the amount of collaboration quality of the group, having an effect on developed trust and developed mutual skepticism respectively. In more detail, we expected that (3.1) in the experimental condition, the amount of collaboration quality of the group would not have an impact on developing mutual skepticism, while (3.2) in the control condition poor collaboration quality of the group would lead to the development of mutual skepticism regarding the others' abilities.

A summary of all postulated hypotheses can be found in Table 1.

## Method

An experimental condition consisting of 20 triads being provided with the KIA approach was compared to a control condition consisting of 20 triads collaborating without this approach.

*Participants* Participants of the study were 120 students (84 female, 36 male) of a German university from different fields of study with an average age of 23.74 years ($SD$=3.47). They t1.1 **Table 1** Summary of hypotheses

| | | |
|---|---|---|
| t1.2 | Effects on group effectiveness | |
| t1.3 | 1.1 | In the experimental condition, initial mutual trust has no impact on group effectiveness. |
| t1.4 | 1.2 | In the control condition with increasing initial mutual trust, group effectiveness decreases. |
| t1.5 | Effects on group efficiency | |
| t1.6 | 2.1 | The experimental condition solves the problems more efficiently than the control condition. |
| t1.7 | 2.2. | Trust has no impact on group efficiency. |
| t1.8 | Effects on mutual skepticism | |
| t1.9 | 3.1 | In the experimental condition, the amount of collaboration quality has no impact on the development of mutual skepticism. |
| t1.10 | 3.2 | In the control condition with a decreasing amount of collaboration quality, more mutual skepticism develops. |

*Notes*: Experimental condition: with knowledge and information awareness approach; control condition: without it

volunteered to participate for payment. The participants collaborating in groups of three were randomly assigned to a control condition (20 triads) or an experimental condition (20 triads).

The compositions of the groups regarding gender were equal between the conditions; that is, both conditions had the same number of groups with no, one, two, or three women.

The members of a group either did not know each other or hardly knew each other: There was no significant difference between the conditions regarding the degree of acquaintance among the members in a group ($F<1$).

The participants were not balanced with respect to the field of study because the domain material was artificial and, therefore, no advantage could exist for a particular field of study.

*Setting and materials* The members of a triad were spatially distributed and collaborated computer-supported. They communicated by using Skype (only audio). The experimental environment consisted of several shared and unshared working windows of CmapTools, a digital concept mapping software developed by the Florida Institute for Human and Machine Cognition (USA).

The study was held in German. Therefore, for this paper, all contents have been translated into English.

The domain refers to rescuing a fictitious type of spruce forest and consisted of 13 concepts, 30 relations between the concepts and 13 pieces of background information (in parts divisible into sub-elements), each linked to a concept. These elements were evenly distributed among the three group members in a way that each member had the same amount of shared and unshared concepts, relations, and background information aspects. The shared elements were shared with either one collaborator or both collaborators.

The following online questionnaires and instructions were used in the study:

An online questionnaire for assessing several control measure items (e.g., experience in working with computers and in groups) and for measuring the amount of initial mutual trust was included. For measuring mutual trust several items taken from Amelang et al. (1984), from Jarvenpaa et al. (1998), as well as from Jarvenpaa et al. (2004) were used that were translated into German and partly adapted to our experimental setting. The 15 control measure items and the 13 items for assessing mutual trust were designed as multiple-choice items with five-point rating scales, ranging from complete agreement to no agreement. Examples of items are: “I can create visualizations by means of a computer” (control measure item) and “In contact with strangers, it is better to be careful until they have provided evidence that one can trust them.”

An online knowledge test was used to measure the knowledge of group members regarding their own and their collaborators' knowledge on particular relations and concepts. It consisted of 24 multiple-choice test items. These items were classified with regard to who possessed the requested knowledge, resulting in four types of items: (1) items asking for *one's own unshared elements*, that is, items measuring knowledge that one alone had in his/her individual map (Item example for Expert A: "Please mark which expert(s) had knowledge about the relation between Topisol and nitrate – Expert A, B, or C?" Only Expert A had this knowledge.), (2) items asking for the *collaborators' unshared elements,* that is, items measuring knowledge that only one of the collaborators had (Item example for Expert A: "Please mark which expert(s) had knowledge about the relation between Oxatrol and potassium – Expert A, B, or C?" Only Expert B had this knowledge.), (3) items asking for *shared elements that one shared with one of the collaborators*, that is, items measuring knowledge that one had together with one of the collaborators (Item example for Expert A: "Please mark which expert(s) had knowledge about the relation between spruce and potassium – Expert A, B, or C?" Only Experts A and B had this knowledge.), and (4) items asking for *shared elements of the collaborators*, that is, items measuring knowledge that only the two collaborators had (Item example for Expert A: "Please mark which expert(s) had knowledge about the relation between spruce and fidget-grub – Expert A, B, or C?" Only experts B and C had this knowledge.). For each item the participants stated whether they were certain that they had answered it correctly (rating scale with three answers possibilities from low, middle, and high certainty).

A second online questionnaire was used to evaluate the study as a whole to assess aspects of collaboration and mutual control, to subjectively rate the quality of the group performance as well as to measure the amount of mutual trust and skepticism after collaboration. For measuring mutual trust and skepticism several items taken from Jarvenpaa et al. (1998) that were translated into German and adapted to our experimental setting as well as our own created items were used. In addition, only in the experimental condition was the usefulness of the KIA approach assessed. Again the items were designed as rating scales with answer categories ranging from one point for no agreement and five points for complete agreement. The questionnaire contained 50 items in the control condition and – due to the additional items – 56 items in the experimental condition.

The group members were provided with a paper-based instruction on how to use CmapTools and with a paper-based instruction to explain all the phases of the study and the tasks to be completed by the group members.

*Procedure* After informing the participants about the framework of the study and obtaining their signed letter of agreement to take part in the study, the three members of a group were sent to separate rooms each equipped with a desk and a computer. They began the study by individually filling out the online questionnaire for assessing several control measure items and their initial mutual trust. After that, each group member practiced using CmapTools until she or he was familiar with the core functions of creating digital concepts maps. This practicing phase took about 10 to 20 min. In the subsequent phase, the group members were informed that they should imagine that they were three experts who would have to mutually rescue a spruce forest. They were told that in order to rescue this forest they would have to solve two problems, namely, first which pesticide and second which fertilizer they would use. The fertilizer problem could only be solved correctly if the pesticide problem was solved correctly. The groups were told that there was only one solution for each problem. Thus, the problems were well-defined. They were further told they should imagine that in the past they had taken some notes regarding these problem domains and that – based on these notes – they had to create their own concept map visualizing their own knowledge and information. They were given the notes containing one of three partly different pieces of expert information and had 20 min to create their individual concept map. This was enough time for each group members to finish the individual map. Log files of creating the individual maps were generated (by CmapTools).

After that the groups of the experimental condition were additionally provided with their collaborators' individual concept maps for 5 min. This individual phase was included to assure that the members of the experimental condition looked at their partners' map. In order to control the time in the individual phase, the group members of the control condition had 5 more minutes for viewing their own individual map.

Then the collaborative problem solving phase started, lasting 35 min. In this phase, the groups had to solve the two problems for rescuing the forest. In order to accomplish this, they had to merge their individual conceptual knowledge by jointly creating a single group concept map in a shared working window. The background information aspects were irrelevant to the problem, but this was not known to the group members. The group members could speak with each other by using Skype (only audio). Besides the shared working window, each member of the control condition had access to their own individual concept map that they had created in the individual phase (see Fig. 3 left side).

The members of the experimental condition were – throughout the whole collaboration phase – additionally provided with their collaborators' individual concept maps visualizing their collaborators' conceptual knowledge and background information (see Fig. 3, right side). Due to the fact that the knowledge and information elements were evenly distributed among the three members of a group, there was no information difference between the conditions. The only difference was the visibility of the partners' knowledge and information.

In this collaborative phase, log files of creating the group maps were generated (by CmapTools), and computer screen contents as well as audio conversations were captured (by Camtasia).

Thereafter, a second individual phase with no time limits and no access to the experimental environment started in which the group members first had to fill out an online knowledge test for measuring KIA and second had to complete a questionnaire for evaluating the study and aspects of collaboration and problem-solving as well as for measuring the amount of developed mutual trust and skepticism.

At the end of the study, the participants were thanked, rewarded, and debriefed.

## Predictor measures

To answer the hypotheses, besides differing between *control condition* and *experimental condition*, the following measures were used as predictor measures:

The factor "trust in others due to experience" (in the following this will be called *initial trust*) was used to answer Hypotheses 1 and 2.[1] There was no significant difference between the conditions regarding this factor ($M_C$=0.16; $M_E$=−0.16; $F(1, 38)$=1.06; $MSE$=1.00; $p$=0.31).

To answer Hypotheses 3, the following predictors were used:

The predictor *solution potential of the individual maps* means the amount of domain content in the three individual maps of a triad needed to solve the problems. The more

[1] A factor analysis with Varimax rotation with the 13 trust items included in the questionnaire on control measurements (cf. Bortz and Schuster 2010) was applied and resulted in these two interpretable factors: initial skepticism, *Cronbach's* $\alpha$=0.59; initial trust, *Cronbach's* $\alpha$=0.78. Since the internal consistency is only acceptable if Cronbach's $\alpha$ is higher than 0.70 (e.g., Nunnally and Bernstein 1994), the factor "initial scepticism" was not included in further analyses.

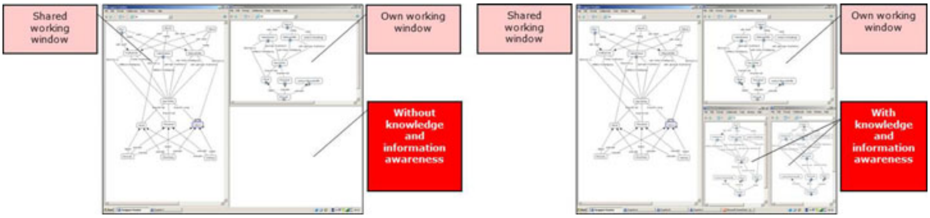


**Fig. 3** Computer screen of the control condition (*left side*) and the experimental condition (*right side*)

problem-relevant aspects were in the three maps, the higher their solution potential was. If the three individual maps of a triad contained all correct domain content aspects that were needed to solve both problems, two points were given. If information was missing or wrong, and therefore only one of both problems could be solved, one point was given. If no problem could be solved by means of the three maps, no points were given. The interrater agreement was *ICC*=0.85 (two-way mixed single measures (cf. Shrout and Fleiss 1979). As assumed, there was no significant difference between the conditions regarding this variable ($F<1$).

For analyzing the completeness of the group maps that the triads created in the collaborative phase, two dependent measures were assessed: the number of correctly drawn nodes in the group map (called *correct nodes in the group map*), that is, nodes with correct labels (max. 13 attainable points) and the number of correctly drawn relations contained in the group map (called *correct relations in the group map*), which means that the start and end node of the relation as well as the label were correct (max. 30 attainable points). In order to determine these measures, the group maps were compared to an original map representing all correct nodes and relations of the artificial domain material. The groups received one point for each entry of each category (e.g., if the group map of Group 3 contained 12 correctly drawn relations, this group received 12 points for the category "correct relations in the group map"). The interrater agreements were *ICC*=1 for correct nodes and *ICC*=0.99 for correct relations (two-way mixed single measures (cf. Shrout and Fleiss 1979).

## Criterion measures

*Criterion measures regarding group performance:* Regarding *group effectiveness* the following measures were differentiated:

Group maps' suitability for problem-solving refers to the amount of domain content in the group map that is needed to solve the problems. The more problem-relevant aspects are in the map, the more it is suited to solve the two problems. In this regard, two dependent measures were differentiated, namely *group maps' suitability for solving the pesticide problem* and *group maps' suitability for solving the fertilizer problem.* If in a group map all correct domain content aspects were available that were needed to solve the pesticide problem, one point was given. If information was missing or wrong, and therefore, the pesticide problem was not solvable by viewing the group map, no points were given. Analogous to this, if the information was provided in the group map for solving the fertilizer problem, one point was given, if information was missing or wrong and as a consequence the fertilizer problem was not solvable by viewing the group map no points were assigned. The interrater agreement was *Cohen's* $\kappa$=1 for "group maps' suitability for solving the pesticide problem" and *Cohen's* $\kappa$=0.87 for "group maps' suitability for solving the fertilizer problem" both indicating high rater agreement (Cohen 1960).

Regarding the quality of the problem solutions of the groups, we differentiated between two dependent measures, namely *solving the pesticide problem correctly* and *solving the fertilizer* *problem correctly*. If a group solved the pesticide problem correctly, one point was given, if the wrong pesticide was chosen, no points were given. Analogous to this, if a group solved the fertilizer problem correctly, one point was assigned, if the wrong fertilizer was chosen, no points could be attained. The interrater agreements were for both measures *Cohen's* $\kappa=1$ indicating perfect interrater agreement (Cohen 1960).

Regarding *group efficiency* the following measures were differentiated:

Because effectiveness was determined as a dichotomy variable in this study (solved vs. not solved), to determined efficiency measures, only those triads were included that solved the pesticide problem and/or the fertilizer problem correctly. Two measures were differentiated: The variable *efficiency of deciding for the correct pesticide solution* refers to the collaboration time needed to decide on the correct pesticide solution. The variable *efficiency of deciding for the correct fertilizer solution* refers to the collaboration time needed to decide on the correct fertilizer solution. The interrater agreement was $ICC=0.96$ for efficiency of deciding on the correct pesticide solution and $ICC=0.96$ for efficiency of deciding on the correct fertilizer solution (two-way mixed single measures, cf. Shrout and Fleiss 1979).

*Criterion measures regarding developed mutual trust and developed mutual skepticism after collaboration* The factors "trust in the others' ability and motivation" (called *developed trust*) and "skepticism regarding the others" (called *developed skepticism*) were used as dependent measures[2].

For validating purposes, we correlated the predictor factor "initial trust" with the criterion factors "developed trust" and "developed skepticism: Initial trust did neither significantly correlate with developed trust ($r=-0.01$, $p=0.96$), as one might have expected, nor with the other criterion factor ($r=-0.17$, $p=0.29$). The reason for this may be ascribed to the type of items that the particular factor was based on: Initial trust refers to items such as "In most of the groups that I have worked with in the past, the group members trusted each other" or "In the past, I have worked mostly together with trustworthy people" and, therefore, it refers to the amount of general trust in others developed by prior experience, in the sense of a trait. In contrast, the factor, developed trust, was mainly based on items such as "The others [in the sense of the collaboration partners in this current study] aimed to successfully contribute to the problem solving" and "The others had knowledge that contributed to solving the problems" and, therefore, refers to mutual trust in the collaborators' performance in the sense of their motivation and their ability. Trust is here a state.



## Results

The experimental condition in which the group members were provided with a KIA approach was compared with the control condition in which the group members collaborated without

[2] The questionnaire after the collaboration phase contained 50 items (that were identical between the conditions), that is, three factor analyses were necessary to comply with the rules for conducting factor analyses (cf. Bortz and Schuster 2010). Factor Analysis 1, including 17 items on trust, resulted in two interpretable factors: Developed trust, *Cronbach's* $\alpha=0.73$; developed skepticism, *Cronbach's* $\alpha=0.78$. Factor Analysis 2, including 19 items on mutual control, coordination, communication, and subjective evaluation of the group outcomes, resulted in one interpretable factor: Developed suspiciousness, *Cronbach's* $\alpha=0.46$. Factor Analysis 3, including 14 items on study evaluation, group map creation, and collaboration, resulted in one interpretable factor: Cognitive effort, *Cronbach's* $\alpha=0.50$. Because of their low *Cronbach's* $\alpha$ values, the factors "developed suspiciousness" and "cognitive effort" were not included in further analyses.

this approach. All analyses presented here were based on the group level because most of the dependent variables were variables on group level (e.g., the group answers, the group maps) and individuals in a group are not independent of each other. Following Cress (2008), the analyses have to be based on aggregated data of individuals, for example, in form of means, if groups are the units of the analyses. Therefore, variables measured on the individual level were aggregated; that is, group means were calculated. This also assures having the same analysis level as the group variables.

The inclusion of a covariate was not necessary.[3]

The reasons for using moderator analyses and the explanation of the procedure can be found in the Appendix "Analytical Procedures".

## Manipulation check

It was analyzed whether our KIA approach fostered the acquisition of knowledge and information awareness.

The analysis of the answers to the knowledge test resulted in a significant higher KIA value for the experimental condition compared to the control condition ($M_C$=18.77, $M_E$=22.87; $F$(1, 38)=7.41; $MSE$=22.66; $p$=0.01; $\eta_p^{2}$= 0.16). This value was calculated as the sum of item Categories 2 and 4 each weighted by the correctness certainty (see section "Setting and materials") because only these categories merely referred to the collaborators' knowledge.

This is accordant with the results of prior studies (e.g., Engelmann et al. 2010; Engelmann and Hesse 2010).

In the questionnaire after the collaboration, the members of the experimental condition mostly stated that they used or viewed the windows with the collaborators' maps only sometimes ($M$=3.29, $SD$=0.52). However, they also maintained that the windows with the collaborators' maps were helpful ($M$=3.92, $SD$=0.59), indispensable ($M$=3.14, $SD$=0.77), helped to recognize differences and similarities between their own and the collaborators' maps ($M$=3.88, $SD$=0.81), helped to acquire a clear mental model of the collaborators' knowledge ($M$=3.63, $SD$=0.80), and to avoid misunderstandings ($M$=3.47, $SD$=0.67).

It is interesting to note that these descriptive values are lower compared to prior studies that used the same domain and tasks (e.g., Engelmann and Hesse 2010). However, less use and lower evaluated helpfulness did not affect the acquisition of knowledge and information awareness.

## Results on postulated effects of the interaction between initial trust and condition on group performance

An overview of the results of all corresponding moderator analyses can be found in Table 2.

*Group effectiveness as criterion variable* The regression analyses with effectiveness measures as criterion variable as well as condition, initial trust, and their interaction as predictor variables led to the following results:



[3] A factor analysis with Varimax rotation with the 15 control measure items resulted in six factors with eigenvalues higher than 1. According to Bortz and Schuster (2010), in a Varimax-rotated factor structure, only those factors can be interpreted that have at least four items with a loading>0.60 or at least ten items with a loading>0.40. This criterion was met only by the factor "computer experience". However, an univariate ANOVA did not result in a significant difference between the two conditions ($F$<1).

t2.1 **Table 2** The results of the moderator analyses of initial trust and condition on group performance, including regression analyses and simple slope analyses

| | | | | | | | Model properties | | |
|---|---|---|---|---|---|---|---|---|---|
| t2.3 | Criterion variable | Predictor variables | *b* | SE | β | *p* | Adj. $R^2$ | F(df) | *p* |
| t2.4 | Solution potential of the pesticide problem in the group map | Initial trust | 0.00 | 0.09 | 0.01 | 0.96 | [0.005] | [0.91(2, 37)] | [0.41] |
| t2.5 | | Condition | −0.03 | 0.08 | −0.05 | 0.75 | | | |
| t2.6 | | Initial trust *x* condition | 0.21 | 0.09 | 0.42 | 0.03 | 0.102 | 2.48(3,36) | 0.08 |
| t2.7 | | Simple slope CC | 0.20 | 0.09 | −0.41 | 0.03 | | | |
| t2.8 | | Simple slope EC | 0.21 | 0.16 | 0.43 | 0.18 | | | |
| t2.9 | Solution of the pesticide problem | Initial trust | 0.04 | 0.09 | 0.09 | 0.62 | [−0.018] | [0.66(2, 37)] | [0.52] |
| t2.10 | | Condition | −0.02 | 0.07 | −0.04 | 0.78 | | | |
| t2.11 | | Initial trust *x* condition | 0.25 | 0.09 | 0.50 | < 0.01 | 0.153 | 3.35(3, 36) | 0.03 |
| t2.12 | | Simple slope CC | −0.21 | 0.08 | −0.42 | 0.02 | | | |
| t2.13 | | Simple slope EC | 0.29 | 0.15 | 0.60 | 0.06 | | | |
| t2.14 | Efficiency of deciding for the correct pesticide solution | Initial trust | −127.96 | 117.38 | −0.23 | 0.29 | | | |
| t2.15 | | Condition | −193.78 | 93.74 | −0.40 | 0.05 | | | |
| t2.16 | | Initial trust *x* condition | −180.10 | 117.38 | −0.32 | 0.14 | 0.16 | 2.50(3, 21) | 0.09 |
| t2.17 | Efficiency of deciding for the correct fertilizer solution | Initial trust | 33.07 | 78.99 | 0.09 | 0.68 | | | |
| t2.18 | | Condition | −166.27 | 63.20 | −0.50 | 0.02 | | | |
| t2.19 | | Initial trust *x* condition | −16.43 | 78.99 | −0.05 | 0.84 | 0.15 | 2.52(3, 23) | 0.08 |

*Notes:* Values in brackets represent the model properties before the inclusion of the interaction. The predictor variable "Initial Trust" was z-standardized

Simple Slope CC=Simple slope analysis for the control condition

Simple Slope EC=Simple slope analysis for the experimental condition

The regression analysis with *solution potential of the pesticide problem in the group map* as the criterion variable revealed no significant conditional effect for initial trust or for the belongingness to a particular condition. Though, a significant interaction between condition and initial trust appeared: Simple slope analyses indicated as hypothesized that higher initial trust significantly reduced the solution potential of the pesticide problem in the group maps of the control condition but did not significantly affect the solution potential of the pesticide problem in the group maps of the experimental condition.

In line with these results, the regression analysis with the *solution of the pesticide problem* as the criterion variable also did not reveal significant conditional effects, however, a significant interaction between condition and initial trust. Simple slope analyses indicated, as expected, that higher initial trust significantly impaired the solution of the pesticide problem of the control condition but did not significantly affect the solution of the pesticide problem of the experimental condition.

Please note that regarding the measures *group maps' suitability for solving the fertilizer problem* as well as *solution of the fertilizer problem* as criterion variables, no significant effects resulted. Therefore, these results are not reported.

*Group efficiency as criterion variable* The regression analyses with efficiency measures as the criterion variable as well as condition, initial trust, and their interaction as predictor variables led to the following results:

According to our hypothesis, the regression analysis with *efficiency of deciding for the correct pesticide solution* as the criterion variable revealed a significant conditional effect for the belongingness to a particular condition. The experimental groups needed less time for finding the correct pesticide solution compared to the control groups ($M_C$=19:56, $SD_C$=7:21; $M_E$=13:15, $SD_E$=7:55). As expected, we neither found a significant conditional effect for initial trust, nor did a significant interaction between condition and initial trust appear.

In line with this result, the regression analysis with *efficiency of deciding for the correct fertilizer solution* as criterion variable also revealed, as expected, a significant conditional effect for the belongingness to a particular condition. The experimental groups needed less time for finding the correct fertilizer solution compared to the control groups ($M_C$=22:40, $SD_C$=4:42; $M_E$=17:16, $SD_E$=5:23). Again, as expected we neither found a significant conditional effect for initial trust, nor did a significant interaction between condition and initial trust appear.

### Results on the postulated effects of the interaction between quality of performance within the group and condition on the development of mutual trust

Because it was expected that the amount of trust also depends on situational factors, the impact of collaboration quality of the group, depending on the condition, on the developed trust, and developed skepticism, respectively, was analyzed. An overview of the results of all corresponding moderator analyses can be found in Table 3.

The regression analysis with *developed skepticism* as the criterion variable revealed a marginally conditional effect for the solution potential of the individual maps, but not for the belongingness to a particular condition. With an increasing solution potential of the individual maps, less skepticism was developed. As hypothesized, a significant interaction between condition and the solution potential of the individual maps emerged. Simple slope analyses indicated that lower solution potential of the individual maps significantly increased the developed skepticism in the control condition, but did not significantly affect the developed skepticism in the experimental condition.

**Table 3** The results of the moderator analyses of collaboration quality and condition on the development of mutual skepticism, including regression analyses and simple slope analyses

| | | | | | | Model properties | | |
|---|---|---|---|---|---|---|---|---|
| Criterion variable | Predictor variables | *b* | SE | β | *p* | Adj. $R^2$ | F(df) | *p* |
| Developed skepticism | Solution potential of the individual maps | −0.26 | 0.15 | −0.26 | 0.09 | [0.007] | [1.14(2, 37)] | [0.33] |
| | Condition | 0.02 | 0.15 | 0.36 | 0.92 | | | |
| | Solution potential of the individual maps *x* condition | 0.36 | 0.15 | 0.36 | 0.02 | 0.12 | 2.7(3, 36) | 0.06 |
| | Simple slope CC | −0.62 | 0.22 | −0.62 | < 0.01 | | | |
| | Simple slope EC | 0.10 | 0.21 | 0.10 | 0.65 | | | |

*Notes:* Values in brackets represent the model properties before the inclusion of the interaction. The predictor variable "Solution Potential of the Individual Maps" was z-standardized

Simple Slope CC=Simple slope analysis for the control condition

Simple Slope EC=Simple slope analysis for the experimental condition



Please note that the corresponding regression analysis with *developed skepticism* as the criterion variable and condition, the *number of correct relations* and their interaction as predictors led to the same result pattern. However, this analysis did not meet the necessary requirements; that is, the assumptions of the global test statistics were not satisfied. Therefore, this analysis was not reported here. In addition, regarding the measure *correct nodes in the group map*, there was no corresponding significant interaction. Regarding the measures with *developed trust* as the criterion variable, no expected interactions were found. Therefore, these results were not reported here.

## An explorative case study

In order to corroborate the expected relations between the amount of mutual initial trust and mutual control as a function of having access to the KIA approach, we conducted a case study: For a qualitative analysis within each of the following four categories we randomly selected a triad: a control group with high initial trust, that is with a trust level above the median (we randomly selected group CC 7), a control group with low initial trust, that is a trust level below the median (we randomly selected group CC 2), an experimental condition with high initial trust (we randomly selected group EC 21) and an experimental condition with low initial trust (we randomly selected group EC 22). Following Fig. 2 we postulated that in the control condition, high initial trust will lead to low effectiveness, because of lower mutual control and thus a low detection rate of errors. The transcripted Camtasia recording of CC 7 seems to confirm that there is hardly any mutual control in such groups even if the situation requires it. For example at time code 5:31 f. (see Table 4, CC 7): A question arose by expert C, expert B wanted to answer it, but C interrupted him to give him drawing suggestions. B, however, had yet another suggestion. Important here is expert C's reaction saying "if you say that, then one gets it." He did not further try to clarify the situation. Instead he relied on the other expert.

In contrast to such control groups with high initial trust, it was postulated that control groups with low initial trust would achieve high effectiveness, because checking each other results in a high detection rate of errors. The excerpt of CC 2's recording seems to support this idea (see Table 4, CC 2): Very often the group members instructed their partners to check their

Intern. J. Comput.-Support. Collab. Learn.

t4.1 **Table 4** Excerpts of the Camtasia files of two control and two experimental groups having either low or high initial trust

| | | |
|---|---|---|
| t4.2 | *Control Condition with high initial trust: CC 7* | |
| t4.3 | Time code (in min.) | Dialog (overall 32:27 min.) |
| t4.4 | 05:22 | Expert B: "Wait. The RP2, it's not right like that, is it?" |
| t4.5 | 05:24 | Expert C: "I think, it was just in the way"[…] |
| t4.6 | 05:31 | Expert C: "What is this Herm+? Does it generate rank spiders during decomposition?" |
| t4.7 | 05:35 | Expert B: "No, just combined with the decomposing rank spider it generates phosphate. I don't know how I should …" |
| t4.8 | 05:43 | Expert C: "Ah, o.k., you can make another arrow there to here" |
| t4.9 | 05:46 | Expert B: "Or I move the Herm" |
| t4.10 | 05:48 | **Expert C: "Or like that, but yes, o.k., if you say that, then one gets it"** |
| t4.11 | *Control Condition with low initial trust: CC 2* | |
| t4.12 | Time code (in min.) | Dialog (overall 35:27 min.) |
| t4.13 | 21:31 | Expert C: "By the way, potassium is not produced, when the pests die. It's nitrate that is being produced when the pests die, isn't it?" |
| t4.14 | 21:38 | Expert A: "No, potassium …wait… potassium yes. Potassium forms, yes. Nitrate, too, definitely, of course, but the info is only potassium." |
| t4.15 | 21:52 | Expert C: "Damn. Am I stupid or what? I don't think I really get it. O.k. never mind. " |
| t4.16 | 22:04 | Expert A: "In mine its presented as relation 8. Perhaps, it is also in yours… is there nitrate in yours, or what?" |
| t4.17 | 22:11 | Expert A: "N-yes" |
| t4.18 | 22:15 | **Expert C: "It's written in your word document that they produce nitrate? During the decomposition process?"** |
| t4.19 | 22:20 | Expert B: "Wait, I can't find it right now" |
| t4.20 | 23:05 | Expert C: "Is it written in yours that dead bugs produce phosphate?" |
| t4.21 | 23:08 | Expert B: "I've got to take a look. […] No, I think, this is not written in mine." |
| t4.22 | 23:20 | **Expert C: "Isn't it written in your word document under point 8?"** |
| t4.23 | 23:23 | **Expert A: "Under pests?"** |
| t4.24 | 23:24 | Expert B: "Oh, wait! Sorry, I've looked in the wrong place" |
| t4.25 | 27:04 | **Expert A: "Has anyone read the background information in detail?"** |
| t4.26 | 27:08 | Expert C: "No, but what do you mean by background information?" |
| t4.27 | 27:10 | Expert A: "Well, what is written next to it, because … wait… ah well, o.k., there is actually nothing interesting there." |
| t4.28 | 28:30 | Expert B: "Well this Herm+and how it is related to the material bug, I've got no clue. It was not written in mine, I believe." |
| t4.29 | 28:31 | **Expert A: "It is definitely written in yours. There is a connection depicted for all others, for sure."** |
| t4.30 | *Experimental Condition with high initial trust: EC 21* | |
| t4.31 | Time code (in min.) | Dialog (overall 21:58 min.) |
| t4.32 | 00:21 | **Expert C: "I have noticed that some things mutually exclude each other, for example the pesticides, uhm, the fertilizers. […] Expert A, you have this Topisol, it extracts nitrate** […] |
| t4.33 | 00:38 | Expert A: "I think all extract, whatever fertilizer we use. It always supplies one thing and extracts all the other things." |

t4.34 **Table 4** (continued)

| | | |
|---|---|---|
| t4.35 | 01:04 | **Expert A:** "Potassium definitely does, if we decide on RP2 for control, potassium would be produced through that control, **and I read in B's,** that if one uses this Herm+thing, then it produces phosphate, right?" |
| t4.36 | 01:28 | Expert B: "Yes, exactly." |
| t4.37 | *Experimental Condition with low initial trust: EC 22* | |
| t4.38 | Time code (in min.) | Dialog (overall 23:55 min.) |
| t4.39 | 05:43 | **Expert B: "What's that info added in Expert A's? Next to that RP2? There is something attached. May I read it?"** |
| t4.40 | 05:50 | A: "Wait, I don't know." |
| t4.41 | 15:55 | Expert C: "Then it has a moderate effect against the flunder caterpillar?" |
| t4.42 | 15:58 | Expert B: "Oh, it also has an effect?" |
| t4.43 | 16:01 | **Expert C: "Yes, that is what Expert A has written here.** It says: 'the effect against other pests is moderate.'" |

individual information in their individual map or their corresponding word document (see e.g., time codes 22:15, 23:20, 27:04 or 28:31).

We expected that members of the experimental condition would control each other independently of the amount of initial trust. The excerpts of EC 21's and EC 22's confirmed this idea (see Table 4, EC 21 and EC 22). There seems to be no difference between these two groups. Independently of the amount of initial trust group members control each other, but not like in CC 2. In contrast to CC 2 in which partners instructed each other to check their individual files, partners in both, EC 21 with high trust and EC 22 with low trust, use the KIA approach to take a look at their partners' maps. The comparison of the statements on time codes 00:21 and 1:04 in EC 21 and the time codes 05:43 and 16:01 in EC 22 indicate that the group members used their access to the partners' maps for mutual control, independently of the amount of initial trust.

## Discussion

In this paper, we investigated two research questions. The first research question focused on the impact of mutual trust in virtual groups on group performance depending on whether the KIA approach is available or not. With regard to group effectiveness, we expected a significant interaction between condition and initial trust on group effectiveness in a way that increasing trust will decrease effectiveness in the control condition, while in the experimental condition trust will not have an effect on group effectiveness (Hypotheses 1.1 and 1.2).

To test these hypotheses, along with the others, 120 participants were investigated, grouped in 20 triads that were provided with the KIA approach and 20 triads collaborating without it.

The analyses confirmed our hypotheses: In the experimental condition, mutual trust did not significantly affect group effectiveness; however, in the control condition with increasing mutual trust, group effectiveness, measured as both solution potential of the pesticide problem in the group map and solution of the pesticide problem, significantly decreased.

These results provide evidence that the negative impact of mutual trust can be counteracted successfully by the availability of the KIA approach. We explained this result with the fostering of mutual control when the KIA approach is available. Our explorative case study seems to confirm this explanation: As expected, in the audio transcript of a control group with high initial trust there was hardly any mutual control, even if the situation required it. In contrast, the transcript of a control group with low initial trust showed that the members often instructed their collaboration partners to check their individual information in their map or in their word document (cf. Fig. 2). However, as expected, the amount of initial trust seems to have no effect on the amount of mutual control in the experimental groups. The transcripts of an experimental group with high mutual trust and of an experimental group with low mutual trust seemed not to differ regarding the amount of mutual control. Independently of the amount of initial trust the participants controlled each other. Yet, they differed from the control group with low initial trust. The experimental group members used the access to their partners' maps (i.e., the KIA approach) for mutual control. To sum up, these case study results supported the assumptions postulated for the control condition (Fig. 2) and the experimental condition.

Another explanation for the significant interaction between initial trust and condition on group effectiveness might be a stronger structuring of the situation in the experimental condition, caused by the KIA approach, in which trust did not have an impact (cf. Dirks and Ferrin 2001; Jarvenpaa et al. 2004). However, further studies are needed to explain the causes of the present findings in more detail.

It is interesting to note that the present effects were only found with the pesticide problem, but not with the fertilizer problem. A reason for this could be that the fertilizer problem could only be solved correctly if the pesticide problem was solved correctly, that is, solving the fertilizer problem depended more on solving the pesticide problem than on other reasons. Another reason could be the different task structures of the two problems. The pesticide problem requires combining some variables with other variables, whereas solving the fertilizer problem mainly depends on finding the correct solution of the pesticide problem and on considering the relevant variables of the pesticide problem for the fertilizer problem. In this way, solving the pesticide problem is more complex than solving the fertilizer problem. This would mean that the KIA approach only reduces the negative impact of initial trust on solving complex problems. However, this has to be corroborated by further studies.

One should note that due to its low *Cronbach's* $\alpha$ value the factor "initial skepticism" could not be used in further analyses. Initial trust was based on items such as "In most of the groups that I have worked with in the past, the group members trusted each other" or "In the past, I have worked mostly together with trustworthy people". Therefore, it refers to the amount of general trust in others developed by prior experience. Initial skepticism was based mainly on items such as "One should be very careful if working together with strangers" or "In current times, with so much competition, you should be on the alert or someone will probably take advantage of you" and, therefore, refers mainly to a generalized skepticism about others, based more on a general attitude. Whether our findings for initial trust could also hold up for initial skepticism has to be investigated with a more reliable initial skepticism measure.

With regard to group efficiency, we expected for groups in the control condition with high trust also low efficiency because efficiency is dependent on effectiveness. For groups in the control condition with low trust, we also expected low efficiency due to much mutual control that takes time. For the experimental condition, we expected, independent of the amount of trust, high group efficiency due to the low process costs for checking the others' work (Hypotheses 2.1 and 2.2).

This hypothesized main effect was found: In line with prior study results (e.g., Engelmann and Hesse 2010), the experimental groups solved both of the problems sooner compared to the control groups. As expected, neither a main effect for trust, nor an interaction between trust and condition, on group efficiency were observed.

Together with the findings on group effectiveness, this result demonstrated that mutual trust may have an effect on group effectiveness, but not on group efficiency. This is accordant with Kanawattanachai and Yoo (2002) and Jarvenpaa et al. (2004). Therefore, this paper also contributes to solving the conflicting findings in literature regarding the effects of trust.

Our hypotheses were derived, among others, from the assumptions regarding mutual control. However, in this study, we did not analyze mutual control. Future analyses could be based on the recorded discussions. However, in order to analyze mutual control in a better way, eye tracking is needed. Eye tracking results could contribute to further clarifying the postulated relations.

While in the first research question, trust was investigated as predictor, in the second research question, it acted as criterion. The second research question addressed whether – depending on the availability of the KIA approach – differences in the amount of collaboration quality have an impact on the development of trust after the collaboration.

We hypothesized that in the control condition, poor collaboration quality of the group will lead to low mutual trust and high mutual skepticism, respectively, because a computer supported environment does not normally allow for easy mutual control; that is, the work of others cannot be checked easily; therefore, poor collaboration quality is more likely to be attributed to the collaborators. In contrast, it was hypothesized that in the experimental condition, poor collaboration quality was not attributed to the collaborators, whose work has been checked, but to external factors such as task difficulties and therefore would not affect the development of mutual trust or mutual skepticism, respectively. To sum up, we expected a significant interaction between condition and the collaboration quality, the latter measured as a solution potential of the individual maps and the completeness of the group map, on the amount of developed trust and developed skepticism, respectively (Hypotheses 3.1 and 3.2).

The analyses for answering the second research question led to the hypothesized results: In the control condition, with decreasing solution potential of the individual maps, the developed mutual skepticism regarding the collaborators' performance increased. In the experimental condition, the collaboration quality of the group had no impact on the development of mutual skepticism.

It is interesting to note that regarding the second research question, the findings in accord with our hypothesis were only found with the factor developed skepticism and not with the factor developed trust. This may be due to a qualitative difference between the two factors. The factor, developed skepticism, is based on items such as "With another group, the problem solving phase would have been more successful" and "I often had the impression that the other experts did not understand their information correctly". This refers mainly to dissatisfaction with the other group members' abilities. In contrast, the factor developed trust was mainly based on the following items: "The others aimed to successfully contribute to the problem solving" and "The others had knowledge that contributed to solving the problems". It refers to mutual trust in the collaborators' performance in the sense of their motivation and their ability.

It also should be noted that regarding the second research question, we failed to find the postulated interaction with variables of the completeness of the group maps. One reason was, as described, that the needed requirements for conducting the analyses were not met.

There are some limitations of the study that have to be considered: The group members were not experts with regard to the knowledge needed for solving the problems in the study. However, each group member was provided with content material, and in an individual phase, they had time to become familiar with it. In real situations, group members often have to acquire new knowledge. For example, especially in collaborative learning settings, learners often divide learning material in such a way that each learner only learns a part of the whole learning material, and then, in a subsequent collaborative situation, they teach each other in order for everyone to learn the not yet learned contents. In an empirical study by Lechner and Engelmann (not yet published), the knowledge and information approach was applied in a school context in which one class was taught one topic in biology and another class was taught a different topic also in biology. In a subsequent collaboration phase, one student of one domain collaborated computer-supported with another student of the other domain, in order to teach each other the respective contents of each domain. The aim was to enable the students to collaboratively solve problems that required the knowledge of the contents of both domains. As in our study, both dyadic learners did not have prior knowledge of the domain they had to learn. However, in this study by Lechner and Engelmann, the effect of trust was not investigated. The impact of trust in real application fields on group performances still needs to be investigated.

It should be noted further that the domain material was artificial due to experimental reasons (e.g., excluding the impact of prior knowledge). Nevertheless, as the questionnaire completed after the collaboration phase has shown, the participants in both conditions stated that they had enjoyed participating in this study ($Mc$=4.62, $SD_C$=0.35; $M_E$=4.52, $SD_E$=0.44). In prior studies, we investigated the impact of the KIA approach on group performances also by using non-artificial domains. Along with the mentioned study by Lechner and Engelmann that used content from the biology curriculum in school, in the study by Schreiber and Engelmann (2010), the group members had to solve a criminal case; however, this study also did not focus on the factor trust.

In our study, the group members did not know each other, but each individual had a certain amount of general trust in others, in the sense of a trait (not a state). In the literature (e.g., Colquitt et al. 2007), this type of trust is also called *trust propensity*. Our study has shown that this type of trust has an impact on group performances, namely, a negative impact in the case of too much trust. Therefore, trust must be considered to be an impact factor if groups have to collaborate and solve problems collaboratively.

In several studies, we varied the task structure and always found a positive impact of the KIA approach on group performances. We varied the domain and the task (for example, in the study by Schreiber and Engelmann 2010, that used a criminal case task), the setting (for example, in the school study conducted by Lechner & Engelmann, not yet published), and the separation of individual and collaborative phases (for example, in the study by Engelmann and Kolodziej 2012). In the study by Engelmann and Kolodziej (2012), it was the decision of the group members whether they wanted to create an individual map visualizing their own knowledge and information or not. We could show that group members in the experimental condition that created their individual maps benefitted in the collaboration phase compared to the groups that directly started to solve the problems collaboratively. Groups in the control condition, that is, groups without access to their partners' maps did not benefit if the members created individual maps. In these earlier studies, the factor trust was, however, not investigated. Yet these studies have been able to show that the effect of KIA on group performances is relatively robust and independent of the task structure. Therefore, it can be assumed that the KIA approach will moderate the effect of trust on group performance also when the task structures are varied.

With regard to the robustness of measures used in the study, we would like to add the following: Both trust as predictor as well as trust as criterion were measured by self-ratings. Self-ratings are subjective and can, therefore, differ among individuals. However, the items used to measure trust were items from established trust scales in the literature. Objective measures of trust are difficult to construct and, to our knowledge, not yet possible. Perhaps it can only be measured indirectly, for example, by assessing mutual control. Whether it will be possible in the future to measure trust neurophysically is still an open question. A lot of research is needed to find objective measures of trust, and for this reason, we used the established method for assessing trust. With regard to all of the other measures, we calculated interrater agreement, which was without exception high. Thus, a suitable robustness regarding the measures used can be inferred.

With regard to the robustness of the results reported in the current study, we would like to point to the fact that we only reported results of analyses that met the statistical requirements. Therefore, robustness of results is ensured.

With regard to the robustness of interpretations, we would like to point out that we have only interpreted our significant results. Additionally, we would like to add that the positive impact of the KIA approach to group performance has been proven in several studies, whereas with regard to the effect of trust on group performance conflicting findings can be found in the literature. We argued that the reason for the different findings regarding the impact of trust is that the variable "errors made by the individuals" has been neglected. This assumption needs to be validated in further studies, especially in settings with increased ecological validity. In addition, to our knowledge, this study was the first that combined research on trust and research on knowledge awareness. Thus, the findings of our study need to be validated by further studies.

## Implications

This study has demonstrated that even in group situations in which the group members do not know each other, general trust in others (as a personal trait) can have a negative impact on group performance. This negative impact can be easily solved by providing external representations of the collaboration partners' knowledge structures and the information underlying these structures. Collaborating with unknown others in ad hoc created groups is becoming increasingly important due to the complexity of today's problems that require the different expertise of several individuals. For collaborating groups, we recommend the externalization of each member's task-relevant knowledge and information to motivate the partners to check over each other's external representations, especially if they have high mutual trust. This leads to the detection of mistakes and consequently to better group effectiveness. In addition, having the possibility to check each other's work in this way improves group efficiency.

Hindering the development of mutual skepticism in virtual groups is also highly relevant, especially if groups need to continue to work together. As our study has shown, the KIA approach can prevent this development.

To sum up, this study demonstrated that the availability of the KIA approach overrides the negative impact of too much mutual trust and prevents the development of mutual skepticism. Additionally, this study further contributes to clarify the impact of trust on group effectiveness and group efficiency in computer-supported collaborative situations depending on different situational factors such as being provided with a KIA approach or not.

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## Appendix: Analytical procedures

Due to the fact that we were interested in interaction effects between condition and variables of trust, as well as between condition and variables of collaboration quality, regression analyses were conducted. More concretely, moderator analyses were conducted following Aiken and West (1991). The necessary requirements for conducting regression analyses were tested in each time, that is, for each analysis the global test statistic was calculated: The global test statistic as a function of the model residuals "is formed from four asymptotically independent statistics, each with the potential to detect a particular violation" (Peña and Slate 2006, p. 353). These independent statistics are linearity, homoscedasticity, uncorrelatedness, and normality. In this paper, only those analyses are reported that met the global test statistic.

For condition as a categorical moderator variable, unweighted effects coding was used (control condition=−1, experimental condition=+1) because then, the regression coefficients represent the difference between each condition's mean and the unweighted mean of both conditions (Cohen et al. 2002). Z-standardization was applied on all other predictors because they were continuous variables. Like centering, z-standardization eliminates the problems of multicollinearity between the categorical moderator variable and the specific continuous predictor variable. In addition to this, it simplifies the comparison of significant moderator effects on different criterion variables and eases their plotting (Aiken and West 1991; Cohen et al. 2002; Frazier et al. 2004).

To calculate the moderator analyses according to Aiken and West (1991), a first series of regression analyses was calculated with only the moderator and another predictor as predictor variables and an outcome measure as the criterion variable. This first series of regression analyses was needed to obtain the change in adjusted $R^2$ in a second series of regression analyses with the same variables and also – by multiplying the moderator with the other z-standardized predictor – the interaction term for the additional explained variance of the interaction. To test the significance of the simple slopes for each level of the categorical moderator variable, two additional regression analyses were conducted (Aiken and West 1991; Frazier et al. 2004): To test the significance of the simple slope for the control condition, a dummy coding of control condition=0 and experimental condition=1 was applied. For the significance of the simple slope for the experimental condition, a dummy coding of control condition=1 and experimental condition=0 was applied. Regression analyses were calculated with one of these newly coded moderators, another predictor, as well as their interaction term as predictor variables, and an outcome measure as the criterion variable.



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