

Identification of a shared answer-making epistemic game in a group context

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Abstract. When physics students engage in collaborative exercises, they must negotiate their different problem-solving strategies in order to work together effectively. One lens through which to understand these interactions is the construct of “epistemic games”. These constructs have been used to describe particular methods of problem solving with which students are observed to engage. In prior work, an “answer-making epistemic game” has been observed, wherein the student perceives the objective of the activity as producing an answer, and reasons until they arrive at an answer or intuit an answer and then tries to justify this answer. This game was observed in the context of individual students working independently on multiple-choice questions. We present preliminary analysis of the appearance of a shared answer-making epistemic game when a group of students worked collaboratively on conceptual problems.

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I. INTRODUCTION

The use of collaborative work is becoming increasingly prevalent in introductory physics classrooms. In such environments, students must engage with not only physics content, but also with their peers and their peers’ understanding of physics content and problem-solving strategies. In order to best provide learning opportunities, it is essential to understand how students interact in such environments. To this end, the construct of epistemic games has been used as a productive lens through which to analyze students’ behavior when problem-solving [1-3]. An epistemic game is defined by Tuminaro and Redish as “a coherent activity that uses particular kinds of knowledge and processes associated with that knowledge to create knowledge or solve a problem” [2].

The *answer-making epistemic game* (AMEG) is relevant to the work presented here [3]. In this game, a student works under the belief that the objective of the activity is to produce a solution. The AMEG begins with students engaging in the entry condition of attempting to remember the answer to the question on which they are working. If they cannot remember an answer, they will attempt to intuit an answer. At this point, students will enter one of two possible paths consisting of different series of moves. If the student can intuit an answer, they will accept this answer, and then attempt to use conceptual reasoning or do math in order to arrive at a justification for the answer (the “answer justify” path, AJ). If a student cannot intuit an answer, they will reason conceptually or do math until they arrive at an answer (the “reason answer” path, RA). Both paths are defined by the same exit condition: a solution that the student finds to be sufficient. These series of moves and entry and exit conditions describe the structure of the AMEG. The AMEG is further defined by an ontology

comprised of its epistemic form, a truth table, and its knowledge base, the physics and mathematical resources that students activate as they engage with the game.

The AMEG was studied in the context of think-aloud interview protocols carried out with individual students working on multiple-choice hydrostatics questions. In this paper, we identify via a case study a shared answer-making epistemic game (SAMEG) in a group context in which four students worked together on a conceptual electricity and magnetism (E&M) problem. The students in this group were observed to engage with the activity in ways that appeared similar to the AMEG, but that could not be fully accounted for by that epistemic game. The model of the SAMEG was developed in order to attempt to describe more fully the behavior of this group. As such, we do not propose the prevalence of the SAMEG, and instead only propose its existence through the case study of this group.

II. STUDY CONTEXT

The data presented in this paper was collected from an introductory E&M course at a large university. There were approximately 120 students in the course, and most were sophomore life-science majors. The students all attended lecture three times a week, and a laboratory session once a week in sections of approximately 20 students. In these laboratory sessions, students worked in groups of three or four collaboratively on a variety of activities depending on the week (labs, tutorials, conceptual and calculational problems, etc.). The data presented here are transcripts from video recorded of one group of four students working during their weekly laboratory section. In the episode, the students are attempting to identify if there is a point of equilibrium in the space surrounding an electric quadrupole, and if so, where that point is. They do so by examining an image of the space surrounding the charges as represented

by electric field vectors. It is worth noting that the students are not told that such a configuration of charges is called a quadrupole, and that they had not seen such a configuration previously in class. The students in question have been given the pseudonyms Buster, George, Lindsay, and Michael. The data will specifically regard George, Lindsay, and Michael, as Buster quickly disengages with the activity. He leans back from the table, does not speak, and does not often look at the students who are speaking.

III. SHARED ANSWER-MAKING EPISTEMIC GAME

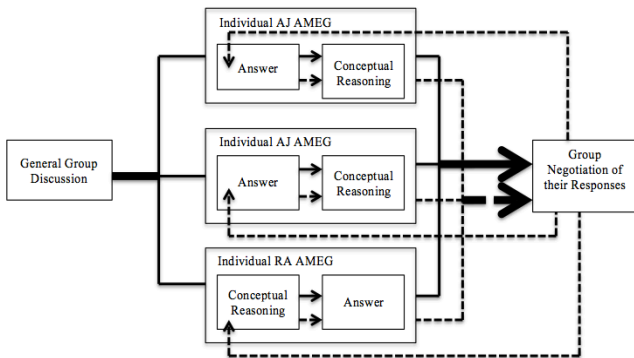


FIG 1. The Shared Answer-Making Epistemic game

As illustrated in Fig. 1, three students participated in the SAMEG, while one was not observed to participate. In these observations, the SAMEG was characterized first by an entry condition, general group discussion. After entering the SAMEG, the participating students played the original AMEG individually. One student played RA, while the other two students played AJ. After the participating students exited their individual AMEGs, they engaged in a group negotiation of their responses. The first time they attempted this, they were unsuccessful, and so their next moves were to return to their individual AMEGs (dashed lines in Fig. 1). The participating students played their individual AMEGs a second time, exited them, and then again attempted a group negotiation of their responses. This time they were successful, and so they exited the game. The exit condition was thus all participating students being simultaneously satisfied with their individual solutions and also having successfully navigated a group negotiation of their responses. We detail the components of the SAMEG below, providing evidence from video data of the four aforementioned students working on this problem.

A. Entry condition

The participating students began playing the SAMEG through the entry condition of a *general group discussion*. All four students' first actions were to discuss together what the problem was asking of them and to begin proposing ideas. The students were observed to lean over the image

and speak in approximately equal amounts about the image. No answers were put forth, and no student offered reasoning directly leading to producing an answer. This stands in contrast to the original AMEG, which is characterized by the entry condition of *remembering* or *intuiting* an answer [3]. By the nature of the problems these students were asked (i.e., the students had never seen the given charge distributions), remembering was unlikely to occur and was not observed. Intuiting answers was also not observed to be any of these students' first actions.

As they begin working, all four students leaned in towards the image at the same time, and began gesturing simultaneously. They took turns identifying charges (00:02-00:18),

Michael: So clearly, right here is a negative.
George (pointing at another charge): Positive.
Lindsay (pointing at different charge): This is positive.

By the student responses, we can interpret that no student remembers or intuits an answer to the problem, and no student reasons conceptually in a way that is directly related to answering the problem. Instead, the students are speaking in equal amounts about the problem; trying to understand the image they have received – a general group discussion.

B. Individual AMEGs

After the students entered the SAMEG by engaging in the entry condition, they entered a sequence of particular moves. In the first of these moves, the students were observed to *play the original AMEG on an individual basis* (thin solid lines in Fig. 1). During this time, the students still spoke and responded to each other while they engaged independently in the AMEG. The intuit, answer, conceptual reasoning, and sufficient solution moves were all present. These moves were observed in the context of individual students playing the RA or AJ paths.

It is at this point in the episode that one student, Buster, disengaged from the group. He leaned back in his seat, and did not speak until the very end of the group's work on the problem. Two students, Lindsay and George, played the AJ game by first intuiting answers, then using conceptual reasoning until they found their solutions sufficient. Having not provided any explicit reasoning first, Lindsay points at the image (00:23-00:29) and says,

Lindsay: So this is the place right where you could put the charge. Because these [electric field vectors] cancel.

Similarly, at (00:25), George agrees with Lindsay's answer without explicitly demonstrating conceptual reasoning first. Instead, it is after affirming an answer that he reasons (00:36-00:38),

George: It's like tic-tac-toe.

where it is interpreted that he is referring to the electric field vectors. The third student, Michael, played the RA game by using conceptual reasoning first until arriving at an answer comprising a solution he found sufficient. While leaning over the image (00:30-00:36) he says,

Michael (pointing at electric field vectors): One in, one out, one in, one out. (now pointing at center of quadrupole) Yeah.

He then leans away from the image and begins to write on his worksheet.

The presence of both the RA and AJ paths suggests this portion of the students' behavior was in fact an individual playing of the original AMEG. They approached the problem in different ways, independent of one another's choice of pathway. Furthermore, the students did not progress through the moves of the original AMEG at the same rate and did not arrive at sufficient solutions simultaneously. Lindsay found her solution sufficient first at (00:31), followed by Michael at (00:36), followed by George at (00:39), as determined by the point at which students stopped speaking and began writing on their worksheets. This also points to the students playing the AMEG as an individual activity, because they determined the sufficiency of their answers on an individual basis.

C. Group negotiation of their responses

In the SAMEG, once all participating students in the group completed playing their individual AMEGs, they engaged in a *group negotiation of their responses*. In this negotiation, students discussed their individual solutions in an attempt to agree upon a final response to the problem that all group members found acceptable. They did not seek to agree upon the specific wording of a response. Instead they assessed first whether each student had a solution that she personally found sufficient, and then that no individuals' solutions were contradictory. The students in this group were observed to carry out a group negotiation of their responses twice (see Sec. III D). The data in this section will regard the group's second, and successful, attempt at this negotiation (thick dashed line in Fig. 1)

After the students (except Buster, who continues to not engage with the group) complete their second passes through the original AMEG, Lindsay asks Michael (04:10-04:15),

Lindsay (addressing Michael): So you're saying it's going to be between two...

Michael: Either two negatives or two positives.

At this point, Lindsay begins writing – an action that we have used to indicate that she finds her solution sufficient. Michael and George continue discussion (05:30-05:48),

Michael: It's two like charges will cancel each other out.

George: You have a positive here and then it [the test charge] wants to go here and here, and it doesn't know where to go.

Michael: Yeah, you're correct.

At this point, George and Michael begin writing, indicating that they find their solutions sufficient, and Lindsay begins reading the next problem on the worksheet.

In this exchange, the students determined that they all had solutions that they individually found sufficient. They further assessed whether their solutions align. In this way, they engaged in a group negotiation of their responses.

D. Disruption and repetition of the individual AMEGs

The data presented in the previous section describes the students' second, and successful, attempt at a group negotiation of their responses. The group negotiation of their responses is not trivial, however, and so a *disruption* caused students to struggle with this negotiation on their first attempt. The data presented in this section will regard the students' first attempt at a group negotiation of their responses (thick solid line in Fig. 1) and their following moves. The disruption was a series of statements made by a student that caused all group members participating in the SAMEG to become dissatisfied with the individual solutions they had arrived at following their individual AMEGs. When the disruption occurred, students sought to again find solutions they personally found sufficient, and did so by *returning to their individual AMEGs* (thin dashed lines in Fig. 1).

The students (with the exception of Buster who still was not engaged) were observed to move through the original AMEG a first time individually and arrive at solutions they personally found sufficient, seen in all three students quietly writing on their worksheets. After a few seconds of this silence, however, Michael stops writing (00:52-00:57),

Michael: Oh actually, will a charge remain where we placed it if it's... oh yeah but...

At this point, George and Lindsay stop writing, and begin watching Michael. The three students now return individually to the original AMEG path they had played before. For example, after his speech and discontinuing his writing, Michael, who played RA path in his first pass, reasons conceptually for the duration of (02:06-05:08), saying things like (03:56-04:06),

So it's [a charge] pushing away from it [the test charge]...and this negative is going to be attracting it [the test charge], so it's going to get pushed in that direction.

before proposing another answer at (05:08), suggesting that he again followed the RA path. Similarly, Lindsay and George were observed to follow the AJ path as they had on their first individual passes through the original AMEG.

By this series of events, we can interpret that Lindsay, Michael, and George became dissatisfied with their individual solutions as a result of Michael's comment, then returned to their individual AMEGs. The presence of both the RA and AJ paths suggests that this is in fact a repeated playing of the original AMEG on an individual basis. Additionally, the three students did not find their new solutions sufficient simultaneously, as determined by being observed to write quietly. Lindsay found her solution sufficient first at (04:16), followed by Michael at (05:08), followed by George at (05:22). This further suggests that they were playing the original AMEG individually following the disruption.

E. Exit condition

The exit condition for the SAMEG is, like the AMEG, a sufficient solution [3]. Due to the group context of the SAMEG, this manifested as all students having solutions that they individually found sufficient. The group context of the SAMEG further adds the necessity of the group negotiation of their responses. As described previously, there was a point at which all three students found their solutions sufficient, but did not exit the SAMEG due to the disruption caused by Michael. Instead, the group only began working on the next problem, evidenced by Lindsay reading it aloud for the group, after they had completed the group negotiation of their responses successfully. Thus, in order for the students to exit the SAMEG, it was necessary for them to all have sufficient solutions *and also* to have successfully completed the group negotiation of their responses.

F. Ontology

In the previous sections, we discussed the structure of the SAMEG. The ontology of the SAMEG is described by its knowledge base and its epistemic form [2]. The knowledge base of the SAMEG is the set of physics resources that the students activated as they worked on the problem. The epistemic form of the SAMEG is a group negotiated worksheet response. The students' actions throughout the SAMEG were directed by the need to complete the worksheet that they had been assigned together. This negotiated worksheet response provided external structure that guided the students as they played the SAMEG [1,2].

IV. DISCUSSION & CONCLUSIONS

The context of this study undoubtedly played a role in the identification of the SAMEG. Due to the collaborative nature of the environment, the students needed to navigate their different and possibly opposing problem-solving strategies in order to successfully complete the assignment. What we observed was the emergence of a shared epistemic game. It remains unclear if this should be interpreted as individual games nested within a group level game, or rather a group level game composed of both individual and group level moves. This ambiguity would benefit from further study.

The particular students analyzed in this case additionally may have had an impact on the appearance of the SAMEG. In this group, Michael disrupted the first attempt at a group negotiation of their responses. It is possible that another group may not face such a disruption, and therefore not repeat their individual AMEGs. The particular students may have also impacted the appearance of the SAMEG via Buster's low level of engagement. The group of four students functioned largely as a group of three. It is unclear what impact this may have had on the actions of the three participating students and how the SAMEG then manifested.

As epistemic frames and games are related, it is worth noting that the SAMEG appears to occur within the "discussion frame" [4]. Throughout the episode, the students spoke in clear voices towards each other, maintained eye contact, and responded to each other's comments, indicating that they all worked under the assumption that their attention should be on one another. The discussion frame is broad, however, and does not attend to group members' individual frames [5]. The SAMEG could allow for a description of individuals' different frames within a shared, group-level discussion frame. Namely, it can be inferred that students engaging in the RA path while participating in the SAMEG are not framing the activity in quite the same way that students engaging in the AJ path are. While it is not clear based on this case study what defines these alternative frames, the SAMEG nonetheless provides a lens wherein individual students' frames could be differentiated within a group-level discussion frame. This lens would benefit from further study, and once better defined, could prove productive in the analysis of group work in other contexts.

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