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Content-Related Interactions in Self-initiated Study Groups

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The central goal of the present exploratory study was to investigate the nature of the content-related interactions in study groups independently organized by college organic chemistry students. We were particularly interested in the identification of the different factors that affected the emergence of opportunities for students to co-construct understanding and engage in higher levels of cognitive processing. Our results are based on the analysis of in situ observations of 34 self-initiated study sessions involving over 100 students in three academic semesters. The investigation revealed three major types of social regulation processes, teaching, tutoring, and co-construction in the observed study sessions. However, the extent to which students engaged in each of them varied widely from one session to another. This variability was mostly determined by the specific composition of the study groups and the nature of the study tasks in which they were engaged. Decisions about how to organize the study session, the relative content knowledge and conceptual understanding expressed by the participants, as well as the cognitive level of the problems that guided group work had a strong impact on the nature of student interactions. Nevertheless, group talk in the observed study groups was mostly focused on low-level cognitive processes. The results of our work provide insights on how to better support students’ productive engagement in study groups.

Keywords: Chemistry education; Cooperative learning; Learning environment

Introduction

Collaborative learning in small groups has been the focus of attention of much research in education in the past 40 years (O’Donnell, 2006; Springer, Stanne, & Donovan, 1999; Webb & Palincsar, 1996). In general, research findings highlight the cognitive and affective benefits of collaborative interactions in educational contexts. Nevertheless, the results of these studies also underscore the many challenges
associated with establishing successful collaborative learning environments, from ensuring equitable student participation (Bianchini, 1997) to engaging students in beneficial group dialogues that support and foster meaningful learning (Hogan, Nastasi, & Pressley, 1999). These challenges point to the need for a better characterization of the types of interactions that contribute to or inhibit coordinated cognitive activity in a group and that allow participants to mutually influence their ideas and co-construct meaning through dialog (Mercer, 2000; Volet, Summers, & Thurman, 2009).

Existing research in collaborative learning is also limited by the nature of the student groups that have been investigated. To a great extent, our current understanding of collaborative learning stems from the observation of groups of students involved in teacher-assigned tasks in diverse classroom settings. Much less is known about the structure and dynamics of self-initiated student groups formed outside the classroom for studying purposes (Tang, 1993). Although student study strategies have been investigated by various authors (Entwistle, 2000; Flippo & Caverly, 2008), most of the information that is available is largely based on individual student self-reports (Winne & Jamieson-Noel, 2002). Given that collaborative work in independent study groups can be expected to be self-selected, self-structured, and self-regulated by the participating students, direct observation and analysis of these types of groups could help us better understand how productive collaborative engagement emerges in different contexts as well as to identify potential strategies to support student thinking in those environments.

Thus, the central goal of the present exploratory study was to investigate the nature of the content-related interactions in study groups independently organized by college students. In particular, we observed and analyzed the work of science and engineering majors enrolled in the first semester of organic chemistry. We were particularly interested in the identification of the different factors that affected the emergence of opportunities for students to co-construct understanding and engage in higher levels of cognitive processing.

**Productive Learning Interactions**

Approaches to the analysis of collaborative group work can be classified into three main categories: sociocognitive, sociocultural, and blended approaches (Oliveira & Sadler, 2008). Although from different perspectives, the central goal of these types of research studies has been to identify and characterize the different factors that facilitate or hinder the emergence of individual or group processes that foster meaningful learning. Overall, findings in this area indicate that individual learning outcomes generally improve as a result of group work (O’Donnell, 2006; Springer et al., 1999; Webb, 2009).

Research studies on collaborative group work that adopt a sociocognitive perspective tend to emphasize the analysis of activities or processes that foster individual learning and cognitive restructuring. These types of studies have shown the positive impact on student learning of creating opportunities for group participants...
to, for example, describe, manipulate, and explain phenomena (Van Boxtel, Van der Linden, & Kanselaar, 2000), share and evaluate ideas (Coleman, 1998), engage in quality argumentation (Chinn, O’Donnell, & Jinks, 2000), observe peers’ problem-solving approaches (Azmitia, 1988), and share strategies to monitor and regulate learning (Gijlers & de Jong, 2005). Similarly, these types of studies highlight the importance of activities in which students are actively involved in generating explanations and summarizing information (Hendry, Hyde, & Davy, 2005).

Research studies framed from a sociocultural perspective suggests a shift of attention from the individual to the activity structures in which learning occurs (Barron, 2000, 2003; Richmond & Striley, 1996). This type of research thus focuses on the role played by social processes during collaboration, looking to characterize and understand the interdependence among context, engagement, participation, and cognitive development. A central idea in these types of approaches is to consider the collaborative group as the core unit of analysis to better understand the nature and emergence of productive learning interactions. Learning is conceived as a complex social activity strongly influenced by cultural beliefs and values. Thus, factors such as individual status within a group (Bianchini, 1997) and personality traits (Bond & Ng, 2004) are seen as potentially having a large impact on individual learning and team performance.

Attempts to blend sociocognitive and sociocultural perspectives in the analysis of collaborative work look at knowledge construction and development of understanding in terms of both cognitive and social processes (Derry, DuRussel, & O’Donnell, 1998; Roschelle & Teasley, 1995; Volet et al., 2009). For example, Derry et al. (1998) have proposed a distributed cognition framework that integrates situated learning and information-processing theories. A central idea in this approach is that knowledge is shared, transformed, and integrated along various routes before leading to actual products. Roschelle and Teasley (1995) have characterized collaboration as a process of constructing and maintaining a joint problem space through the coordinated production of talk and action. Their results suggest that productive collaboration does not just happen because the individuals are co-present; they need to make a continued effort to coordinate their language and activity with respect to shared knowledge.

Volet and coworkers (2009) have suggested that the levels of social regulation and of content processing in a given group may be used as indicators of productive engagement and participation. In this framework, social regulation refers to how group participants socially regulate each other’s learning while content processing characterizes the mental activities used by students to process content knowledge. According to these authors, social regulation in collaborative groups needs to be understood as a dynamic process driven by one or more individuals. It may quickly vary from situations in which a single individual temporarily leads group work by providing information or asking questions (instances of ‘individual regulation within group’) to instances of co-regulation in which multiple members regulate and monitor joint activity (instance of ‘co-regulation as a group’). Co-regulated group interactions
and activity are expected to be more productive as they open spaces for the co-construction of shared understandings by refining partial meanings presented in the group space (Reusser, 2001). Co-construction of understanding tends to involve utterances from different people that, taken individually, do not represent a complete idea but, taken together across speakers, either complete or continue another speaker’s idea (Rafal, 1996). Co-construction requires collaborative thinking in which group participants maintain a common joint problem space and actively seek some form of shared understanding that no single participant entirely possessed beforehand (Roschelle & Teasley, 1995). Mercer (2000) has referred to this type of dialogic process as ‘interthinking’.

Several authors have explored different types of social regulation in collaborative learning groups. For example, Kumpulainen and Mutanen (1999) developed an analytical framework based on sociocultural discourse analysis in which different types of social regulation, such as collaborative, individualistic, tutoring, and domination were identified. In a study of collaborative group work in open-inquiry labs, Roychoudhury and Roth (1996) identified three major types of social regulation patterns: symmetric, asymmetric, and shifting asymmetric. In symmetric interactions the participating students contributed similarly to the discourse while in asymmetric interactions one of the participants achieved a higher status by carrying the main bulk of the work. During shifting asymmetric interactions one student dominated the discourse for extended periods of time but roles shifted within the group.

Co-construction of meaning and understandings requires more than instances of co-regulatory activity; it demands sustained engagement in high-level content processing. Thus, identifying levels of cognitive processing is critical in the analysis of productive interactions in collaborative group work (Cohen, 1994). A variety of authors have discussed the validity of using students’ discourse and activity as proxies for cognitive processing (Cohen, 1994; Mercer, 2000; Soter et al., 2008). For example, building explanations, developing models, drawing inferences, synthesizing ideas, or critically evaluating arguments are types of talk often linked to high-level thinking and comprehension (Entwistle, 2000; Krathwohl, 2002). On the other hand, sharing information, exchanging ideas, providing definitions, or clarifying procedures often involve low-level cognitive processing. Analysis of different levels of cognitive processing in groups of university students working in case-based projects reveals a large variability within and across groups in the extent to which they engage in high-level discourse (Volet et al., 2009).

Although the different research studies mentioned in the previous paragraphs have involved different populations of students and diverse research methodologies, many of them have relied on the observation of groups of pre-college students engaged in teacher-assigned tasks inside a science classroom, or as part of course projects. In this regard, our study contributes to this body of literature by providing insights into the nature of both social regulation and cognitive processing in self-initiated study groups in higher education.
Methodology

Goals and Research Questions

The central goal of this exploratory study was to investigate the nature of the content-related interactions, involving both social regulation and cognitive processes, in study groups independently organized by students enrolled in college organic chemistry. In particular, our investigation was guided by the following research questions:

- What types of social regulation processes are commonly present in self-formed study groups?
- What levels of content processing are commonly present in these types of groups?
- What major factors related to group composition and group activity influence the nature of these social and cognitive processes?

Context and Participants

This study was conducted in a research-intensive public university in southwestern USA. All of the study participants were science and engineering majors enrolled in different sections of the first organic chemistry lecture course offered at this institution during three consecutive academic semesters. Participants were recruited by asking for volunteers enrolled in one of these lecture sections who were planning to form groups to study for this class and were willing to have an observer in their meetings. From this perspective, we did not have any control on the size, composition, or frequency of meetings of any of the observed groups; the goal of this exploratory study was to observe as many groups as possible under the conditions in which they normally worked. Some of these groups met regularly throughout the academic semester, and others ended up meeting only once or twice. Most study groups were formed by students who knew each other, although there were a few groups created through open invitation of one student to the rest of the class. In addition to these participants, study groups sometimes included members who were taking second semester organic chemistry, or students who came to study alongside the group but were not enrolled in a chemistry course. In a few circumstances, teaching assistants or even the course instructor were invited to the study session.

A total of 131 individuals (69 females and 62 males) organized in 14 dynamic self-initiated study groups participated in the study. We highlight the word ‘dynamic’ to emphasize the variability in size, composition, and meeting frequency of the observed groups. Analysis of general achievement data indicated that, on average, participants in our study had higher grade point averages (GPA = 2.78/4.00) than the average for all of the students in the organic chemistry course (GPA = 2.20/4.00). This suggests that observed study groups comprised students mostly in the middle to upper levels of academic performance in college chemistry.

Data Collection

Research data included observation notes and full transcripts of audio recordings of 34 different study sessions. In each case, general observations were made to register...
the meeting location, the types of resources used by the students (such as textbook or class notes), and other details of the group composition and interactions. During most study sessions, students drew molecular structures and other chemical symbols on a whiteboard or in their notes. Copies of these representations were made to the extent that was possible without disturbing the group dynamics; these drawings were later embedded into the appropriate points of a session’s transcript to facilitate their analysis and interpretation.

Study group meetings took place in a variety of locations, often in the library, in study rooms, or in students’ dormitory lounges. Meetings could last for several hours but observations were limited to an average length of 60 min per study session. Some of these observations occurred at the beginning of a study session, when groups were making decision about how to proceed, but in most cases our data corresponded to mid-stages in the study sessions. In all of the cases, group participants made their own decisions about when and where to meet and what and how to study. The first author of this work was informed of the meetings and invited to attend the sessions via e-mail. During a study session, this researcher made every effort to remain as a detached observer of the group, refraining from initiating any content-related conversation with the participants. Observer-initiated interactions were limited to ensuring informed consent of all members of the group to participate in the study, and to informal introductions and conversations that helped build rapport with the students. In some cases, students struggling with a concept or problem asked content-related questions to the observer. In these situations, help was provided as needed. Study sessions in which these types of interactions exceeded 15% of the content-related discussions of a group were excluded from the data pool.

Study sessions were observed as many times as possible (a total of 34 observations). We made every effort to complete observations throughout the different academic semesters and encouraged each study group to invite us back to observe their work multiple times. However, given our lack of control on meeting schedules and students’ decisions to invite us to a study session, not all of the study groups were observed the same number of times. Thus, of the 14 dynamic study groups that participated in the study, 7 of them were only observed once, 3 of them were observed in two different occasions, 2 groups were visited three times, 1 group was observed five times, and 1 group was visited in 10 occasions. It is important to point out that for those groups observed more than one time, group composition did not remain necessarily constant. For subsequent sessions, some of the original members may not have been present or new members may have joined. This was particularly characteristic of the group that was observed 10 different times, which was formed by the open invitation of a single student to all of the other students in her class. In this case, although the average number of group participants (seven) was higher than the average for other groups (around four students per group), the majority of the students attended only 1 of the 10 study sessions.

Observations of study groups were made throughout the academic semester as we tried to explore how students studied at different points in their classes. Generally, students met in preparation for one of the four midterm exams or for the
comprehensive final exam in the organic chemistry course. Information about the percentage of observed study sessions that focused on learning the content associated with each of the various exams is included in Table 1. When students met to prepare for the final exam, it was common for them to organize separate study sessions targeting the content of a specific earlier midterm exam. For purposes of analysis, such study sessions were grouped with the sessions corresponding to that same exam. Study sessions categorized as studying for the final exam correspond to cases in which students reviewed content from the entire semester.

Data Analysis

Audio recordings were transcribed and carefully analyzed using an iterative, nonlinear constant comparative method in which different types of interactions and content processing were identified (Charmaz, 2006). This approach allows researchers to use the data to create diverse categories of analysis and start generating theoretical properties for each category. The methodology leads to theoretical constructs that would need to be tested by further quantitative analysis. In our case, the analytical process began by examining study group transcriptions in order to extract all of the episodes in which students were on-topic and discussing chemistry content. Segments where students were off-task or discussing non-content-related aspects of the course were not used as part of the analysis. Results from prior studies on classroom interactions were

<table>
<thead>
<tr>
<th>Exam number</th>
<th>Target content</th>
<th>% of sessions observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Naming compounds using IUPAC nomenclature, translating representations (ex. line structures and Lewis structures), identifying hybrid orbitals, drawing structural isomers and resonance structures, drawing simple mechanisms, and predicting acidity/basicity trends</td>
<td>35.3</td>
</tr>
<tr>
<td>2</td>
<td>Identifying types of stereoisomers, labeling stereocenters as ‘R’ or ‘S’, translating between methods of representation (ex. Fischer and Newman projections), predicting the most stable chair conformation, and classifying general types of reactions</td>
<td>23.5</td>
</tr>
<tr>
<td>3</td>
<td>Predicting the product of reactions involving alkene or alkyne reactants, proposing mechanisms involving functional group transformations, and proposing synthetic pathways</td>
<td>17.6</td>
</tr>
<tr>
<td>4</td>
<td>Differentiating between substitution and elimination reactions, predicting the product of organometallic reactions, and proposing mechanisms and synthetic pathways, using spectroscopy (such as NMR, IR, or mass spectroscopy) to predict the structure of a compound</td>
<td>17.6</td>
</tr>
<tr>
<td>Final</td>
<td>Comprehensive (all of the above)</td>
<td>5.9</td>
</tr>
</tbody>
</table>
used to develop a list of initial codes that helped us identify different types of social regulation processes (Kumpulainen & Mutanen, 1999; Roychoudhury & Roth, 1996; Volet et al., 2009). These initial codes were then iteratively modified, collapsed, or redefined based on the analysis of the transcripts and on discussions between the authors. Coding in this area was done by paying attention to the types of utterances made by each member of a group in a given episode (e.g. question, response, and information) as well as to the perceived nature of the interactions (e.g. clarification, explanation, and argumentation). This type of analysis allowed us to identify major roles played by the participants in a given episode (e.g. questioner and explainer) and characterize the nature of the interaction.

Our data analysis led to the identification of three major codes associated with different forms of social regulation: teaching, tutoring, and co-construction. Teaching processes involved a stratification of roles, where one student explained a concept or provided information to the rest of the group members. In this type of interaction, the student acting as the ‘teacher’ decided what content to address and how to discuss it. This person normally took the role of a lecturer covering certain content, while the other members of the group acted as relatively passive listeners. In tutoring processes, role stratification was still present as one or several students acted as the main providers of information, but the nature of the content to be discussed was mainly determined by the questions posed by other group participants. In contrast, during those processes identified as co-construction, two or more students took on equivalent roles attempting to understand a concept or idea. In this case, students shared and discussed their understandings trying to answer a question or solve a problem.

Analysis of different levels of content processing was guided by the application of a revised Bloom’s taxonomy (Krathwohl, 2002), which led to codes such as remember, apply, and analyze. This basic coding system was modified, expanded, and revised as needed to better capture the specific types of reasoning in which students engaged while discussing organic chemistry questions and problems (e.g. mechanistic and synthetic analysis). The set of codes used in this part of the analysis together with the type of reasoning that they described and some specific examples from the observed study sessions are presented in Table 2.

Data analysis was completed in various steps. An initial coding system was proposed and discussed by the two researchers involved in the study based on the analysis of existing research literature and independent informal coding of several transcripts. This initial coding system was then applied by the first author of this paper to the formal analysis of one transcript. During this task, coding segments were defined at the episodic level. That is, codes were assigned every time there was a shift in either the type of group interaction or the cognitive level of the discussion. Both the proposed segmentation of the transcript and the specific codes assigned to each segment were then independently reviewed by the second researcher, who either agreed with the assignations or proposed alternative segmentations or codes. Comparison and discussion of ideas helped refine the coding system and the identification of boundaries between segments. Once agreement was reached, the process was repeated with more transcripts until total disagreements on a single transcript were less than 10%
Table 2. Levels of content processing as defined and coded in the analysis of students’ interactions in self-initiated study groups

<table>
<thead>
<tr>
<th>Level of content processing</th>
<th>Excerpts from study sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Remember</strong>: Students were remembering relevant information and using it to, for example, define concepts, recall values, identify categories, or recognize processes in order to solve a problem or answer a question</td>
<td><em>(Students identify a functional group)</em>&lt;br&gt;R: This is an amine, right?&lt;br&gt;P: NH₂ I think it is.&lt;br&gt;R: Amine, right?&lt;br&gt;P: It’s an amide? Yeah, double bonded to the oxygen</td>
</tr>
<tr>
<td><strong>Understand</strong>: Students were trying to determine the meaning of concepts or ideas by, for example, interpreting chemical representations, comparing chemical processes, building inferences, and explaining ideas</td>
<td><em>(Students try to understand how isopropyl and propyl substituents differ)</em>&lt;br&gt;E: Why is it called isopropyl in this circumstance?&lt;br&gt;L: What does that mean, that weird line with the squiggly around it? I know it means iso, but I don’t understand what that means.&lt;br&gt;M: It means it’s attached to something else that could be like, attached to another chain…</td>
</tr>
<tr>
<td><strong>Apply</strong>: Students were using their knowledge to solve a problem following two main approaches:</td>
<td><em>(Students try to determine which conformation of a cyclohexane ring is most stable given some data)</em>&lt;br&gt;J: So higher kilojoules is more stable always, right?&lt;br&gt;K: Well no. This is diaxial strain. You want the one to be axial that has the lower number of kilojoules, because it’s telling you the kilojoules of strain. So&lt;br&gt;A: So wouldn’t the 2.1 be good?&lt;br&gt;J: I think it’s 3.8 right?&lt;br&gt;K: I’m pretty sure it’s the 2.1 one. Because that’s telling you the value of the strain, and you want less strain not more strain…</td>
</tr>
<tr>
<td>• Executing: Carrying out a well-established procedure&lt;br&gt;• Implementing: More freely applying learned principles</td>
<td></td>
</tr>
<tr>
<td>Level of content processing</td>
<td>Excerpts from study sessions</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td><strong>Analyze:</strong> Students broke down information into parts trying to detect how the different components related to one another. At this level, we differentiated content-specific methods of analysis:</td>
<td></td>
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<tr>
<td>† Connect the dots: Students created reaction mechanisms based on structural differences between reactants and products</td>
<td></td>
</tr>
<tr>
<td>† Mechanistic: Students created reaction mechanisms using chemical principles to propose a sequence of events</td>
<td></td>
</tr>
<tr>
<td>† Synthetic: Students compared structural differences between products and reactants to propose reaction conditions or synthetic pathways</td>
<td></td>
</tr>
<tr>
<td>† Generic: Students used generic procedures to analyze chemical structures and processes</td>
<td></td>
</tr>
<tr>
<td><strong>Create:</strong> Students were assembling information in order to generate an answer, for example, inferring the structural formula of a chemical compound from different types of spectroscopic data</td>
<td></td>
</tr>
<tr>
<td><em>(Students draw a mechanism by considering the structural differences between the product and reactant)</em></td>
<td></td>
</tr>
<tr>
<td>A: Didn’t this give this thing to the O and C: Then you’ve got Cl hanging out there. N: Yeah, H came in and broke this bond? K: Well H came in and attached first. But actually it breaks that bond. C: H attaches to, um, to the oxygen, on the OH A: Look, that has to go there because it has to lose that? N: Cleave that bond…</td>
<td></td>
</tr>
<tr>
<td><em>(Students derive a structure from spectroscopic data)</em></td>
<td></td>
</tr>
<tr>
<td>A: Well, so there’s a hydrogen attached to the oxygen, you know that. So write down your fragments. Now count what you have so far. P: Like in this? 1,2,3, and then this connected would be the four. A: So there is four. (pause) Now, what’s on the other end though? No. What fragment have you not added yet? You have it under your fragments, that’s your hint. P: What, the isopropyl? Like that…</td>
<td></td>
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</tbody>
</table>
of the total segments and codes. The authors then separately coded another set of transcripts, compared and discussed their results, repeating the process until achieving over 90% agreement in consecutive sets. The resulting coding system and methodology was then applied by the first author to analyze the totality of the data.

For comparison purposes, the length of an episode was determined by counting the number of words spoken during that segment. In some instances, conversations between students would involve long pauses. In other cases, students would rapidly respond to one another and overlapping conversations may ensue. Students would also often begin one statement before another student finished a sentence. Thus, keeping track of the number of words rather than the number of full statements or span of time allowed us to better capture the comparative length of different episodes. Number of words was also used to compare individual contributions to a given conversation, the types of contributions made by each student (e.g. asking questions and providing explanations), as well as the extent of the discussions associated with different types of questions or problems. The relative frequency of these different categories was determined by finding the percentage of words that corresponded to each category within any given study session. We used these frequencies to calculate average values within and across study groups.

Findings

The presentation of the results of our study has been organized using our three central research questions as a guide. In particular, the first two subsections focus on the description of general interactional patterns at the level of social regulation and content processing, while the last subsection includes our analysis of the main factors that seem responsible for such interactions.

We recognize the limitations of our findings given the lack of control on the number of study sessions observed, the frequency of our observations, and the variability of group membership and size. We also acknowledge that the results that we describe in this section may have been influenced by the fact that our observations only included a subset of volunteer students who may not have been representative of the average targeted population. However, given that our central goal was to develop a better understanding of the nature of content interactions in self-initiated groups, we believe that the above limitations do not critically affect the validity of our findings. Considering these limitations, we did not attempt to analyze the evolution of group interaction patterns across the academic semester or to evaluate the impact of student participation in study groups on course performance. Recognizing the highly dynamic composition of the groups that we observed, we also did not attempt to compare interaction patterns across groups. In fact, our findings mostly focus on comparisons between different study sessions, rather than between different study groups.

Social Regulation

Participants in all of the observed study groups and sessions engaged in several forms of social regulation spanning from individual regulation within a group (e.g. a single
student takes on an instructive role) to co-regulation as a group (e.g. all members regulate a joint activity). In particular, we identified three major types of social regulation processes within these self-initiated collaborative groups: teaching, tutoring, and co-construction, differentiated mainly by who in the groups guided the discussions by asking questions, providing information, or generating explanations.

As shown in Table 3, teaching, tutoring, and co-construction processes were observed in almost all of the study sessions but to different extents. Interactions between students often shifted from one of the above types of processes to another during a single study session and even during the discussion of a single problem. In

<table>
<thead>
<tr>
<th>Group</th>
<th>Study session (no. of participants)</th>
<th>% teaching</th>
<th>% tutoring</th>
<th>% co-construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 (3)</td>
<td>23.2</td>
<td>43.8</td>
<td>33.0</td>
</tr>
<tr>
<td>2</td>
<td>1 (3)</td>
<td>31.8</td>
<td>37.3</td>
<td>30.9</td>
</tr>
<tr>
<td>3</td>
<td>1 (3)</td>
<td>20.6</td>
<td>12.5</td>
<td>66.9</td>
</tr>
<tr>
<td>4</td>
<td>1 (5)</td>
<td>74.5</td>
<td>20.6</td>
<td>4.9</td>
</tr>
<tr>
<td>5</td>
<td>1 (5)</td>
<td>30.7</td>
<td>51.0</td>
<td>18.3</td>
</tr>
<tr>
<td>6</td>
<td>1 (3)</td>
<td>26.6</td>
<td>28.1</td>
<td>45.3</td>
</tr>
<tr>
<td>7</td>
<td>1 (2)</td>
<td>13.3</td>
<td>64.6</td>
<td>22.1</td>
</tr>
<tr>
<td>8</td>
<td>1 (5)</td>
<td>31.4</td>
<td>29.2</td>
<td>39.4</td>
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<tr>
<td></td>
<td>2 (5)</td>
<td>26.1</td>
<td>52.2</td>
<td>21.7</td>
</tr>
<tr>
<td></td>
<td>3 (7)</td>
<td>58.4</td>
<td>37.9</td>
<td>3.7</td>
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<tr>
<td></td>
<td>4 (4)</td>
<td>29.5</td>
<td>39.3</td>
<td>31.2</td>
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<td></td>
<td>5 (6)</td>
<td>36.3</td>
<td>49.1</td>
<td>14.6</td>
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<td>9</td>
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<td>9.6</td>
<td>68.1</td>
<td>22.3</td>
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<td>2 (3)</td>
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<td>3 (5)</td>
<td>16.6</td>
<td>40.3</td>
<td>43.1</td>
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<td>10</td>
<td>1 (3)</td>
<td>14.3</td>
<td>51.9</td>
<td>33.8</td>
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<td></td>
<td>2 (3)</td>
<td>19.2</td>
<td>7.1</td>
<td>73.7</td>
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<td>11</td>
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this sense, study sessions were quite diverse, with some groups strongly relying on one type of interaction and others engaging in each of the identified regulation processes to similar degrees during a given session. For example, in 18 of the 34 sessions over 50% of the group talk was characterized by a single type of interaction while in close to a fifth (8/34) of the observed study sessions conversations were more evenly distributed among the three major types of interactions with none of them corresponding to less than 25% of the group talk. Individual engagement or participation in each type of interaction for any given study group was also quite varied, with some students taking on the same role from one study session to another while others shifted roles within and across study sessions. Considering the totality of the study sessions observed, none of the three main types of social regulation processes could be identified as dominant or characteristic of organic chemistry self-initiated study groups. Based on word count, on average 34.7% (SD 21.1) of the interactions observed per study session were of the teaching type, 35.4% (SD 16.8) involved tutoring, and 29.9% (SD 19.1) were based on co-construction.

**Teaching processes.** Although the teaching interaction was present in all of the study sessions that were observed, it did not dominate group talk in most cases; it was the most common type of interaction for only 9 of the 34 study sessions that were observed, and the least common for 15 of these sessions (Table 3). During this type of interaction, group participants took one of two distinctive roles, they either behaved as a didactic instructor making decisions on what to study and providing knowledge and explanations to the rest of the participants or they acted as relatively passive students who listened, took notes, and asked clarification questions. On average, close to 79.2% (SD 11.9%) of the group talk during teaching interactions was done by single individuals giving explanations or providing information and only 20.8% of the talking involved other students making comments or asking questions. The following excerpt is illustrative of the typical group dynamics during a teaching interaction (with student ‘O’ as the teacher):

O: Well we’ll go through it. We’ll go through it. Okay, so numbering system. Where do you start? (pause) So. You didn’t notice there’s a tie. Okay, so there’s a tie, 1,2,3,4. 1,2,3,4.
K: So it’s a tie so you go to this one?
O: But here you are missing one thing. So you can go to the next one, right? So it’s four here, right? Well what’s the next one? It’s like in the middle. (pause) That chain… So you’re gonna find the counting word, right? So it’s where the carbon, you start where it’s the first substituent, the first substituent you can get.
K: Right.
O: So this is your one substituent right here, and that’s on the end carbon, so that’s a one.

**Tutoring processes.** Tutoring was the most common type of interaction for 15 out of the 34 observed study sessions, playing the lesser role in only five of all sessions (Table 3). Students who interacted in this way took on distinctive roles, either asking questions to the other group members or generating answers and providing information; these roles
tended to remain fixed during a given study session. In this type of interaction, the focus of the conversations was mostly determined by the students asking the questions rather than by those providing the answers. Contributions to group talk as measured by word counts were equally divided between these two types of participation, with 48.8% (SD 11.6%) of group talk coming from individuals asking questions, and 51.2% of group talk corresponding to students answering questions.

Our analysis of those study sessions in which tutoring interactions dominated over 50% of the content-related conversations revealed two main formats in which this type of interaction occurred. On the one hand, there were groups in which students spent a significant portion of the study session working individually on similar or different types of problems, and used their study partners as more knowledgeable others whenever they had a question. On the other hand, there were groups that worked in a collaborative manner with the entire group participating in a question–answer session. As shown in the following excerpt, in this latter case, it was common to have more students taking the roles of questioners than that of answerer:

A: On the halohydration one, don’t they go on opposite sides?
K: Halohydrin?
A: Halohydrin, yeah.
K: It’s syn addition. Not anti addition.
C: So they’re on the same side?
A: So we don’t need to know anti addition?
N: So of addition? There’s syn and anti addition?
K: You need to know anti addition. Anti addition happens in halogenation.
N: Is that right? There’s like, the addition and substitution, duh duh duh. And for the addition? There’s syn and anti? Okay, can we go over that?
C: But couldn’t syn also happen for the halogen, the...
K: Halogenation? It doesn’t. Trans is more stable. That’s why anti addition happens.

**Co-construction processes.** Co-construction was the most common type of interaction in 10 out of 34 of the study sessions in our data pool, but the least frequent in 14 of all the observed study sessions (Table 3). Students who engaged in the co-construction of knowledge at the highest rates tended to do so in groups that were relatively small in size, with only two or three students involved in the interaction (compared to almost five students for the average group size). The participants in these groups focused on one given problem at a time, discussing ideas and potential answers collaboratively. They brainstormed ideas, proposed tentative answers, questioned or approved suggestions to solve a problem, and collectively evaluated their knowledge. In these types of cases, it was common for students to use a whiteboard to write the problems or represent chemical structures and reaction mechanisms, which facilitated the group discussions. Based on word count, contributions to group talk from different group members varied from problem to problem and across study sessions. The following excerpt is representative of this type of interaction:

A: Alright, so OCH₃ is … would you have to draw that as a leaving group? Like OTs?
P: OMe?
A: You have to get back to the triple bond somehow. Yeah, so is that a leaving group?

P: Yeah.

A: It is?

H: Are you guys going backward?

P: Yeah.

A: Okay, so.

H: Could you do like a NaOCH₃ or like in the parenthesis, OCH₃, close parenthesis 2CuLi? Do you get that? If that makes sense?

A: No. Hold on, let me think real quick. Okay, so you have the OCH₃. So that got added on. So write that out. Just write OCH₃ on the last thing somewhere. That got added. What would it have been added with? Base. Some sort of base.

P: Why?

A: Because that would bring us back to at least a double bond, right?

P: Yeah.

Content Processing

Our observations of self-initiated study groups involving college organic chemistry students indicated that a majority of the group work focused on solving problems provided (e.g. practice exams) or suggested (e.g. end-of-chapter problems in textbooks) by the course instructors. On average, this type of work corresponded to 63.6% (SD 36.9%) of the groups’ talk. In some cases, students worked on self-generated problems (13.0%, SD 29.4%) or questions (10.0%, SD 14.8%), or used their time to review course content (13.4%, SD 29.4%).

The analysis of students’ conversations while working on different types of problems and questions revealed the levels of content processing summarized in Table 2. The extent to which students engaged in these different levels of reasoning varied among the different study sessions. Average results for all of the observed study sessions are presented in Table 4, where the percentage of content-related words associated with

<table>
<thead>
<tr>
<th>Levels of content processing</th>
<th>Teaching, avg. % (SD)</th>
<th>Tutoring, avg. % (SD)</th>
<th>Co-construction, avg. % (SD)</th>
<th>Overall, avg. % (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remember</td>
<td>34.7 (28.3)</td>
<td>49.1 (27.5)</td>
<td>32.0 (23.5)</td>
<td>39.0 (26.6)</td>
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<td>Understand</td>
<td>9.36 (11.5)</td>
<td>16.1 (17.2)</td>
<td>9.76 (15.6)</td>
<td>11.9 (14.7)</td>
</tr>
<tr>
<td>Apply</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Executing</td>
<td>28.4 (35.9)</td>
<td>14.4 (18.5)</td>
<td>20.4 (19.9)</td>
<td>21.1 (24.9)</td>
</tr>
<tr>
<td>Implementing</td>
<td>8.31 (14.4)</td>
<td>9.94 (15.8)</td>
<td>17.8 (20.1)</td>
<td>11.7 (16.6)</td>
</tr>
<tr>
<td>Analyze</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Connect the dots</td>
<td>2.24 (6.70)</td>
<td>3.03 (9.28)</td>
<td>2.01 (7.92)</td>
<td>2.45 (7.98)</td>
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<tr>
<td>Mechanistic</td>
<td>4.71 (13.4)</td>
<td>1.47 (4.40)</td>
<td>4.46 (15.2)</td>
<td>3.49 (10.7)</td>
</tr>
<tr>
<td>Synthetic</td>
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<td>0.53 (3.07)</td>
<td>3.73 (12.4)</td>
<td>1.63 (6.35)</td>
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<td>4.92 (10.8)</td>
<td>9.40 (23.1)</td>
<td>7.90 (16.3)</td>
</tr>
<tr>
<td>Create</td>
<td>1.70 (6.44)</td>
<td>0.33 (1.31)</td>
<td>0.44 (2.52)</td>
<td>0.83 (3.45)</td>
</tr>
</tbody>
</table>
different levels of content processing are separated based on the different type of social regulation process in which students were engaged (teaching, tutoring, or co-construction). In general, over 80% of the observed content-related conversations corresponded to lower levels of cognitive processing in our coding system (remember, understand, and apply) regardless of the nature of the social interactions (see rightmost column in Table 4). However, as we discuss in the following section, the analysis of the data revealed the existence of nuanced relationships among types of social regulation, levels of processing, and other contextual factors.

Influential Factors

The types of social regulation processes and the levels of content processing observed in each study session were influenced by factors related to both the group’s composition and the nature of the tasks in which the students were engaged. Given the central role that solving chemistry problems had on the groups’ approaches to studying, the specific content and structure of such problems had a strong influence on the level of content processing and the type of social regulation among study session participants. However, the effect of task features on group work was mediated by a group’s decisions about the organization of the study session and by the different levels of content knowledge and conceptual understanding of the various attendees.

Group composition features. Students’ decisions about how to organize a study session frequently imposed constraints on the nature of group interactions. For example, students who studied by working individually, rather than collectively, in solving problems often relied on tutoring as their main form of social regulation. In these situations, students tended to work at their own pace on individual tasks and the communication between group members was often brief and shallow. Students who worked by themselves on a task often interacted one-on-one with other students in the group by asking low-level factual or procedural questions about how to solve a problem. Consequently, a large proportion of tutoring interactions in the observed study groups led to low levels of content processing (Table 4).

Group dynamics in those cases in which the majority of the group members participated in a shared activity was influenced by the relative content knowledge and conceptual understanding as expressed by the participants during the study sessions. Thus, study sessions in which one or two individuals seemed to have a better understanding of the different concepts, ideas, and procedures needed to solve the study problems often evolved into a teaching session in which the more knowledgeable others took the role of explainers or deliverers of information. For study groups that were observed more than one time, the absence of the student who tended to play the teacher role changed the group dynamics by either having another member of the group become the teacher or generating a more collaborative environment in which co-construction of knowledge was more prevalent. In general, the presence of the individual who regularly assumed the role of teacher in a group suppressed
participation from other students who took on more active roles when that individual was absent.

In fewer occasions, the mismatch in levels of understanding among group members also led to tutoring interactions in which the more knowledgeable individuals became the answerers to the multiple questions of the other students in a group. Either through teaching or tutoring interactions, the presence of a knowledgeable person in a study session, whether a peer student, a teaching assistant, or the course instructor, tended to increase the level of content processing that was observed. Often this person provided the answers to the more challenging problems or questions and explained the underlying concepts, ideas, or procedure. Thus, most of the explicit analysis or construction of knowledge was done by the ‘teacher’ or the ‘answerer’ in the group with little contribution from other participants.

From the perspective of group composition, the emergence of co-construction processes was correlated with the absence of a person in the group who knew how to solve a selected study problem as well as with group size. Common lack of knowledge or understanding was often the main trigger of co-construction interactions in the observed study sessions, but this form of social regulation often involved groups or subgroups comprising only two or three people. The level of content processing in these situations was largely determined by the specific content and structure of the targeted study problems. For the observed study groups, co-construction of knowledge often was prompted by the lack of a readily available answer known to a member of the group.

Task features. The specific nature of the questions and problems worked out by the students had a strong influence on the level of content processing observed in the study sessions. Problems that required students to, for example, give the chemical name of an organic compound or to identify structural features in a chemical compound traditionally triggered lower levels of thinking than problems that asked them to design a synthetic path or to infer a chemical structure from different sources of spectroscopic data. Although some students tried to simplify the solution of some complex tasks by searching for and applying standard algorithms or procedures (executing), in general the higher the cognitive demand of a problem the higher the level of content processing exhibited by those students involved in generating the answer.

The level of difficulty of a problem relative to the content knowledge, conceptual understanding, and procedural skills of the study session participants influenced social regulation. For example, tasks that demanded intermediate (apply) or high levels (analyze, create) of content processing were often approached using a teaching format if there was a member of the group who knew how to generate the answer. If that was not the case, the groups either skipped the problem or engaged in co-construction. The less cognitively demanding tasks (those based on remembering and understanding the content) were more frequently addressed via tutoring interactions. Given the typical distribution of content in college organic chemistry courses, in
which mechanistic and synthetic thinking are introduced later in the course (Table 1),
instances of high-level content processing were more frequently observed in the
second half of the academic semester. However, engagement in higher levels of think-
ing as the semester progressed was more frequently observed in the context of teach-
ing interactions than associated with co-construction.

The source of the problems used to guide the study session also influenced the level of
content processing that was observed. In general, study groups worked on problems
suggested by the course instructors or on student self-generated problems. These latter
types of problems were frequently easier to solve and resulted in lower levels of content
processing (remember, understand, and apply) in 94.5% (SD 13.4%) of the conversa-
tions that they triggered. Comparatively, only 78.9% (SD 23.2%) of the group talk that
characterized the discussion of instructor-suggested problems corresponded to these
lower levels of reasoning. Group discussions linked to instructor-suggested problems
were on average longer (~1.6 times) and more varied and in-depth than those that
resulted from a group’s engagement in student self-generated problems. In general, the
discussion of instructor-suggested problems was regulated in the form of co-construction
(35.2%, SD 19.4%) and tutoring (35.0%, SD 19.1%), while work on student self-
generated problems tended to result in teaching (65.4%, SD 36.5%). In these latter
types of cases, the students who created the problems frequently also provided the
answers, acting as a teacher or tutor for the rest of the group members.

The general types of problems self-generated by students in a study group were
similar to those provided or suggested by course instructors. They addressed tasks
such as naming organic compounds, predicting the nature of a reaction product,
and proposing synthetic pathways. However, instructor-provided problems tended
to have higher levels of complexity, requiring students to take into consideration
several variables at a time or analyzing competing conditions in order to make
decisions. Thus, for example, while student-generated problems involving the predic-
tion of a reaction product triggered reasoning at the ‘remember’ level in 78.7% of all
related episodes, instructor-suggested problems in the same category triggered this
type of reasoning in only 39.8% of the associated discussions. Besides differences in
problem complexity, student-generated problems many times also failed to engage
students in deeper discussions because, in the face of difficulties, the author of the
problem often stepped in to provide the solution.

A small portion of content-related conversation in the observed study sessions
focused on students’ posing questions or on the review of course content. In these
cases, lower levels of content processing also dominated group talk. A majority of
the conversations when the groups were answering questions (99.8%, SD 0.22%) or
reviewing course content (93.9%, SD 14.5%) corresponded to remembering,
trying to understand, or applying knowledge. On average, 71.6% (SD 31.1%) of
the questions posed by participants in the study sessions were expressed in the
context of a tutoring interaction while approximately half of the groups’ talk
(50.3%, SD 30.7%) associated with content review was done using a teaching
format (on average, the reviewing of content through tutoring and co-construction
occurred less frequently but to a similar extent).
Discussion and Conclusions

Most of our current knowledge about students working in small collaborative groups has been derived from the analysis of students engaged in teacher-assigned tasks. Little direct information is available about how they self-organize and self-direct their learning while working in self-initiated groups outside the classroom. In fact, a major limitation of research on college students’ approaches to learning has been its overreliance on self-reports of individual strategies rather than on actual observation of students studying for their courses. From this perspective, the results of our work contribute to the development of a better understanding of how students self-regulate their own learning while working in small groups.

The central goal of our study was to investigate the types of social regulation processes and the levels of content processing commonly present in self-initiated study groups organized by college organic chemistry students. These types of groups tended to be highly dynamic, with variable size and composition. This variability imposed important limitations in our ability to compare the work of different study groups across an academic semester or to further explore the effect of student participation in these types of groups on their learning and achievement in organic chemistry. However, our exploratory study provides insights into different factors that seem to affect the emergence of opportunities for students to co-construct understanding and engage in higher levels of cognitive processing.

Our investigation revealed three major types of processes, teaching, tutoring, and co-construction, as characteristic of the social regulation patterns in the observed self-formed study groups. On average, none of these processes was more prevalent than the others. However, the extent to which students engaged in teaching, tutoring, or co-construction varied widely from one study session to another. This variability seemed to be mostly determined by the specific composition of the study groups and the nature of the study tasks in which they were engaged. Students’ implicit and explicit decisions about how to organize the study session, the relative content knowledge and conceptual understanding expressed by the participants, as well as the cognitive level of the problems selected to guide group work had a strong impact on how students interacted with each other.

Group work was commonly focused on solving problems provided or suggested by the course instructors. Much less frequently students generated their own problems or questions, or reviewed the course content. Thus, studying through solving exam-like problems was the main study strategy used by all of the observed groups. Similar results have been reported in the analysis of individual college students’ approaches to studying in other scientific disciplines (Tomanek & Montplaisir, 2004). It was in the context of solving problems either individually, under the direction or guidance of others, or collaboratively that students mainly engaged in reviewing, analyzing, or discussing the course content. Consequently, the level of content processing observed in a group was closely correlated with the cognitive level of the problems that the students solved. In general, instructor-provided problems were more varied and of a higher cognitive level than student-generated problems which frequently
focused on perfecting low-level cognitive skills (e.g., how to execute an algorithmic procedure, such as naming a compound or identifying a structural feature). Nevertheless, independently of the source of the problem, group talk in the observed study groups was mostly focused on low-level cognitive processes such as remembering information and discussing how to apply well-established procedures to solve a problem.

The different types of social regulation processes and the levels of content processing interacted in particular ways in the observed study groups. For example, somewhat surprisingly for us, tutoring processes often were associated with surface-level discussions of the content. Although the level of participation of tutors and tutees was on average similar during these types of interactions, tutoring exchanges were mostly focused on procedural issues rather than on discussion or elaboration of concepts or ideas. This outcome seemed to be largely determined by the conditions that regularly favored the emergence of tutoring interactions in the study groups. Students tended to engage in tutoring exchanges while solving problems individually, which often resulted in them working on different tasks. Their interactions were thus frequently constrained to short verbal exchanges that mainly helped clarify aspects of a problem or provided specific guidance on solution procedures. These sporadic exchanges limited the opportunities for group members to engage in the types of tutoring activities that are known to favor high-level cognitive processing and meaningful learning, such as generating explanations, asking and responding to thoughtful questions, and actively engaging in content-related discussions (Chi, Roy, & Hausmann, 2008; Roscoe & Chi, 2007, 2008). From a group coordination perspective (Barron, 2000), tutoring in the observed study groups lacked the level of mutuality in interaction, shared goals, and joint attentional engagement that is characteristic of productive group work.

While low levels of content processing were more closely correlated with tutoring processes, the fewer instances of higher level thinking (analyze and create in our coding system) in the observed study sessions occurred more frequently during teaching and co-construction segments (Table 4). However, the involvement in content processing of different group members was rather different in these two types of interaction events. Teaching processes commonly involved the presence of one individual with an expressed higher level of content knowledge and conceptual understanding than the rest of the participants. When facing challenging problems, this person was the one summarizing information or providing explanations to others. Thus, although high levels of content processing may have been displayed in the group, most of the meaning-making was done by a single individual whose presence highly constrained other people’s involvement. In this case, the lack of mutuality in participation limited the opportunities for all of the students to meaningfully analyze and discuss the content, challenge their knowledge, and recognize the extent and limits of their understandings (Barron, 2000; Roscoe & Chi, 2007; Scott, Mortimer, & Aguia, 2006).

In contrast with the teaching events, content processing during co-construction segments was characterized by high degrees of mutuality and consistent joint
attention as participants’ efforts were directed towards a shared goal. High levels of reasoning in these types of events were normally associated with work on challenging problems that no one in the group knew how to solve. In the particular case of the organic chemistry course, these events typically involved the solving of problems that required students to design a chemical synthesis or generate mechanistic pathways using chemical models and principles. Noticeably, even in those cases in which students engaged in solving problems of lower cognitive demand, co-construction frequently led to longer and more in-depth discussions. Unfortunately, our results indicate that co-construction in self-initiated study groups, although not significantly less or more frequent than other types of interactions, was an activity that tended to emerge as a last resort in trying to solve a problem.

The perceived lack of intentionality of students’ engagement in co-construction interactions, compared to the more purposeful approach taken by some of the groups to organize their study sessions using a tutoring or a teaching format, may have been determined by a variety of personal and contextual factors. Several research studies indicate that college students’ epistemological beliefs (Rodrı´ guez & Cano, 2006), conceptions of learning and effective studying (Marton & Säljö, 1997), and motivation (Biggs, 1987), together with the nature of the teaching–learning environment and the content and demands of the instructional and assessment tasks (Entwistle, 2000) shape students’ approaches to learning. In our case, study participants were enrolled in college courses in which lecturing was the prevalent teaching strategy and assessment of learning was based on students’ ability to solve traditional organic chemistry problems during classroom exams. In this context, our results suggest that the majority of the observed study groups adopted a rather strategic approach to studying (Entwistle, 2000) by using instructor-suggested problems to guide their work, focusing on the development of the knowledge and skills needed to answer old exams, and minimizing time and cognitive effort by depending on the direction and guidance of more knowledgeable others (either through teaching or tutoring). In this context, co-construction of knowledge seemed to be a last-resort strategy in the absence of more direct sources of information.

Implications

Research in higher education has shown the strong influence that both students’ perceptions of the learning environment (Ramsden, 1992) and instructors’ approaches to teaching (Trigwell, Prosser, & Waterhouse, 1999) have on students’ approaches to learning. One may thus speculate that the strategic approach to studying that was characteristic of the observed study groups may have been influenced by the traditional teaching and learning environment in college organic chemistry courses. Students are likely to make strategic study decisions based on what they perceive as the best approach to ensure success in the types of tasks and assessments in which they engage in the classroom. They may also have reproductive beliefs about the nature of learning (Marton & Säljö, 1997) and lack the metacognitive knowledge needed to engage in more productive and meaningful study practices. Thus, our results
underscore the need to transform college teaching practices to create learning opportunities for students to modify their beliefs about learning and studying, as well as to develop collaborative learning skills.

Given the central role that teacher-provided and teacher-suggested problems seem to have in study group work, instructors may be able to strongly influence the nature of students’ interactions and the level of content processing through the types of questions and problems that they pose in their classroom, suggest in their study guides, and include in their exams. Study resources, as well as formative and summative assessment tools, need to be enriched and diversified to include questions and problems that require students to think about core concepts and ideas in deeper and unfamiliar ways, and to self-formulate more thoughtful study questions and problems. In particular, it would be desirable to design multi-component problems that cannot be solved without thoughtful integration of diverse knowledge components and that carefully scaffold student thinking. These types of problems may ask students to, for example, compare and evaluate the strengths and weaknesses of different synthetic approaches to produce a substance or to analyze the composition of a chemical system. In this regard, Raker and Towns (2012) have made various useful suggestions about how to create more authentic problems in organic chemistry. These problems may, for example, explicitly require students to develop mechanistic models of chemical processes to justify their answers. In any case, students need to be confronted with problematic situations that demand the consideration of alternative reasoning strategies to find a plausible solution (Christian & Talanquer, 2012).

Most of the students that we observed seemed to be genuinely interested in making sense of chemistry concepts and ideas. However, they seemed to lack important cognitive and metacognitive tools to think more productively about the content. They also frequently failed to take advantage of the collaborative environment that they had created and they did not engage in the co-construction of understandings. In the presence of a more knowledgeable person, most students took on a passive role, listening to explanations rather than generating them. Although students in self-initiated study groups make independent decisions about what and how to study, our results suggests that their decisions and actions are highly influenced by their experiences in the actual classroom and their assessment expectations. Thus, college instructors have the ability, and the responsibility, to indirectly intervene in their approaches to studying. Instructors could, for example, devote some in-class time for students to engage in high-level, co-regulated small group discussions that involve students in elaboration of central chemistry concepts and ideas. For this purpose, the instructor could openly discuss the advantages and disadvantages of working in small versus larger groups when learning to solve problems, as well as the pros and cons of heterogeneous versus homogenious groups in terms of the participants’ content knowledge and conceptual understanding.

If college students are to appropriate the forms of group interaction that are most productive in meaning-making and meaningful elaboration of content, teachers’ instructional and assessment practices need to open spaces and create opportunities for more generative forms of meaning-making through collaboration. Students are
unlikely to intentionally engage in that form of interaction unless they see value in doing it and the strategy is well established in their metacognitive skill set. Sandi-Urena, Cooper, and Stevens (2011) have shown that involvement in collaborative problem-solving activities that promote cognitive imbalance and are scaffolded with explicit metacognitive prompting significantly increases college chemistry students’ metacognitive skills. These types of explicit interventions may be useful not only to foster cognitive development but also to model the types of activities we would like students to engage in on their own.

References


