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Guided Heads-Up: A Collaborative Game that Promotes Metacognition and Synthesis of Material While Emphasizing Higher-Order Thinking

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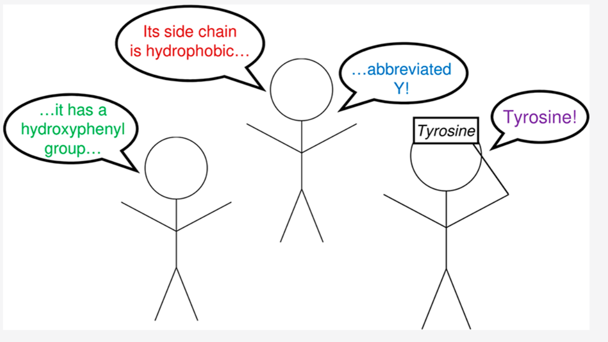
ABSTRACT: Games are a way to engage students with course material in a low-stakes environment. In the popular game app "Heads Up!", participants give clues to a guesser who is holding a word on their forehead. Here, we present a modified version of this game where students are required to give clues in a specific order that emphasizes higher-order thinking in the early rounds and moves to lower-order recall events in the later rounds. The collaborative group environment promotes oral communication, metacognition, and student–student interactions and may lead to improved student learning. This game, called guided heads-up, was used in three courses at two institutions. Student perceptions were gathered and analyzed for all three classes. Recommendations from students and instructors for designing and implementing the guided heads-up activities into additional courses are included.



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Incorporating educational games into the undergraduate chemistry classroom has many potential benefits, including promoting engagement with the material, improving student learning, and providing alternative study strategies.[1−5] Games reported for college-level chemistry and biochemistry courses take many forms, with common categories including computer simulations,[6−9] card games,[10,11] drawing games,[12] word games,[13] and board games.[3,14−16] Educational chemistry games have been incorporated into a range of college-level courses, including nonmajor courses,[6,17] general chemistry,[1,13,18−22] organic chemistry,[23−33] biochemistry,[9,12,34−36] and analytical courses.[37,38] These recent examples are not meant to be an exhaustive list, but the breadth of those cited here suggests that there are many opportunities to design and adapt games for educational purposes.

We describe a collaborative activity during which students interact with the course material with descriptions that go beyond rote memorization. The style of the activity was inspired by a game played on *The Ellen DeGeneres Show* that was later developed into a mobile application (app), "Heads Up!"[39] When playing "Heads Up!" on her show, Ellen holds up a phone or tablet which displays a word toward her game partner. The person seeing the word gives clues in attempt to get Ellen to guess the word. In the original version of the game, Ellen held a card to her forehead, which explains why the app was named "Heads Up!" This popular app is intended for use in casual social settings, but there are suggestions online for incorporating the app into elementary, middle, and high school classrooms.[40−43] Two groups previously have reported on the use of this style of game in this Journal.[20,31] O'Halloran reported on a game, "The Organic Compound Name Game", which involves guessers holding a sticky note with an organic structure on it to their forehead and asking teammates yes/no questions about the unknown class of the compound.[31] Koh and Fung adapted the mobile app "Charades!" to incorporate lists of laboratory equipment and procedures.[20] For this game, termed "ChemCharades", the guesser holds a phone to their forehead with the laboratory term displayed and remains silent while the clue givers provide descriptions. Clue givers are not allowed to make gestures or use nonchemical descriptions.[20] Both "The Organic Name Game" and "ChemCharades" give students opportunities to interact with course material in engaging ways that emphasize appropriate use of technical and scientific language. However, neither of these activities necessarily require students to move beyond lower-order learning behaviors like remembering and recognizing.[44,45]

We saw an opportunity to adapt the familiar game style of "Heads Up!" to chemistry content while also incorporating

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more direction into the activity to help students better sort and synthesize course material while becoming aware of their own knowledge in a cooperative environment. Our game, guided heads-up, uses the familiar "Heads Up!" structure but requires clues to be given in a particular order. The specific sequence of clues requires students to consider the material beyond lower-order learning activities, such as memorization and drills, that often are observed with educational games,[3] and instead, it challenges them to engage in higher-order thinking skills of analysis, application, and evaluation of knowledge to reach their goal. We present our approach to designing guided heads-up activities with three examples that were implemented in two institutions. Student perceptions of this approach are discussed, and recommendations for implementation in additional courses are provided.

■ INSTITUTIONS AND COURSES

Guided heads-up activities were implemented in selected courses at Saint Mary's College (J.F.) and Mercer University (G.L.C. and K.D.K.). Saint Mary's College is a Catholic liberal arts women's college with approximately 1,600 students. Mercer University, a medium-sized comprehensive institution, enrolls approximately 8,800 undergraduate, graduate, and professional students. Both institutions offer the American Chemical Society-certified curriculum.

Three guided heads-up activities were designed, implemented, and evaluated for Biochemistry (CHEM 324) at Saint Mary's College and Quantitative Analysis (CHM 241) and Biochemistry II (BMB 466) at Mercer University. CHEM 324, a survey course that covers structures of biomolecules, cellular reactions, and major metabolic pathways, is a requirement for Chemistry majors (BS) and frequently is taken by Biology majors and other students who intend to pursue medical school or other health professional careers; it also is an option for the Chemistry minor. CHM 241 includes topics related to fundamental techniques for quantitative chemical analysis. This course is required for majors in Chemistry (BS), Chemical Commerce (BA and BS), and Biochemistry and Molecular Biology (BS) and is an option for the Chemistry minor. BMB 466 includes content related to integrated cellular metabolism and molecular physiology, is required for Biochemistry and Molecular Biology majors, and is an option for majors in Chemistry (BS) and Biology (BA and BS).

■ GUIDED HEADS-UP

Design and Rationale

Triboni and Weber point out that educational games can have the unintended outcome of promoting lower-level thinking when they emphasize drills or memorization tasks; they summarize work by Ruggiero and Watson,[46] saying that for games to move students to higher-order learning activities, this "usually requires a cycle of action and reflection, which can be attained only if the game design naturally promotes a reflective practice during gameplay."[3] Additionally, two of the authors (G.L.C. and K.D.K.) have observed the difficulty many students have with articulating chemical concepts with their peers.[47] Thus, the authors designed and implemented a new group educational game, guided heads-up, that aimed to promote higher-order learning activities by incorporating a required order of clues or prompts into the game.

Groups of two to four students are given a set of cards with words on them and the activity rules. The instructor first goes over the purpose of the activity, letting the students know that the guided heads-up activity will give them practice bringing together some class concepts and material while also learning from their partner(s). The instructor then walks the class through the rules. Students are instructed that one "player" will take a card from the set and place it on their forehead with the words facing out and that this student will attempt to identify the word on their forehead from the clues provided from the other members of their group. Students are instructed that clues are to be given in the order outlined in the activity rules and that proper chemical terminology should be used. Working as a team, the other members of the group are encouraged to discuss the language for the best answer to give to the player guessing the word. The clue order for each of the sets was designed to start with a more descriptive task that would apply to a number of possible answers and moved toward more specific recall clues. After a card is correctly identified, the next player draws a card to take their turn. Each turn typically takes about 1 min, and play can continue until the card deck is completed. If the player holding the card identifies the word before the clues are all given, their teammates are encouraged to complete the clues for additional practice. In the case where a turn exceeds 1 min, students could be encouraged to look at the answer, move on, and return to the missed card later; however, this was not commonly observed for the guided heads-up games and students described in this work.

Examples

Guided heads-up activities are appropriate for use with material that benefit from a learner going beyond straight memorization to higher-order learning methods of categorization, sorting, and synthesis. For example, when learning amino acids in a biochemistry course, students readily memorize how to draw structures, names, and one- and three-letter abbreviations but can struggle when distinguishing between amino acids by their chemical properties and functionalities. Thus, the first guided heads-up activity gave students in CHEM 324 practice with the properties of amino acids (Box 1 and Supporting Information). Giving descriptions of side chains encouraged the clue givers to use thoughtful hints that would apply to only the correct answer. The more vague the description, the more amino acids that will be captured by that description. Students giving descriptions are rewarded for the use of appropriate technical language by guessers arriving at the correct answer faster (e.g., clue givers who use imidazole to specifically describe histidine compared to those who use hydrocarbon to describe alanine). The instructor, by circulating among groups during the gameplay, also should verbally acknowledge good use of technical language. The order of the clues proceeds from higher-order learning tasks toward specific recall tasks, all of which are necessary for learning the amino acids.

Later in CHEM 324 a second guided heads-up activity was developed for metabolic pathway reactants and intermediates (Supporting Information). This activity was also expanded upon and used in BMB 466 (Supporting Information). This iteration was an increase in the complexity of the game compared to amino acids. Students tend to approach these pathways as a linear set of reactions and only recognize the molecules in the context of that pathway, often missing connections between pathways that are important for integrated metabolism. Additionally, it is important that students differentiate between the reactions in which these

Box 1. Guided heads-up example: amino acids

Rules of play:

In turn, each player chooses a card from the deck and, without looking at it, holds it to their forehead so their teammates can see it.

The team has 60 seconds to give clues to the identity of the amino acid on the card.

Clues can be given in the following order only:

1. Describe the side chain using words.
2. Class of the side chain (polar, uncharged, charged, hydrophobic)
3. pKa of the side chain (if applicable)
4. One-letter abbreviation
5. Three-letter abbreviation

If the player holding the card guesses it before the clues are all given, the teammates still need to complete the clues.

molecules may serve as a reactant or as a product. Example reactants include glucose, succinate, and phosphoenolpyruvate. The required clue order was as follows:

1. Pathway(s) the reactant is involved in
2. Type of reaction catalyzed
3. Products formed (including NADH, ATP, CO_2, etc.)
4. Structure (in words)
5. Name of enzyme that catalyzes the reaction

The third guided heads-up activity was implemented in CHM 241 after students were introduced to spectroscopy and separations (Supporting Information). While students can readily give definitions or block diagrams related to instruments such as the spectrophotometer or graphite furnace, they can struggle with deciding which instrument or separation method to use when faced with more open-ended, real-world problems. Thus, a guided heads-up activity was developed that included cards with combinations of techniques and clue orders that incorporated both sample information and expected data:

1. Possible analytes
2. Required sample preparation steps
3. Sample state
4. Expected data (describe)
5. Special requirements (give specific mobile phase, stationary phase, reagents, etc.)

Student and faculty perceptions of these specific guided heads-up activities are discussed in the section below, followed by recommendations for extension to other topics and courses.

■ ASSESSMENT AND RECOMMENDATIONS

Overview

Student perceptions of guided heads-up activities were assessed with anonymous surveys administered at the end of the semester. This study was approved by both Mercer University's Institutional Review Board for Human Subjects Research (H1810275) and Saint Mary College's. The surveys included ten Likert-type scale statements (Table 1) and five free-response questions about guided heads-up activities (Box 2). Common themes were identified in the responses for Q2 and Q3 and summarized in Table 2 and Table 3. These themes were identified in an iterative process and confirmed by each of the authors. Instructor observations yielded some additional, unexpected insights.

Overall, student perception of the guided heads-up activities implemented at the two institutions was positive (Table 1). Likert-type scale responses indicate that, on average, students enjoyed the approach and found them engaging (S1 and S2). Student data and instructor observations suggest three main outcomes for guided heads-up activities: (1) they promote student learning, (2) they facilitate student−student interactions, and (3) they encourage metacognition. These

Table 1. Student Perceptions of Guided Heads-Up Activities

	Statements for Student Response about the Guided Heads-Up Activities (HAs)	Mean Scores[a] by Course: CHEM 324[b] (N = 14)	BMB 466[c] (N = 32)	CHM 241[d] (N = 43)	Overall Mean Scores[a] (N = 89)
S1	I enjoyed the heads-up activities.	4.7	4.5	4.3	4.5
S2	The HAs are an engaging in-class activity.	4.7	4.6	4.5	4.6
S3	The HAs helped me understand the course material better.	4.1	4.3	4.0	4.1
S4	The HA is an effective approach to reviewing course material.	4.4	4.3	4.3	4.3
S5	I prefer the HA over traditional reviewing of material with peers.	4.0	3.9	3.7	3.9
S6	HAs helped me improve my study skills.	3.6	3.7	3.3	3.5
S7	Having a specific order of clues helped me prioritize material.	4.1	3.9	3.7	3.9
S8	Having a specific order of clues helped me understand material.	3.9	4.0	3.7	3.9
S9	More HAs should be developed for this course.	4.1	4.4	4.0	4.1
S10	The HAs helped me assess my knowledge about the material covered by the activity.	4.6	4.5	4.3	4.5

[a]Students responded using a Likert-type scale with a range of 1−5: 1, strongly disagree; 2, disagree; 3, neutral; 4, agree; and 5, strongly agree. [b]CHEM 324 (Biochemistry lecture at Saint Mary's College) had a total enrollment of 27 junior and senior Chemistry and Biology majors. [c]BMB 466 (Biochemistry II lecture at Mercer University) had a total enrollment of 34 junior and senior Biochemistry and Biology majors. [d]CHM 241 (Quantitative Analysis lecture and lab at Mercer University) had a total enrollment of 52 sophomore and junior Chemistry, Chemical Commerce, and Biochemistry majors and Chemistry minors.

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Table 2. Summary of Main Themes in Student Responses for Most Helpful Aspects of Guided Heads-Up Activities

Most Helpful	Student Responses[a] by Course (%)			Overall Average (%) (N = 84)
	CHEM 324 (N = 14)	BMB 466 (N = 31)	CHM 241 (N = 39)	
Learning	64	90	56	70
Group work	14	16	26	20
Oral communication	7	6	26	15
Clue order	7	6	18	12
Engaging	29	3	3	7
Competition	0	3	5	4

[a]Some student free responses to Q2 (see Box 2) were coded with more than one theme.

Table 3. Summary of Main Themes in Student Responses on Improvements for Guided Heads-Up Activities

Area for Improvement[a]	Student Responses by Course (%)			Overall Average (%) (N = 73)
	CHEM 324 (N = 12)	BMB 466 (N = 30)	CHM 241 (N = 31)	
Make it easier	50	20	16	23
Make more types of sets	8	27	13	20
Use thicker paper	8	3	6	5
Make more available	8	3	3	4
Increase the competition	0	7	3	4
Give more time in class	0	7	0	3
Use it earlier in the semester	0	7	3	3

[a]Responding to Q3 (see Box 2) of the free-response questions, 32% of students' responses directly stated that there was no area that needed improvement.

outcomes are discussed in more detail in the sections that follow.

Promoting Student Learning

These activities were designed to help promote student learning by giving students guided practice with sorting and synthesizing large amounts of related course material. When students were given the free response question Q2, the most common helpful aspect cited by students was related to the improvement of their learning (Box 2, Table 2). An unexpected benefit to guided heads-up activities observed by the instructors was how rapidly missing information and misconceptions were identified and addressed within the groups. For example, students who used technical language incorrectly (confusing hydrophobic and hydrophilic) or gave a definition when they could not remember the technical term ("the functional group with a carbon and two oxygens") were corrected by their teammates during the game or immediately following the end of that round. Students helped one another fill in knowledge gaps, and the instructors observed that, unsurprisingly, students paid careful attention to their peers' feedback. Pairing in-class time for a guided heads-up activity with a full-class discussion postactivity provided additional opportunities for students to reflect on their own knowledge compared to that of their peers. This postactivity reflection also can be used as a time to remind students of the goals of the activity's guided approach and reinforce the benefits of effective group study. For example, when the guided heads-up activity was used in CHM 241, the instructors circulated around the lecture hall to observe the groups. When groups were at stopping points, they were asked to comment on which card was the most challenging in the set. This impromptu interaction provided surprising answers. Once all groups completed the activity, a full-group debrief was held to discuss the overall activity and review the correct answers to the cards the students identified as the most challenging. Many students informally commented after class that the combined approach of working through the material with their peers and then going over the trouble spots as a class helped them improve their understanding of the course material.

Statements S3−S8 yield insight into the students' perceptions about the effectiveness of the guided heads-up activities as a study strategy and for understanding the course material. While students reported good agreement with S4, that guided heads-up activities (HAs) are effective approaches to reviewing course material, the response was not as strong as the response for S6 ("HAs helped me improve my study skills"). When asked to agree or disagree with S3, "The HAs helped me understand the course material better", 82% of all student respondents agreed or strongly agreed with the statement.

The main guidance of the approach is provided through the required clue order. Student perception of clue order was evaluated through two of the Likert-type statements (S7 and S8) and free responses (Box 2). Overall, students agreed that the clue order helped with prioritizing and understanding the course material (S7 and S8). In the free responses, one student said that the guided heads-up activities were "less memorization and more brain mapping." Another representative comment related to clue order stated the following: "the details and order of how to approach... lets you know the importance."

Student−Student Interactions

The conversation that occurs between the card holder and clue givers is central to student engagement and learning. While students no doubt learn from their instructors and on their own, social interactions can promote the construction of new knowledge through reflection on previous learning and understanding.[48−50] The group work nature of the activity requires that students work together, but it was not known if students would find the group discussion part of the activity appealing. In fact, 20% of responses described group work as the most helpful part of the guided heads-up activities, while 15% of responses cited oral communication as being most

Box 2. Free response questions

Q1. If you did not use heads-up activities outside of class, please explain why not. If you did use them, please explain why you chose to, how many times you used them, and how you used them (on your own, with classmates, or with others).

Q2. What was the most helpful aspect of the heads-up activities?

Q3. What could be improved about the heads-up activities? Feel free to comment broadly and/or about a specific heads-up activity.

Q4. Which courses, if any, would benefit from heads-up activities, assuming the content matched course content?

Q5. Please share any additional feedback you have about this type of activity.

helpful (Table 2). A representative response described the importance of group conversation: "having to explain terms to each other helps grasp if you are really saying it correctly." Many student comments described the key role of collaboration in their discussions.

Encouraging Metacognition

A secondary theme that emerged in free response questions was the benefit of guided heads-up activities for evaluating one's learning. Statement S10 probed the connection between these activities and metacognition. With an average agreement value of 4.5, this was among the strongest agreement for all three classes surveyed. Within the 70% of free response questions that were coded as relating to learning as a helpful aspect, 24% (or 17% overall) mentioned metacognition. One student explained the benefits of guided heads-up activities as, "the nature of the game naturally promotes verbalization of one's thought process [when] articulating clues, revealing everyone's held misconceptions and unique insights." Another student shared that it "helps me better understand how to study."

Of course, we as instructors would like all of our students to routinely reflect on their own learning. It could be that the incorporation of guided HAs both earlier in the semester and throughout may encourage increased metacognition activity by students.

Student Recommendations

Students were asked what could be improved about the guided heads-up activities (Table 3). Approximately one-third of respondents stated that no aspect of the guided heads-up activities needed improvement. The responses that did provide a suggestion fell into seven common themes related to activity content or mechanics. For example, some students suggested providing more time during class for the activities, and others encouraged use of them earlier in the semester. Both of these suggestions could be addressed with planning by faculty. Others pointed out that thicker paper should be used for the cards because an observant participant could read the word on the card through the paper when it was on the top of the deck of cards. Using a cover sheet over the clues, thicker paper like card stock, or lighter ink colors could address this concern. A later iteration of this activity using light blue card stock and light gray font color resolved this issue. A small number of comments suggested increasing the competition aspect of the activity by providing bonus points or prizes. Having bonus points attached to the activity did not appear to be necessary; the instructors observed that students were sufficiently self-motivated to give the activities true effort.

Several students suggested making the activity more available outside of class. While students were given the option to take the activity with them, the majority of students reported in Q1 that they did not use the activities outside of class. The main reasons cited for not using them outside of class was lack of availability of the card sets and poor time management by the students. A small number of students indicated that they would not have used them even if available. One student supported the use of guided heads-up activities outside of class, saying, "this would really encourage outside of classroom collaboration/studying between students, which I have found to help me a great deal in studying for exams." Some students pointed out that each group only had one set in class, so they were not all able to take the activity with them. These availability concerns could be addressed if the guided heads-up file was made available to students on the course management system, allowing students to print out copies on their own.

The most common area for improvement suggested by students was related to making the activity easier (23% of respondents). Suggestions for making the activities easier included removing the clue order requirement or changing a specific aspect of the activity's content, such as giving the chemical structures in addition to names or writing out instrument acronyms. Although having the structure of an amino acid on the card may help prompt the clue givers, the design of the activity takes into account that it requires all participants to recall the characteristics of the molecule in the moment. Having to synthesize that knowledge in order to give a good clue is an additional challenge for the clue giver, while the student answering has to be able to select and integrate that information to come to the correct answer.

With respect to the clue order requirement, one student wrote, "The heads-up material was not efficient for my learning style. Having to do the clues in order wasn't helpful because sometimes it was the last clue in the order that helped me know the answer." This comment highlights two observations

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already made by the instructors and echoed in the literature:[51,52]

1. Students can be resistant to new, more challenging learning methods.
2. It is important to struggle with and practice with unfamiliar material rather than only reviewing mastered material.

It is uncomfortable to review material that is not easy or that one makes mistakes on. However, both are essential activities for growth and improved learning. Additionally, many of our students still view learning as fully occurring during recall and other rote memorization activities; they found the game design of not discovering the answer on the first clue frustrating. Thus, despite the comments about making the guided heads-up activity easier by removing or relaxing the clue order requirement, we believe that this very guidance is what makes this an effective activity. Some students are resistant to discussing concepts with their peers, especially concepts with which they are not completely familiar, but encouraging practice with low-stakes opportunities like guided heads-up activities may help these students better understand the benefits of group discussion.

Additional Recommendations

It is notable that 20% of respondents suggested that the guided heads-up activities could be improved by making additional guided heads-up activities on more topics (Table 3). Students were asked in Q4 to list courses that would benefit from the incorporation of guided heads-up activities. Unsurprisingly, suggested courses tended to reflect the science courses the students had completed previously, with the most common suggested courses being organic chemistry, general biology, and additional upper-level biology courses. Interestingly, courses outside of chemistry and biology were suggested, too, including history, philosophy, and foreign languages.

Our general recommendation for instructors seeking to use this activity in their own classes is to consider what students should be getting from the activity. Guided heads-up activities work best for topics that have a number of overlapping concepts that students may confuse. Clues should be written to highlight these overlapping concepts and to lead students to develop the descriptive tools to navigate them.

The discussion observed in the group setting was helpful to promote student−student interactions and provided an example of group study that can be applied to other courses. Following game play with a full-class debrief helps address activity-identified class misconceptions, giving students additional formative feedback about their progress with course material.

An unanticipated potential pitfall to guided heads-up activities is that students will get stuck if group members are not caught up on course material. While we did not observe this directly in class, one student pointed this out in the post-semester survey, writing, "I think one potential issue you could have is students who aren't as familiar with the material or student(s) who are struggling [may] feel inadequate/self-conscious. It could potentially create a discouraging learning environment and hinder student success." This thoughtful reflection suggests a non-observed but certainly possible outcome. This could be addressed by giving students notice in a prior class meeting that an upcoming activity will require them to verbally communicate and synthesize course material. This could provide students with the encouragement necessary to study up on material and may even lead to improved outcomes when the guided heads-up activity is implemented.

CONCLUSION

Guided heads-up is a useful tool to highlight the overlap of material, to promote student interactions, and to identify misconceptions. The game design is especially helpful to model for students' areas where recall is not sufficient to understand the material. Through a low-stakes conversation with their peers in a fun game environment, students discern how course concepts overlap, identify areas for improvement, and develop a better understanding of the material. Student-driven development of new guided heads-up activities for a class could also be a valuable teaching and learning exercise, as students would need to consider how material is grouped, organized, and related.

The student feedback summarized herein supports instructor observations that guided heads-up activities are an engaging, productive strategy to help students sort and synthesize material in chemistry and biochemistry courses. A required clue order helps students move beyond memorization to higher-order learning modes. These activities have wide applicability in a range of classes, and instructors are encouraged to consider where they might adapt this approach to their own course material.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available at https://pubs.acs.org/doi/10.1021/acs.jchemed.9b00904.

Amino acid activity rules (PDF)
Amino acids activity cards (PDF)
Techniques activity rules (PDF)
Techniques activity cards (PDF)
Metabolism 1 activity rules (PDF)
Metabolism 1 activity cards (PDF)
Metabolism 2 activity rules (PDF)
Metabolism 2 activity cards (PDF)

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Notes

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