Patterns in Classroom Activities for Process Oriented Guided Inquiry Learning (POGIL)

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There is a global need to improve the accessibility, quality and effectiveness of education. A variety of evidence-based instructional strategies have been developed, including Process Oriented Guided Inquiry Learning (POGIL). In POGIL, student teams work on classroom activities specifically designed to guide them to understand key concepts and develop key process skills, with active facilitation by a teacher. This paper describes POGIL and some advantages of using patterns with POGIL. This paper also presents patterns for the structure and elements of POGIL activities, including models for learning cycles (chart or graph; game or puzzle; terms and definitions), and ways to categorize questions (Bloom's Taxonomy; directed, convergent, and divergent; explore, invent, and apply). Pattern languages for POGIL should help us to better identify and understand elements and factors that make an activity effective (or not), and provide a vocabulary to promote higher-level discussions among POGIL practitioners, to help them develop, review, and facilitate classroom activities. Similarly, documenting POGIL patterns should help other educators to understand practices that are effective, wide-spread, and well understood in the POGIL community.

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1. INTRODUCTION

There is a global need to improve the quality and effectiveness of education, particularly in science, technology, engineering, & mathematics (STEM) disciplines, and to expand access for people from under-represented populations. Research in education, psychology, and neuroscience (e.g. Committee on Developments, 2000; Zull 2002) shows that motivation and learning are enhanced when learners: receive prompt, regular feedback; work in teams; combine and connect content, process, and multiple representations; create or construct their own understanding; and reflect on their processes and progress. Similarly, the ICAP model (Chi and Wylie, 2014) describes how learning outcomes increase as the learning environment shifts from *passive*, to *active*, to *constructive* (students create their own understanding), to *interactive* (students collaborate to construct understanding). A variety of evidence-based instructional strategies build on these principles (e.g. Eberlein, Kampmeier, Minderhout, Moog, Platt, Varma-Nelson, and White, 2008; Prince and Felder, 2007). Many include elements that particularly help students from underrepresented populations (e.g. Chávez, 2008; Chávez, 2011; Finley and McNair, 2013; Kuh and Schneider, 2008). For example, active engagement increases learning; student engagement and positive attention from teachers reinforce each other; and collaborative learning helps students develop self-efficacy, self-regulated learning, and a malleable view of intelligence (Boykin and Noguera, 2011).

1.1 Patterns

Given the variety of evidence-based instructional strategies, it is useful to have rich, subject-independent vocabularies to describe their elements and structures. It is also useful to have schemas to help abstract, analyze, and generalize learning activities, and to help compare and contrast activities. One effective approach is to use *patterns*, which are detailed descriptions of effective practices. For example, "light on two sides of every room" is specific enough to be useful, but can be adapted to many contexts.

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Patterns were introduced for architecture (Alexander, Ishikawa, and Silverstein, 1977), and have been adapted in other areas, particularly software development (e.g. Fowler, 2002; Gamma, Helm, Johnson, and Vlissides, 1995). Pedagogical patterns have been described and used for 20 years (e.g. Anthony, 1996; Bergin, 2000), including patterns for active learning (Eckstein, Bergin, and Sharp, 2002b), broadening perspectives (Bergin, Eckstein, Manns, and Wallingford, 2001; Eckstein, Manns, Sharp, and Sipos, 2003), experiential learning (Eckstein, Marquardt, Manns, and Wallingford, 2001), feedback (Eckstein, Bergin, and Sharp, 2002a; Larson, Trees, and Weaver, 2008), flipped classrooms (Köppe, Niels, Bakker, and Hoppenbrouwers, 2016; Köppe, Niels, Holwerda, Tijsma, Van Diepen, Van Turnhout, and Bakker. 2015a; Köppe, Niels, Holwerda, Tijsma, Van Diepen, Van Turnhout, and Bakker, 2015b), lectures (Köppe and Schalken-Pinkster, 2013; Köppe and Portier, 2014; Köppe and Schalken-Pinkster, 2015; Köppe, 2015), and seminars (Fricke and Völter. 2000).

The description of a pattern can use different formats, but typically contains several elements. The pattern's *name* should be concise and evocative. The *context* describes situations in which a pattern may be relevant. The *problem* statement is supported by a description of *forces* that could influence the problem. The *solution* statement is supported by a description of *consequences*, and potential responses. Pattern descriptions often include further *discussion* and *examples*, and refer to other related patterns.

From a pattern perspective, each evidence-based strategy is a high-level pattern, usually composed of sub-patterns that might be shared with other strategies. For example, many strategies involve teams and classroom discussion. As we identify and document patterns, we develop a common vocabulary that helps us to better understand how to use and combine patterns.

The rest of this paper is organized as follows. Section 2 describes Process Oriented Guided Inquiry Learning (POGIL), including key concepts, history, research evidence, an example, and the potential benefits of patterns in POGIL. Section 3 presents some patterns for POGIL activities, and section 4 present patterns for POGIL activity models. Section 5 describes conclusions and some future directions. The appendix summarizes previously documented patterns that are particularly relevant for POGIL.

2. PROCESS ORIENTED GUIDED INQUIRY LEARNING (POGIL)

Process Oriented Guided Inquiry Learning (POGIL) is an evidence-based instructional strategy that is collaborative and constructivist (Moog, Creegan, Hanson, et al, 2006; Moog and Spencer, 2008). In POGIL, student teams work on specifically designed activities that guide them to discover and understand core concepts (the *guided inquiry*). At the same time, teams develop process skills, such as communication, teamwork, critical thinking, and problem solving (the *process oriented*).

POGIL activities are carefully designed to guide higher-level thinking and learning. Students answer a series of questions about models (e.g. diagrams, graphs, tables, code excerpts) to build deep understanding. The models and questions guide students through *Explore-Invent-Apply (EIA) learning cycles* (see Figure 1) to *explore* a model, *invent* their own understanding of a concept, and finally *apply* it in other contexts (Abraham, 2005). Questions are also categorized as *directed* (easily answered from the model or prior knowledge), *convergent* (most teams will reach the same answer, or one of a few answers), or *divergent* (teams may reach quite different answers). The models and learning cycles must be explicit, robust, and well-aligned, and they distinguish POGIL from worksheets that students complete alone or in small groups.

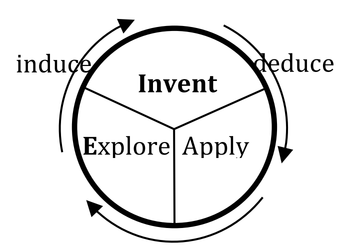

Figure 1: The EIA Learning Cycle

POGIL uses teams of 3-4 students who work together; team discussion improves understanding for all members. To encourage full participation, teams stay together for weeks or months, but each member has a different role each day. For example, the *manager* makes sure everyone focuses, participates, and understands the activity, the *recorder* takes notes for the team, and the *speaker* presents results to the rest of the class.

In POGIL, the teacher's role shifts from disseminator ("sage on the stage") to facilitator of learning ("guide on the side"), who continually assesses when and how to guide teams as they work (Hanson, 2006). Thus, the teacher might use probing questions or short whole-class discussions to ensure that all teams reach the correct answers. The teacher monitors the rate of progress and team interactions, and supports teams that are moving too slowly (or too quickly). In small classes or labs the teacher can carefully design and monitor teams; in large classes, teams may use tools (e.g. classroom response systems, a.k.a. "clickers") to facilitate interactions.

POGIL was originally developed in college general chemistry courses (e.g. Farrell, Moog, Spencer, 1999; Moog, Creegan, et al 2006; Moog and Farrell, 2008), and is now used across STEM disciplines, including engineering (Douglas and Chiu, 2009; Rutten 2012), computer science (Kussmaul, 2012; Hu and Shepherd, 2013; Hu and Avery, 2015), mathematics (Lenz, 2014), and physiology (Vanags, Pammer, and Brinker, 2013), and at a variety of institutions including minority-serving and community colleges (e.g. Higgins 2013).

Typically, POGIL increases pass rates (grade of A, B, or C) (e.g. Farrell, Moog, and Spencer, 1999; Straumanis, Simons, 2008). POGIL activities on team communication helped students in a software project course to understand the importance of communication in real software projects (Kumar and Wallace, 2014). A survey of CS faculty who use POGIL found that students learn more, are more engaged and active, and develop better communication skills (Hu, Kussmaul, Knaeble, Mayfield, and Yadav, 2016).

2.1 Sample POGIL Activity

This section describes a POGIL activity used on the first day of an introductory CS course to show students that CS is about analyzing problems and solutions, not just software tools or language syntax (Kussmaul, 2016a). This sample activity is also the basis for some of the examples in sections 3 and 4.

In the first learning cycle, the *model* is a set of instructions for a two-player game where Player A picks a number from 0 to 100 and then answers “too high” or “too low” as Player B guesses (see section 4.2). Questions prompt the student teams to answer some initial questions and play the game a few times (*explore*). Next, teams identify strategies (algorithms) for player B, such as “guess at random”, “count up by 1s”, “count up by 10s and down by 1s”, or “divide the range in half” (i.e. binary search). As the teams work, the teacher circulates to listen, answer questions, and prompt teams to improve their descriptions. When most teams have 3-5 strategies, the teacher has each team describe one to the class; this increases student confidence, and ensures that all teams have a variety of strategies. Next, teams rank their strategies by number of guesses (speed) and how hard they are to describe (complexity), and then compare or graph the rankings. This leads them to discover (*invent*) the common tradeoff between speed and complexity. To *apply* this concept, teams identify other situations with similar tradeoffs, and share them with the class.

In the second learning cycle, the *model* is the set of strategies, which teams *explore* to determine the maximum (worst case) and average number of guesses for each strategy. They start with a range of 100 values, then consider a range of 1000 values, and finally the general case of N values, leading them to *invent* the concept of O()-style complexity analysis, which they then *apply* to other situations (e.g. as homework). As teams work, the teacher observes, asks or answers questions, and helps teams identify and solve problems. For example, some teams notice that the average is often half of the maximum, and assume (incorrectly) that this is always true. Rather than tell students that an answer is right or wrong, the teacher might have two teams compare answers and resolve any disagreements, or have a team play the game several times to test for the predicted behavior.

2.2 Patterns and POGIL

The POGIL community could benefit from pattern perspectives, both for activity authoring and for classroom facilitation. Writing POGIL activities is a complex, time consuming process that is similar in many ways to software development. Each activity is designed to achieve specific learning objectives, but activities use learning cycles, models, and questions in similar ways, and experienced authors combine these elements effectively and efficiently. A POGIL teacher must plan carefully to form and guide teams, stay on schedule, and help students achieve learning objectives. However, a teacher must also be ready to respond to the unique needs and opportunities in a particular class, and use different approaches for pacing and to “report out” between teams. Thus, pattern languages for POGIL should help us to better identify and understand the elements and factors that make an activity effective (or ineffective), and provide a vocabulary to promote higher-level discussions among POGIL practitioners, to help them develop, review, and facilitate classroom activities. Similarly, documenting POGIL patterns should help the pattern community and other educators to understand practices that are effective, wide-spread, and well understood in the POGIL community.

The Appendix summarizes documented pedagogical patterns that are relevant for POGIL, including patterns related to: POGIL principles and philosophy (*Table 5*), the design of POGIL activities (*Table 6*), and facilitation in a POGIL classroom (*Table 7*). In each table, the first column lists the pattern, source(s), and a brief “patlet” description; the second column describes how the pattern and POGIL practices are related. These remarks include references to patterns presented in this paper (summarized in *Table 1*), and to potential patterns that are not yet documented (*Table 4*), which are shown graphically in *Figure 5*.

Table 1: Patterns (with section number) described in this paper, listed in alphabetical order. See *Table 4* for possible future patterns.

Section & Pattern	Section	Patlet
CLIMB BLOOM'S TAXONOMY	3.3	Both within and across activities and assignments, progress from lower levels (remember, understand) toward high levels (apply, analyze, evaluate, create) of Bloom's Taxonomy.
COMPARE ANSWERS	3.4	Have teams compare their answers with other teams and resolve disagreements.
DCV QUESTIONS (DIRECTED, CONVERGENT, & DIVERGENT)	3.2	Use a variety of question types, including *directed*, which are based on prior knowledge or given information; *convergent*, which require student effort and one (or a few) correct answer; and *divergent*, which also require effort and may have varied answers.
EIA LEARNING CYCLES (EXPLORE-INVENT-APPLY)	3.1	Use learning activities that include EIA LEARNING CYCLES where students answer questions that guide them to *explore* a model, *invent* their own understanding of a key concept, and then *apply* that understanding in another context.
MODEL: CHART OR GRAPH	4.1	Use EIA LEARNING CYCLES where the model is a chart or graph to help students understand concepts based on data, and to help students develop skills in information processing.
MODEL: GAME OR PUZZLE	4.2	Use EIA LEARNING CYCLES where the model is a game or puzzle that captures the essence of the problem in a COLORFUL ANALOGY that avoids extraneous details.
MODEL: TERMS & DEFINITIONS	4.3	Use EIA LEARNING CYCLES where the model is a set of terms and definitions that are not conceptually difficult and that students may need to refer to in the future.

3. PATTERNS FOR POGIL ACTIVITY DESIGN

This paper introduces 7 patterns (summarized in *Table 1*) related to POGIL activity design, and Section 5 (*Table 4*) briefly describes 18 potential patterns that are not yet documented. Patterns can describe various elements of POGIL activities, including the structure of questions, sequences of questions for a model, and sequences of models in an activity. Section 3 describes 4 general patterns for POGIL activity design, and section 4 describes 3 patterns for POGIL activity models. We use an adapted Alexandrian format (Alexander, Ishikawa, and Silverstein, 1977) consisting of: the *name*, the *context*, a separator, the *problem* (in bold) and *forces*, another separator, the *solution* (in bold) and *consequences*, followed by discussion and examples, including sample learning cycle questions for the model patterns in Section 4. The pattern name appears in small caps to highlight cross-references to other patterns.

This paper does not describe patterns for POGIL classroom facilitation, which requires planning but also responds to the pacing and needs of a particular classroom and its student teams. POGIL facilitation also has more in common with other forms of classroom interaction, for which there are many existing patterns and other excellent resources (e.g. Angelo and Cross 1993; Barkley 2009; Barkley, Major, and Cross, 2014; Bean, 2011). (Note that these references are pattern catalogs, in some ways.)

3.1 Activity Pattern: **EIA (Explore-Invent-Apply) Learning Cycles**

Context: Students need to have a deep understanding of key concepts, and particularly THRESHOLD CONCEPTS that are both troublesome and transform student understanding (Meyer and Land, 2003; Meyer and Land, 2005), so that a lack of understanding can prevent student progress.

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Problem & Forces: **In most subjects, there are core THRESHOLD CONCEPTS that students may find difficult but must understand deeply in order to move forward.** You feel pressure to "cover" more content in courses, so you try to "teach" more material using lectures, notes, and slides, as assigned readings, or assignments outside of class. However, students find it more difficult to identify, focus on, and truly understand all of the content. Students must also develop important *process skills* (also called *professional skills* or *soft skills*) such as communication, critical thinking, problem solving, and teamwork. However, many faculty feel they do not have the time or expertise to teach such skills.

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Solution & Consequences: **Therefore, use activities with "EIA" *learning cycles* where students answer questions that guide them to *explore* a model, *invent* their own understanding of a key concept, and then *apply* that understanding in another context** (Abraham, 2005; see Figure 1). Choose or develop learning activities that help students develop THRESHOLD CONCEPTS efficiently, since an EIA activity takes more class time than a lecture to "cover" the same content. Actively monitor team progress to ensure that all students participate and reach the correct understanding. Students with a better understanding of THRESHOLD CONCEPTS will be more able to relate and apply them in other contexts and learn other content more quickly (e.g. Farrell, Moog, and Spencer, 1999; Straumanis, Simons, 2008). EIA activities also help students develop process skills. You could attend professional development workshops to help you adjust your teaching style. Spend part of a class explaining why evidence-based approaches are more effective, and show students relevant data on learning outcomes, since some students may object to the effort required or complain that you "aren't really teaching".

Discussion: EIA LEARNING CYCLES are based on the biology of how people learn (e.g. Zull, 2002), are similar to the scientific method, and are a form of COLLABORATIVE KNOWLEDGE CONSTRUCTION that PREFERS WRITING and prompts students to express concepts in their OWN WORDS. Thus, EIA is related to ACTIVE STUDENT, TRY IT YOURSELF, CHALLENGE UNDERSTANDING, MISCONCEPTION ASSESSMENT, and REFLECTION. Carefully consider LEARNING OUTCOMES and use CONSTRUCTIVE ALIGNMENT to choose effective learning cycles. Use CAREFULLY CRAFTED QUESTIONS to guide students. Exploration questions often have SIMPLE ANSWERS, and application may include OPEN ENDED QUESTIONS. Inventing a concept from observations requires inductive thinking; applying the concept in another context requires deductive thinking. Students simultaneously develop process skills, so EIA is also related to MULTI-PRONGED ATTACK.

Examples: The sample activity (section 2.1) contains two EIA LEARNING CYCLES. The first uses a children's game as the model and guides students to invent a set of strategies and tradeoffs between them. The second uses the strategies as the model and guides students to invent and apply key concepts in O()-style algorithm analysis.

3.2 Activity Pattern: **DCV Questions (Directed, Convergent, & Divergent)**

Context: You are designing an activity or assignment with questions for students to answer.

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Problem & Forces: **Questions can guide students in many ways, and it can be difficult to design the right set of questions.** If there are too many questions, students may get discouraged; if there are too few, students may miss key connections. If questions are easy, students gain confidence but might get careless; if questions are difficult, students might struggle and get discouraged. Students often want the "correct answers", but also need to consider open-ended questions to CLIMB BLOOM'S TAXONOMY. With a mix of easy, hard, closed, and open questions, students may struggle to allocate the right time and effort to each question.

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Solution & Consequences: **Therefore, use a combination of DCV (directed, convergent, and divergent) questions.** *Directed questions* are based on prior knowledge or provided information and are rarely difficult to answer. *Convergent questions* require more effort, but most students or teams will reach the same answer, or one of a few answers. *Divergent questions* also require more effort, but students and teams will often reach very different answers and explore broader issues. Help students identify the effort and sort of answer needed with cues such as wording (e.g. "recall", "look up", "jot down", "discuss and agree"), the space for an answer (e.g. cell in a table, blank line to fill in, or half a page) or a suggested amount of time (e.g. 1 min, 5 min).

Discussion: DCV QUESTIONS are related to but distinct from the phases in EIA LEARNING CYCLES. *Exploration* questions are often *directed* with a SIMPLE ANSWER, but may be *convergent* or even *divergent*; *invention* questions are often, but not always, *convergent*; and *application* questions are usually either *convergent* or *divergent,* OPEN ENDED QUESTIONS. *Directed* and *convergent* questions are useful for MISCONCEPTION ASSESSMENT; *convergent* and *divergent* questions are useful to CHALLENGE UNDERSTANDING.

Examples: The sample activity (section 2.1) begins with *directed* questions to ensure that students understand the rules, such as "How many different responses can player A give?" and "How does the game end?" Defining possible strategies seems *divergent*, but is usually *convergent*, since most teams reach a similar set of strategies. Describing other examples of the speed-complexity tradeoff is *divergent*. Finding the maximum and average number of guesses for each strategy is *convergent*, since it requires effort but there is a single correct answer. In section 4, each POGIL activity model pattern contains a set of sample DCV QUESTIONS.

3.3 Activity Pattern: **Climb Bloom's Taxonomy**

Context: You want students to demonstrate knowledge, skills, and attitudes in a variety of ways beyond rote memorization. *Bloom's Taxonomy* (Bloom, Engelhart, Furst, Hill, and Krathwohl. 1956; Anderson and Krathwohl, 2001) organizes educational learning objectives into three domains: *cognitive* (knowledge-based), *affective* (emotive-based), and *psychomotor* (action-based). Each domain is organized into levels; the cognitive levels are: *1: Remember*; *2: Understand*; *3: Apply*; *4: Analyze*; *5: Evaluate*; *6: Create*.

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Problem & Forces: **Lectures and tests often focus on lower levels (remember, understand) but you need to prepare students for future work at higher levels (apply, analyze, evaluate, create).** Students do not always remember and understand content they were taught previously, which makes it more difficult to use or build on that content later. Some teachers believe that beginning courses should focus on lower levels, and advanced courses should focus on higher levels, but this can lead to beginning courses that encourage rote learning, are less engaging, and do not prepare students for advanced courses.

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Solution & Consequences: **Therefore, progress from lower to higher levels of Bloom's Taxonomy, both within and across learning activities and assignments.** Although beginning students do not yet have the knowledge, skills, and attitudes of advanced students, every course, activity, and assignment is an opportunity to help students develop higher-order skills.

Discussion: CLIMB BLOOM'S TAXONOMY occurs naturally in EIA LEARNING CYCLES and with DCV QUESTIONS. A cycle usually starts with *directed exploration* questions that prompt students to *remember* prior knowledge or notice features in the model, which is useful for MISCONCEPTION ASSESSMENT. Next, *convergent* questions guide students to use this knowledge and *understand* new concepts. Finally, *convergent* and *divergent* questions prompt students to *apply* their new understanding in other contexts, which may involve *evaluation* or *creation*. Thus, lower level questions are useful for MISCONCEPTION ASSESSMENT, while higher level questions are useful to CHALLENGE UNDERSTANDING, to TRY IT YOURSELF, and for REFLECTION. A POGIL activity often contains several models that are increasingly complex or abstract, guiding students to higher levels of cognitive activity.

Examples: The sample activity (section 2.1) contains two EIA LEARNING CYCLES that each CLIMB BLOOM'S TAXONOMY, and the second cycle requires more analysis and evaluation than the first.

3.4 Activity Pattern: **Compare Answers**

Context: Students are answering the same questions and you want them to be confident in their answers.

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Problem & Forces: **Students need FEEDBACK to know if their answers are correct, but may be careless if they know you always give the "right" answer.** Students work at different speeds - some are more deliberative; some have more background, ability, or motivation. However, it is usually better if most of the class progresses at similar rates; if you move too quickly some will be unprepared, but if you move too slowly some will be idle and you may run out of time. In large classes, it may not be feasible to check on everyone, or to engage everyone in one discussion. Thus, teachers and students need scalable approaches for FEEDBACK and pacing.

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Solution & Consequences: **Therefore, have students compare answers with each other**, in a form of PEER FEEDBACK. This also provides MISCONCEPTION ASSESSMENT to help you focus on the most difficult or confusing questions. When students explain their answers, they improve their understanding and their communication skills (see INTERACTIVE CONSTRUCTIVE STUDENT). COMPARE ANSWERS helps manage classroom pacing – students that finish quickly can help others, or move on to other tasks. COMPARE ANSWERS scales well for large classes, particularly with GROUP WORK and SELF-MANAGING TEAMS (see below).

Carefully choose when and how to COMPARE ANSWERS, since it takes longer than just giving answers to students. Some students expect you to be the authority, and don't think they should be able to identify correct answers themselves; remind them that as professionals they must solve problems with unknown answers.

Discussion: COMPARE ANSWERS can be especially effective with GROUP WORK. This can be done in several ways:

- Have each student answer the question(s) individually, then COMPARE ANSWERS within their team and reach consensus. Then have one student from each of several teams SPEAK FOR TEAM to COMPARE ANSWERS with the whole class to REPORT OUT. (This is related to THINK...PAIR…SHARE.)
- Instead of answering individually, have SELF-MANAGING TEAMS answer questions together, then have a few students from different teams SPEAK FOR TEAM to COMPARE ANSWERS and REPORT OUT.
- Instead of having a few students SPEAK FOR TEAM to REPORT OUT, have pairs of teams meet or have each team send an ambassador to another team to SPEAK FOR TEAM and COMPARE ANSWERS. This can be more difficult to organize, but can scale well for larger classes.
- If some teams finish quickly, have them meet or trade ambassadors to COMPARE ANSWERS and resolve disagreements. Once their answers are correct, send them to help slower teams.
- Instead of waiting for the slower teams, allow teams that finish quickly and COMPARE ANSWERS to move on to the next questions. This might be most appropriate for difficult activities, laboratory periods, or when teams are working asynchronously.

Examples: The sample activity (section 2.1) includes several opportunities to COMPARE ANSWERS. When most teams have identified several strategies, the teacher asks each team to describe one of their strategies, so that all teams identify a rich variety. When teams rank the strategies and plot their rankings, the teacher might have each team (or a few teams) sketch or describe their rankings for the class. Later, when teams are finding the number of guess needed, the teacher could have each team compare answers with another team.

4. PATTERNS FOR POGIL ACTIVITY MODELS

As described above, a POGIL activity targets specific LEARNING OUTCOMES and contains a set of models with CAREFULLY CRAFTED QUESTIONS that guide students through COLLABORATIVE KNOWLEDGE CONSTRUCTION using GROUPS WORK. Models take many forms, including ACQUAINTANCE EXAMPLES, COLORFUL ANALOGIES, and MISSION IMPOSSIBLE. Thus, we can describe common models as patterns with their attributes, advantages, and disadvantages; common variations; and typical DCV QUESTIONS. A catalog would include model patterns that could be used across many disciplines, including the models described below, as well as patterns based in specific disciplines – for example, in computer science this might include API listings, code listings, flow charts, and various UML diagrams.

The following subsections briefly describe three patterns for activity models; it seems likely that these are specializations of a higher level pattern for POGIL models (not yet documented). We may also find patterns that describe how to combine models in an activity. An activity might use similar models, such as a set of graphs or diagrams that gradually add complexity through a CONSISTENT METAPHOR. An activity might also use different models for variety and to focus attention on different aspects of the concept; for example, the sample activity (section 2.1) starts with a game, and then a list of strategies to play the game.

4.1 Model Pattern: **Chart or Graph**

Context: You teach subjects and concepts based on the analysis and interpretation of experimental data. Students will understand and remember the concepts better if they study and analyze the data. A chart or graph can present complex information succinctly, and in a form that students are likely to encounter in lab activities, other courses, and the workplace.

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Problem & Forces: **Students must understand and be able to identify relationships based on experimental data.** However, students often lack the skills, experience, or time. Thus, teachers may be reluctant to use activities or assignments where students must perform such tasks.

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Solution & Consequences: **Therefore, use a chart or graph as the model for EIA LEARNING CYCLES.** Questions will guide students to *explore* the chart or graph and notice things that an expert would see, and then to *invent* their own understanding of the concept, which they then *apply*. This takes longer than a lecture or reading on the concepts, but students will understand the concepts better and be better able to apply them in the future. This practice with information processing and critical thinking will help students develop skills to work more effectively with a CHART OR GRAPH in the future.

Discussion: The chart or graph can use real or simulated data. MODELS WITH AUTHENTIC DATA may appeal to students, but may also contain complexities, noise, or outliers that can distract students. MODELS WITH SYNTHETIC DATA give more control to the activity author to adjust variability, construct special cases, and so forth. Use *directed* questions to *explore* the model and notice what an expert would notice (e.g. axes, scales, legends). Use *convergent* questions to *explore* further and *invent* their own insights and understanding of key concepts. Use *convergent* and *divergent* questions to *apply* the concepts in other contexts.

Figure 2: Sample Models - Charts or Graphs.

Examples: *Figure 2* shows a histogram (left) and a scatter plot (right) fitted with a straight line. Note that both are clearly labeled (e.g. axes and scales) and avoid potentially distracting information.

Typical DCV QUESTIONS (D=Directed, C=Convergent, V=Divergent)

- D: *What information is shown on each axis? What units are used?*
  Prompts students to examine the axes, which some might not do otherwise.

- D: *What is the range (min & max) of values on each axis? How many data sets are shown?* Prompts students to examine the data and legend, etc.
- C: *Which points might be considered outliers?* Prompts students to look at the distribution of values.
- C: *Describe the general shape of the data* (e.g. linear, quadratic, exponential, logarithmic).
- C: *Draw a best fit line through the data and estimate its slope*.
- C: *Predict how this graph would look if <SOMETHING IS CHANGED>.* Prompts students to apply the current concept to a modified context.
- V: *What factors might have contributed to the outliers?* Prompts students to consider sources of error.
- V: *Where have you a similar relationship before?* Prompts students to relate this to another context.

4.2 Model Pattern: **Game or Puzzle**

Context: You teach subjects where realistic applications of concepts are not always obvious or may be too complex for students.

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Problem & Forces: **You need engaging examples that contain important elements of a concept or problem but minimize distractions.** Patterns like EIA LEARNING CYCLES, SOLUTION BEFORE EXAMPLE, and MISSION IMPOSSIBLE develop abstract concepts from examples. A MODEL WITH AUTHENTIC DATA can motivate students, but can also discourage them if it is too complicated, or involves concepts that are unfamiliar or distracting. A MODEL WITH SYNTHETIC DATA focus on the relevant characteristics, but may seem unrealistic or boring to students.

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Solution & Consequences: **Therefore, use a game or puzzle that captures the essence of the problem as the model for EIA LEARNING CYCLES.** Questions will guide students to *explore* the game or puzzle and notice things that an expert would see, and then to *invent* their own understanding of the concept, which they then *apply*. This will take more time than a lecture or reading about the concepts, but an appropriate game or puzzle can help students to understand concepts apply them more effectively in the future. Thus, this approach can be more engaging than a MODEL WITH SYNTHETIC DATA and more manageable than a MODEL WITH AUTHENTIC DATA.

Discussion: A GAME OR PUZZLE can be familiar, interesting, or engaging for students – a COLORFUL ANALOGY. If they try to play the game or solve the puzzle themselves, it may be easier for them to consider effective strategies or to apply the same concepts in other contexts, including later models in the same activity. Use a GAME OR PUZZLE when it captures key elements of the concept being developed, particularly when a more realistic example might be too complicated or distracting, at least at first. Avoid games or puzzles with too much extraneous information. It might help to have several models with successively more complex versions. Consider that students have different cultural contexts, and may not be equally familiar with a given GAME OR PUZZLE, even if you consider it an ACQUAINTANCE EXAMPLE. Thus, describe it in enough detail to be clear to someone unfamiliar with it.

Examples: *Figure 3* (left) shows a game that is part of an activity (Kussmaul, 2016a), described in section 2.1, on design tradeoffs and algorithm analysis used early (often the first day) in an intro CS course to introduce students to several important CS concepts. *Figure 3* (right) shows a puzzle that is part of a POGIL activity (Kussmaul, 2016b) on search strategies. Questions guide student teams to explore the possible moves, representations for those moves, a tree of accessible states for the puzzle, and different strategies to search that tree (*depth first*, *breadth first*, *best first*, etc.). The same activity uses several other puzzles (e.g. magic square, eight Queens) to apply concepts in other contexts, and to invent related concepts.

Hi-Lo is a child's number guessing game with simple rules.

a. There are two players – A and B.
b. Player A thinks of a number from 1 to 100.
c. Player B guesses a number.
d. A responds with "too high", "too low", or "you win".
e. B and A continue to guess & respond until B wins.

1	**2**	**3**
4	**5**	
7	**8**	**6**

An **8-puzzle** has a 3x3 board with 8 tiles and 1 space. The goal is to move one tile at a time (up down, left or right) until the tiles form a familiar picture or sequence.

Figure 3: Sample Models – Game (left) and Puzzle (right).

Typical DCV QUESTIONS (D=Directed, C=Convergent, V=Divergent)

- D: *How many moves are possible from <POSITION>?* Prompts students to study the rules.
- D: *Play the game with your team, and write down any questions or concerns*. Prompts students to study and become familiar with the rules before answering later questions.

- C: *Describe or show a sequence of moves starting from <POSITION>.*
  Guides students to use their understanding of the rules, which might help to develop a new concept.
- C,V: What would happen if <*RULE IS CHANGED*>? Prompts students to apply concepts in other contexts.

4.3 Model Pattern: **Terms & Definitions**

Context: Most academic disciplines and subjects involve specialized vocabulary, including terms unfamiliar to most students, or familiar terms used in unfamiliar ways. Some terms involve concepts that are new and/or difficult, while other terms involve concepts that are familiar or easy for students to master.

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Problem & Forces: **Students must understand a set of terms and definitions, but avoid doing do.** Some students skim over terms and definitions, particularly if they are unfamiliar or presented without context or motivation. Some assume that the meanings will become apparent from context. Some plan to memorize everything immediately before a test (and then promptly forget them).

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Solution & Consequences: **Therefore, use a set of terms and definitions as the model for EIA LEARNING CYCLES.** Questions will guide students to *explore* the definitions, and then to *invent* their own understanding of the concept, which they then *apply*. This motivates students to carefully read and understand the definitions. This will take more time than a lecture or reading about the concepts, but less time than guiding students to create the definitions themselves, and the students are more likely to remember and use the terms later.

Discussion: A set of terms and their definitions presents information efficiently. Students have seen them in dictionaries and textbooks, so they seem familiar. Use terms and definitions when the definitions are not conceptually difficult, and when they provide a convenient summary that students can refer to later. If the concepts are more difficult, it may be better to develop them separately and have students summarize them later. A list of definitions can seem boring or tedious, so you might combine this with another model that provides an engaging motivation, or where students apply the definitions. Do not assume that all students will read and understand the terms and definitions; include questions to guide students to explore and apply the definitions. To save time, consider having students read the list before class and answer some review questions.

Propositions and logical operators

A **proposition** is a statement that can have one of two values: true or false. For example:

A = It is raining. B = It is snowing. C = The air temperature is above freezing.

For conciseness, propositions are represented by symbols, usually capital letters. (Fuzzy logic is another logical system for propositions that may be partially true.) Propositions are manipulated and combined using **operators**, such as:

i.	**not**	if P is false,	(¬P) is true;	otherwise, (¬P) is false.
ii.	**and**	if P and Q are both true,	(P ∧ Q) is true;	otherwise (P ∧ Q) is false.
iii.	**or**	if either P or Q is true,	(P ∨ Q) is true;	otherwise (P ∨ Q) is false.

Figure 4: Sample Model - Terms & Definitions.

Examples: *Figure 4* shows a set of terms and definitions for propositional logic. In the POGIL activity, questions prompt students to use the definitions to complete a truth table with symbols and operators, and then to use proposition statements to write sentences that describe the effect of other operators.

Another POGIL activity uses a set of roughly 20 terms for software development activities (e.g. *Acceptance Testing*, *Architecture*, *Coding*, *Code Inspection*), each with a 2-4 sentence description (adapted from Wikipedia). Questions prompt students to group the activities into categories (e.g. *Analyze*, *Design*)and rate them in several ways. Thus, this encourages students to read and think about the descriptions, not just skip or skim over.

Typical DCV QUESTIONS (D=Directed, C=Convergent, V=Divergent)

- D: *How many terms are defined above? How many of the terms are defined using terms in the list?* Prompts students to look at a set of definitions and start to see how they are related.
- D: *Which of these examples satisfy the definition of <TERM>?* Prompts students to compare and apply the definition to a set of examples, which should be chosen and ordered to increase understanding.
- C: *Rewrite the definition of term using <CONSTRAINTS>*. Prompts students to rephrase definition using a particular example, notation, or vocabulary.
- V: *Give an example of <TERM> from <CONTEXT>*. Prompts students to apply definition in another context.

5. CONCLUSIONS & FUTURE DIRECTIONS

This paper has described how a pattern perspective should be useful to design and analyze classroom activities for POGIL and other evidence-based instructional strategies. It has provided some background on POGIL, and described a set of patterns for POGIL activities. Just as Extreme Programming (Beck, 1999) took existing software engineering practices to "extreme" levels, POGIL uses "extreme" versions of patterns like ACTIVE STUDENT, CHALLENGE UNDERSTANDING, REFLECTION, and TRY IT YOURSELF. *Table 4* lists possible future patterns that are grounded in POGIL and might interest the broader pedagogical patterns community.

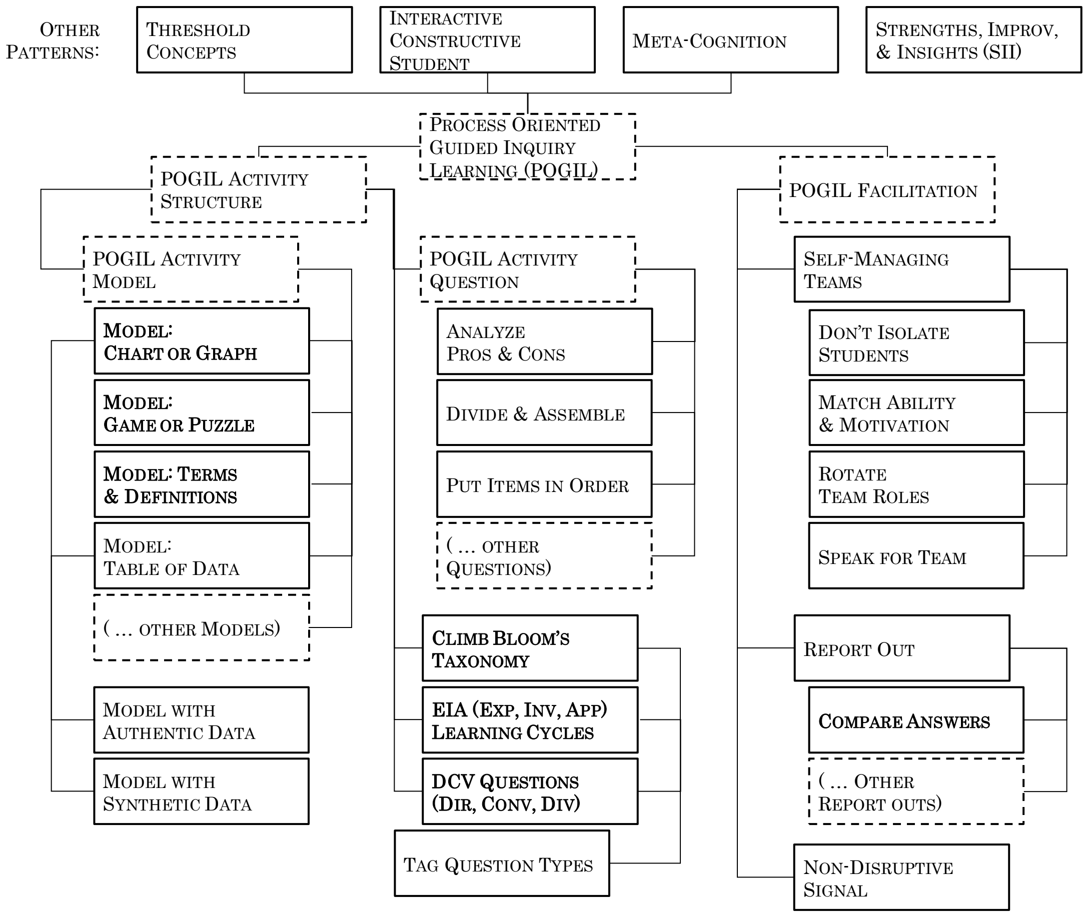

Figure 5: Relationships between patterns described in this paper (bold), possible future patterns (solid), and broader concepts (dashed).

5.1 Pattern Analysis of POGIL Activities

Table 2: TPM for EIA LEARNING CYCLES.

	to E	to I	to A
start	95%	<5%	<5%
from E	70%	20%	10%
from I	40%	30%	30%
from A	10%	5%	70%

Table 3: TPM for DCV QUESTIONS.

	to D	to C	to V
start	90%	10%	0%
from D	40%	60%	0%
from C	15%	70%	10%
from V	0%	40%	40%

POGIL activities share a distinctive structure, and hundreds of activities have been written across disciplines. Thus, a pattern perspective may help to analyze POGIL activities to better understand how and where patterns are used, and their relative effectiveness. An initial investigation (Kussmaul and Wenzel, 2012) analyzed over 350 questions in 17 POGIL activities from 10 authors in 3 disciplines. Each question was categorized by: EIA LEARNING CYCLES phase; DCV QUESTIONS type; and BLOOM'S TAXONOMY level. Each set of category assignments was used to create a *transition probability matrix* (TPM) that shows the probability of each type leading to each other type. For EIA *LEARNING CYCLES phase* (*Table 2*), activities started with explore (95%); explore questions were followed by explore (70%), invent (20%), or apply (10%); invent questions were followed by explore (40%), invent (30%), or apply (30%); and apply questions were followed by explore (10%), invent (5%), apply (70%), or the end of the activity (20%). For *DCV QUESTIONS type* (*Table 3*), activities started with directed (90%) or convergent (10%); directed questions were followed by directed (40%) or convergent (60%); convergent questions were followed by directed (15%), convergent (70%), or divergent (10%); and divergent questions were followed by convergent (40%), divergent (40%), or the end of the activity (20%). Thus, this analysis confirms that these activities generally follow the expected patterns for EIA LEARNING CYCLES and DCV QUESTIONS. Similarly, the analysis for CLIMB BLOOM'S TAXONOMY found that lower level questions (remember, understand, apply) were more common, and that the level tends to increase through an activity. Future work in this area might attempt to measure the effectiveness of individual activities, and determine whether there is a correlation between effectiveness and the degree to which activities use patterns such as EIA LEARNING CYCLES, DCV QUESTIONS, and CLIMB BLOOMS TAXONOMY.

Table 4: Possible Future Patterns related to POGIL.

Pattern	Patlet
ANALYZE PROS & CONS	Have students consider the strengths and weaknesses of one or more viewpoints or approaches. Several approaches are possible: draft bullet points, rate on set of factors, match items to options
DIVIDE & ASSEMBLE	Each team member does part of the work, then the team puts the pieces together. Works well when there are many similar pieces, not when pieces are different.
DON'T ISOLATE STUDENTS	Avoid teams or other situations where one member is different – by gender, ethnicity, or other factors.
INTERACTIVE CONSTRUCTIVE STUDENT	Extends ACTIVE STUDENT using the ICAP model (Chi and Wylie, 2014), which describes how outcomes improve as the learning environment shifts from *passive*, to *active*, to *constructive*, to *interactive*.
MATCH ABILITY & MOTIVATION	Assign pairs or teams by ability and motivation – high and middle students together, middle and low together, but not high and low. Students who are too different tend to have more problems.
META-COGNITION	Prompt students and teams to think about how they work and how they could work more effectively.
MODEL: TABLE OF DATA	Use EIA LEARNING CYCLES where the model is a chart or graph to help students understand concepts based on data, and to help students develop skills in information processing.
MODEL WITH AUTHENTIC DATA	Use models (e.g. CHART OR GRAPH) with real experimental data so that students learn concepts and process skills for critical thinking and problem solving.
MODEL WITH SYNTHETIC DATA	Use models (e.g. CHART OR GRAPH) with artificially generated data to focus student attention on key concepts and avoid distractions.
NON-DISRUPTIVE SIGNAL	Use signals that get student attention quickly without disrupting important discussions.
PUT ITEMS IN ORDER	Give students parts of a solution to put in the correct order, rather than creating the entire solution themselves. (Parsons and Haden, 2006)
REPORT OUT	Stop during class and have some of the teams report their answers or conclusions to the rest of the class, so everyone knows where they stand.
ROTATE TEAM ROLES	Assign a role to each team member, and rotate the roles each so each student gets experience with each role, not just the role(s) they prefer.
SELF-MANAGING TEAMS	Have students work in classroom teams that manage and support themselves, to help all students develop process skills such as communication, teamwork, critical thinking, and problem solving.
SPEAK FOR TEAM	Have a team member ask or answer questions on behalf of the team, not as an individual. If a team has agreed on a question or answer, it will likely be of interest to other students and teams.
STRENGTHS, IMPROVEMENTS, & INSIGHTS (SII)	When evaluating a product or process, focus on areas of strength and why they are important, areas for improvement and how they might be improved, and broader insights that occurred.
TAG QUESTION TYPES	When creating or reviewing activities and assignments, tag each question with its type in DCV QUESTIONS, its position in CLIMB BLOOMS TAXONOMY, and its position in EIA LEARNING CYCLES.
THRESHOLD CONCEPTS	Focus on concepts that are both troublesome and transform student understanding (Meyer and Land, 2003; Meyer and Land, 2005), such that a lack of understanding can prevent student progress. Once students master these, they will be more able to figure out other concepts on their own.

5.2 Next Steps

To move the POGIL Pattern effort forward, we see several interconnected next steps:

- Identify and refine patterns for activity structure, models, team organization, and classroom facilitation. In addition to the possible future patterns above, it might be useful to define sub-patterns for each alternative in DCV QUESTIONS, EIA LEARNING CYCLE, and CLIMB BLOOM'S TAXONOMY.
- Network with other pattern researchers for advice and insights on how to promote the use of patterns in the POGIL community.
- Educate the POGIL community about the benefits and challenges of a pattern perspective.
- Enlist experienced POGIL activity authors and other collaborators to study a broader range of POGIL activities to identify and document a broader range of POGIL activity patterns.
- Assess the utility of patterns for POGIL activity authors and classroom teachers.
- Use pattern languages to develop future authoring and learning tools, in which activities could be drafted more efficiently from building blocks based on patterns.

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APPENDIX

As indicated in section 2.2, this appendix summarizes documented pedagogical patterns that are relevant for POGIL principles and philosophy (*Table 5*), activity design (*Table 6*), and classroom facilitation (*Table 7*). In each table, the first column lists the pattern, source(s), and a brief "patlet" description; the second column describes how the pattern and POGIL practices are related. These remarks include references to patterns described in this paper (summarized in *Table 1*), and to some patterns that have not yet been documented (*Table 4*).

Table 5: Patterns related to POGIL philosophy.

Pattern, Source, Patlet	**Remarks from POGIL Perspective**
ACTIVE STUDENT (Eckstein, Bergin, Sharp, 2002b) *Keep the student active in and out of class with questions or exercises.*	The ICAP model (Chi and Wylie, 2014) describes how outcomes improve as the learning environment shifts from *passive*, to *active*, to *constructive*, to *interactive*. In POGIL, students interact to construct understanding.
CHALLENGE UNDERSTANDING (Eckstein, Bergin, Sharp, 2002a) *Give exercises, tasks, or activities that challenge students to see how well they understand a topic.*	Students often overestimate what they learn from a lecture (e.g. Carpenter, Wilford, Kornell, Mullaney, 2013). A POGIL Activity seeks to guide students to CHALLENGE UNDERSTANDING and construct knowledge through REFLECTION.
FEEDBACK (Eckstein, Bergin, Sharp, 2002a) *Give feedback that is differentiated and objective.*	A POGIL teacher continually monitors student progress to give FEEDBACK, but also to receive feedback on how to improve the activity and experience.
ITERATIVE COURSE DEVELOPMENT (Anthony, 1995) *Develop courses iteratively so they grow and improve over time.*	A POGIL teacher finds problems quickly, and can respond by asking questions, giving a mini-lecture, and revising the activity for the future. A lecturer may not find problems in what students understand until an assignment or exam.
MISCONCEPTION ASSESSMENT (to be published) *Explicitly assess students for common misconceptions of key concepts to identify corrective actions.*	POGIL activities and classroom facilitation are designed for continual MISCONCEPTION ASSESSMENT, and to correct misconceptions through interactions with other team members, the teacher, and the rest of the class.
MULTI-PRONGED ATTACK (Eckstein, Manns, Sharp, Sipos, 2003) *Choose examples and exercises that cover several ideas or topics at once.*	POGIL guides students to develop their own understanding of key concepts and develop important process skills (communication, critical thinking, problem solving, teamwork, etc.).
REFLECTION (Bergin, Eckstein, Manns, Wallingford, 2001) *Allow discovery and let students uncover solutions to complex problems.*	POGIL guides students to develop their own understanding of key concepts. (In POGIL, "reflection" refers to student META-COGNITION about learning.)
THREE STARS AND A WISH (Larson, Trees, Weaver, 2008) *When grading assignments, tell each student three things you liked and one "wish" for improvement.*	POGIL community members often solicit feedback using STRENGTHS, IMPROVEMENTS, & INSIGHTS (SII). First, list areas of *strength* and why they are strengths. Second, list areas for improvement and an idea to make the improvement. Third, describe any *insights* gained during the experience.
TRY IT YOURSELF (Eckstein, Bergin, Sharp, 2002a) *Use an exercise that requires students to understand the topic and for which you can give immediate feedback.*	Instead of "teaching" a topic and finding out later what students understand, POGIL guides students to create their own understanding. While teams work, the teacher monitors and actively facilitates their learning.

Table 6: Patterns related to POGIL activity design.

Pattern, Source, Patlet	**Remarks from POGIL Perspective**
ACQUAINTANCE EXAMPLE (Anthony, 1995) *Use examples that are likely to be familiar to students, but not in their areas of expertise.*	POGIL uses varied models, some of which are ACQUAINTANCE EXAMPLES.
CAREFULLY CRAFTED QUESTIONS (Larson, Trees, Weaver, 2008) *Prepare questions before class.*	POGIL uses DIRECTED, CONVERGENT, & DIVERGENT QUESTIONS, and EIA LEARNING CYCLES with 3 types of questions..
COLORFUL ANALOGY (Anthony, 1995) *Use a colorful analogy to help students remember a concept and context.*	POGIL uses varied models, some of which are COLORFUL ANALOGIES.
CONSISTENT METAPHOR, AKA ANALOGY (Bergin, Eckstein, Manns, Wallingford, 2001) *Create a metaphor that is consistent with the topic being taught and with the same basic elements that interact in the same way.*	POGIL uses varied models, some of which use CONSISTENT METAPHORS.
CONSTRUCTIVIST ALIGNMENT (Bergin, Kohls, Köppe, et al, 2015) *Define learning outcomes first, and then create assessment activities.*	POGIL activities are designed based on learning objectives that are active, specific, student-centered, and measurable.
EXPOSE THE PROCESS (Eckstein, Marquardt, Manns, Wallingford, 2001) *When showing examples or solutions, also show and explain the process and critical decisions.*	POGIL often uses a sequence of models, which often start with simple models and gradually add complexity. EIA LEARNING CYCLES use questions to guide students through the process and critical decisions.
LEARNING OUTCOMES (Bergin, Kohls, Köppe, et al, 2015) *Set clear and measurable outcomes to help students study and ensure that you capture elements you will teach and assess.*	POGIL activities are designed based on learning objectives that are active, specific, student-centered, and measurable.
MISSION IMPOSSIBLE (Eckstein, Marquardt, Manns, Wallingford, 2001) *Use problems that seem straightforward but which require deeper understanding to solve completely.*	POGIL often uses a sequence of models, which often start with simple models and gradually add complexity. EIA LEARNING CYCLES use questions to guide students from the surface problem toward deeper understanding.
NAME IS LAST (Fricke, Volter, 2000) *Make sure students understand a topic before you give it a name.*	POGIL uses EIA LEARNING CYCLES that often develop student understanding of a concept before introducing terminology.
OPEN ENDED QUESTIONS (Larson, Trees, Weaver, 2008) *Design open-ended questions that require a full, meaningful answer using the student's existing knowledge and/or feelings.*	POGIL uses EIA LEARNING CYCLES that often end with DIVERGENT, APPLICATION QUESTIONS.
OWN WORDS (Eckstein, Bergin, Sharp, 2002a) *Have students express the key ideas using their own words to better assess their understanding.*	POGIL uses EIA LEARNING CYCLES that guide students to express key ideas in their own words, and then to REPORT OUT to the rest of the class.
PREFER WRITING (Eckstein, Bergin, Sharp, 2002b) *Prefer writing exercises over reading exercises.*	POGIL uses EIA LEARNING CYCLES that guide students to express key ideas in their own words. Some activities prompt students to modify programs, documentation, proofs, or other materials.
SIMPLE ANSWER (Larson, Trees, Weaver, 2008) *Design questions with simple answers to draw out student response.*	POGIL uses EIA LEARNING CYCLES that often begin with DIRECTED, EXPLORATION QUESTIONS.
SOLUTION BEFORE ABSTRACTION (Eckstein, Marquardt, Manns, Wallingford, 2001) *Give students a sample problem in a setting they find comfortable. After it is solved, focus on aspects they can apply to other problems.*	POGIL guides students from specific examples in models to general concepts.
STUDENT MINERS; COLLABORATIVE KNOWLEDGE CONSTRUCTION (Köppe, Schalken-Pinkster, 2013a) *Introduce a concept through questions that relate to existing knowledge and lead towards the new concept.*	POGIL uses DIRECTED, CONVERGENT, & DIVERGENT QUESTIONS, and EIA LEARNING CYCLES.

Table 7: Patterns related to POGIL classroom facilitation.

Pattern, Source, Patlet	**Remarks from POGIL Perspective**
CLEAR STARTING SIGNAL (Köppe, Portier, 2014) *Have a signal that indicates the start of lecture.*	In POGIL, there are frequent shifts between work by SELF-MANAGING TEAMS, when they REPORT OUT to the class, and comments or mini-lectures by the teacher. The teacher needs NON-DISRUPTIVE SIGNALS that capture attention without too much disruption, such as RAISE HAND FOR ATTENTION and CLAP FOR ATTENTION.
COLLABORATIVE SUMMARY (Köppe, Schalken-Pinkster, 2013a) *Collaborate with students to create a list of key elements from a previous lecture.*	In POGIL, when students ROTATE TEAM ROLES, one role is the Recorder, who writes answers and other observations on behalf of the team.
CONSIDERATE LECTURER (Köppe, Portier, Bakker, Hoppoenbrouwers, 2015) *Proactively ask and observe how students react.*	In POGIL, the teacher is a GUIDE ON THE SIDE who moves around and actively observes and facilitates student learning.
DEBRIEF AFTER ACTIVITIES (Anthony, 1995) *After an activity or exercise, lead a discussion of what students learned.*	In POGIL, teams REPORT OUT to the class to ensure that all teams are on task and reach the correct insights. This often happens at the end of an activity, but also occurs frequently during an activity, as cued by the teacher.
GROUPS WORK (Eckstein, Bergin, Sharp, 2002b) *Emphasize group work – large and small groups, long lived (weeks) and short lived (minutes).*	In POGIL, SELF-MANAGING TEAMS that ROTATE TEAM ROLES create their own understanding. Typically, teams stay together for weeks or months, and rotate roles each class period so every student fills every role.
HANDS FREE HELP (Larson, Trees, Weaver, 2008) *Assist students by offering guidance, not by solving the problem.*	In POGIL, SELF-MANAGING TEAMS that ROTATE TEAM ROLES create their own understanding, The teacher provides guidance, not answers.
HONOR QUESTIONS (Fricke, Volter, 2000; Eckstein, Bergin, Sharp, 2002b) *Motivate students to ask questions and show them how to ask questions.*	POGIL includes several elements to encourage and honor questions. Many questions are answered within the SELF-MANAGING TEAM. If the team is stuck, one member can SPEAK FOR TEAM. If several teams have similar questions, the teacher can have teams interact with each other, or discuss with the entire class.
INVISIBLE TEACHER (Fricke, Volter, 2000; Eckstein, Bergin, Sharp, 2002b) *Focus the course on students, and direct them to ask peers for help.*	POGIL is learner-centered, not teacher-centered. Many questions are answered within the SELF-MANAGING TEAM. If the team is stuck, one member can SPEAK FOR TEAM. If several teams have similar questions, the teacher can have teams interact with each other, or discuss with the entire class.
LATE ATTENDANT DISCOURAGEMENT (Köppe, Portier, 2014) *Use interventions to discourage late arrivals.*	In POGIL, SELF-MANAGING TEAMS often provide peer pressure to arrive on time. Many POGIL teachers start class with a PREPARATION MATERIAL CHECK - a short quiz on concepts from the previous day.
MINIMUM DISTANCE (Larson, Trees, Weaver, 2008) *Walk around the room and show an interest in what each student is doing.*	In POGIL, the teacher is not a SAGE ON THE STAGE who lectures, but a GUIDE ON THE SIDE who moves around and actively facilitates student learning.
PEER FEEDBACK (Eckstein, Bergin, Sharp, 2002a) *Invite students to evaluate each others' work.*	In POGIL, SELF-MANAGING TEAMS discuss and agree on answers to questions. From time to time they REPORT OUT to get FEEDBACK from other teams.
PREPARATION MATERIAL CHECK; ENTRANCE MATERIAL (Köppe, Portier, 2014) *Check that students have studied the material or content and are prepared.*	Many POGIL teachers start class with a short quiz on concepts from the previous day, rather than on readings or other preparation for a new topic. A POGIL teacher may check student understanding in a variety of ways (e.g. clickers, finger voting, small whiteboards, shared documents).
ROUND ROBIN (Eckstein, Marquardt, Manns, Wallingford, 2001) *Ask each person in turn to contribute an idea, and write down all ideas.*	In POGIL, students work in SELF-MANAGING TEAMS and most discussion happens within a team, not across the entire class, so many more students are engaged. Teams ROTATE TEAM ROLES; typically, one role is the Manager and makes sure everyone participates, and one is the Reflector (or Strategy Analyst) and considers how the team could work more effectively.
TEACHER SELECTS TEAMS (Eckstein, Bergin, Sharp, 2002b) *Choose student teams to encourage active learning and discussion.*	In POGIL, the teacher usually assigns students to SELF-MANAGING TEAMS. A variety of approaches and principles are used, including ROTATE TEAM ROLES, DON'T ISOLATE STUDENTS, MATCH ABILITY & MOTIVATION, etc.
THINK…PAIR…SHARE (Larson, Trees, Weaver, 2008) (Lyman, 1987) *Have students* think *about a question, then* pair *with another student to discuss, and then* share *their response with the class.*	In POGIL, SELF-MANAGING TEAMS discuss and agree on answers to questions. From time to time they REPORT OUT to the class. A variety of techniques are used for this, depending on the type of question and answer, class size, available time, and other factors. In some activities, students also answer specific questions on their own before they discuss with their team.