Process Oriented Guided Inquiry Learning (POGIL), A Teaching Method From Physical Sciences, Promotes Deep Student Learning In Aviation

Joseph J. Vacek
University of North Dakota

ABSTRACT

Aviation educators can increase the depth of student learning in their classes by implementing Process Oriented Guided Inquiry Learning (POGIL). The goal of this study was to determine whether POGIL, a uniquely effective teaching strategy used primarily in chemistry or biology, stimulates deeper student learning outside the flight lab. Results from measured test scores on identical assessment instruments between the control and experimental groups indicate the use of POGIL can significantly increase the depth of student learning in collegiate aviation classes with or without a flight lab.

INTRODUCTION

Aviation education takes place both in the classroom and in the aircraft. The aircraft is a highly motivating three-dimensional laboratory setting where students can test and apply knowledge and receive instantaneous and intense feedback. "Flight lab" learning is gestalt, stimulating multiple senses and engaging several domains of learning, and gestalt experiences generally result in deeper learning (Ratey, 2002). The author's observations of typical aviation classroom learning and conversations with students indicate that much learning is not gestalt but rather focuses mostly on rote learning, resulting in less student engagement and shallow learning. Students frequently describe typical lecture-based aviation classes as "boring" in course evaluations. That is particularly concerning to teachers of the millennial generation of students who are used to a more stimulating environment (Niemczyk & Ulrich, 2009). The goal of this study is to determine whether Process Oriented Guided Inquiry Learning (POGIL), a uniquely effective teaching strategy used primarily in chemistry or biology, stimulates deeper student learning outside the flight lab in collegiate aviation education. POGIL was chosen because of the strong similarities between flight lab learning and the POGIL model. Aviation educators have been teaching effectively in the aircraft all along, but many have not made an explicit transfer of the same principles to the classroom.

What is Process Oriented Guided Inquiry Learning (POGIL)?

POGIL is a pedagogical technique that synthesizes teaching both content and process skills together. Such goals as student collaboration and teamwork and analytical thinking are part of POGIL activities. (What is Process Oriented Guided Inquiry Learning, 2010). "POGIL is based on research indicating that a) *teaching by telling* does not work for most students, b) students who are part of an interactive community are more likely to be successful, and c) knowledge is personal; students enjoy themselves more and develop greater ownership over the material when they are given an opportunity to construct their own understanding." (What is POGIL, 2010). POGIL also promotes peer learning, which has been shown to significantly increase the depth of student understanding, especially on the part of the peers acting as teacher (Hockings et al, 2008). Essentially, POGIL is more specific, structured, and focused than "regular" group work, and promotes even deeper student learning.

While POGIL has traditionally been used in large, science education classes such as general chemistry, organic chemistry, or biology (Effectiveness of POGIL, 2010), it is adaptable to other disciplines. A classroom using POGIL consists of small groups of students working on specifically designed problems and materials (Hanson, 2006). The materials give students a limited amount of information followed by questions designed to guide them to formulate their own conclusions using the scientific method. The teacher serves as a guide and discussion facilitator, observing the small group dynamics and answering individual and group-generated questions. (What is POGIL, 2010). While the purpose of this article is not to provide a guide to using POGIL, a sample POGIL activity follows in Appendix A for illustration. More information about POGIL theory and techniques is available at www.pogil.org. In studies of teaching and learning, POGIL has demonstrably increased the depth of student learning in the physical sciences (Hanson, D.M., 2006; Farrell, J.J. et. al., 1999, Heller, P., et al., 1992). Although a common concern about using POGIL is that less class time is available to cover content, POGIL explicitly and effectively rewards student preparation for content acquisition, (Straumanis A., and Simons E. (2006) and the combination of content acquisition with process skills ensures required content will be covered.

Deep Learning Occurs in Multiple Cognitive Domains

This author has observed that much traditional classroom instruction in collegiate aviation focuses on lecture and memorization. While that is efficient in terms of basic content acquisition, deep learning involves more than that. Teachers encourage deep student learning by engaging students in multiple domains. One of the effects of using POGIL in the classroom is that student learning is facilitated in a variety of domains, not just the cognitive domain. It is well accepted that students learn in multiple domains (Ratey, 2002) and separation of emotion, cognition, and the physical body is no longer pedagogically acceptable as it once was. Students learn most deeply in gestalt experiences, and POGIL provides a pedagogical tool to facilitate that. In aviation, teachers and instructor pilots use similar methodology to POGIL when teaching "flying" courses--those courses that involve a laboratory component where the student learns specific aviation skills and applies them in flight. In fact, flight instructor trainees are explicitly taught fundamentals of instruction for aviation which are strikingly similar to a well-designed POGIL lesson (Aviation Instructor's Handbook, 2008).

Authentic Assessment is Necessary for Deep Learning

Authentic assessment is assessment that aims for realism, where the evaluated task reproduces how a student's knowledge and abilities are tested in real life situations. It requires students to use judgment, innovation, and their toolbox of learned knowledge and skills to perform a complex task or solve a complex problem. Students must integrate multiple skills. Finally, authentic assessment is formative rather than summative--students have opportunities to practice their skills and get feedback on their performance without fear of evaluation pressure. (Wiggins, 1998). While this kind of assessment occurs routinely in the aircraft when practicing maneuvers with instructor pilots, it is less common in an ordinary classroom.

In aviation, an illustrative example of authentic assessment is the first solo flight. Rather than testing whether a student can remember aircraft speeds and limitations and air traffic control procedures via written quiz, the student performs a solo flight and concretely demonstrates ability to do those things. Authentic assessment like that is real, and is also highly motivating in this author's experience. The more relevant and realistic the assessment, the more likely students will be motivated to learn the underlying material deeply to perform well on assessment.

RESEARCH METHODOLOGY

POGIL was selected as the teaching method to be tested. It has been shown to be successful in promoting deep learning in chemistry and biology, so the author wondered whether it would have a significant effect in collegiate aviation education. The following hypothesis was established for the purpose of this study:

H0: POGIL has no significant effect on the depth of collegiate aviation students' learning.
H1: POGIL has a significant effect on the depth of collegiate aviation students' learning.

Because of the complex variables affecting student learning, no one single inquiry into the effect of a particular method on the depth of student learning can be conclusive (Entwistle, 2009 at 5). But an accepted measurement of depth of learning begins with an analysis of whether basic content knowledge is merely surface, or rote, learning (Tagg, 2003; Aviation Instructor's Handbook, 2008) or whether it encourages students to explore underlying meanings and apply their knowledge in real-world situations (Tagg, 2003; Biggs,1989; Aviation Instructor's Handbook, 2008). "Deep learning is learning that takes root in our apparatus of understanding." (Tagg, 2003 p. 70). Simply put, if aviation students can apply their knowledge of facts, regulations, or aircraft limitations in a task that simulates a complex in-flight situation, they have demonstrated deeper learning--an apparatus of understanding--that can be measured.

Study Design

The study was conducted over two consecutive semesters after the author participated in a POGIL training workshop. The first semester (the control group) was conducted the same way as the author had always taught the courses – lecture-based and content-focused. During that semester the POGIL activities were created for use the next semester (the experimental group). The same two classes, IFR Regulations and Procedures and Aviation Law, were taught in the control semester and experimental semester. Both the control group and the experimental group were notified that their class was the subject of a research study and had the option to switch to another section taught by a different professor. The study timeline follows in tabular form:

Table 1. *Timeline of Study Design*

Semester	Activity	Assessment
Summer	POGIL training workshop	
Fall (control)	Traditional lecture & Creation of POGIL lessons	Pre & Post tests
Spring (experimental)	POGIL lessons	Pre & Post tests

While the classes are different and IFR Regulations and Procedures has a flight lab associated with it, the study does not attempt to measure any effect POGIL has between classes within the experimental group, or whether it is more effective in certain classes than others. The study is designed to measure solely whether POGIL has an effect on overall learning within collegiate aviation.

Identical syllabi, course content, classroom materials, management software (class website), and assessment tools were used for both control and experimental groups. The same professor taught both groups. The POGIL activities were developed in accordance with POGIL guidance for each class in the experimental semester and used in substitution of traditional class lectures throughout the experiment semester. Initial knowledge assessments and final examinations were compared using an independent samples *t*-test, and inter-class block exams and other assessments were compared using Analysis of Variance (ANOVA). A *t*-test assesses whether the means of two groups are statistically different from each other. This analysis is appropriate in comparing the means of only two groups, where the ANOVA generalizes a *t*-test to more than two groups. (Trochim & Donnelly, 2006). For significance, the critical p value was $p < .05$.

Sample Selection

The participating collegiate aviation students were regularly enrolled undergraduate students within several majors in the department of Aviation at the University of North Dakota. Institutional Review Board (IRB) approval was granted to compare the students' assessment scores after de-identification of the assessment tool. All subjects were given the option of opting out of participation by placing a discreet symbol on their assessment and again once the assessments had been graded. No subjects opted out.

Four total classes of two different academic subjects were used as samples. The classes were IFR Regulations and Procedures and Aviation Law. The control groups (one IFR class and one law class) were taught in Fall and the experimental groups (one of each) were taught in Spring. The mean and median sample sizes were 22 students. Demographically, females were underrepresented (no female subjects in either IFR classes) and 2 and 3 females in the Law control and experimental classes, respectively. Ages were typical of university sophomores (IFR) and senior (Law) classes. Between groups, therefore, the control and experimental samples were demographically similar.

POGIL activities

Learning groups or teams are an integral part of POGIL, and students spend much of class time working in small learning teams, different from traditional lecture-based classes of between 15-30 students. In a small team setting, it is important to structure the team by assigning different roles to students to ensure consistency of process. While the team's membership may be flexible to accommodate changes throughout the semester and the students may play different roles, the roles themselves should remain constant to facilitate the process. The teams used in the experimental groups were as follows:

- <u>Manager</u> Manages the group. Ensures that members are fulfilling their roles, that the tasks are being accomplished on time, and that all group members participate. The instructor responds to questions from the manager only, who must raise his or her hand to be recognized.
- <u>Presenter</u> Presents oral reports to the class using recorder's notes. The reports should be short and concise.
- <u>Recorder</u> Records the group's consensus answers, notes any dissent, discussions, observations, etc., to be reported to the class. It may also include a log of the concepts the group has learned.
- <u>Researcher</u> Performs all the technical operations, searches, or other data operations for the group. Only the researcher in each group may use a computer, phone, or other technical equipment in solving the problem.
- <u>Processor</u> Acknowledges the good ideas and insights of group members or the group as a whole at appropriate times in writing. Also observes and comments on group dynamics. These acknowledgements and observations must be attached to the recorder's notes at the conclusion of the exercise, but need not be reported orally by the reporter.

While other team roles may be used (e.g. an encourager or a significant figure checker), these four categories worked in the experimental groups. The team manager was free to assign additional or multiple roles as he or she saw fit.

The teams were given explicit activities designed specifically for the learning objective at hand, which varied by lesson. For illustration, one example POGIL activity the author designed follows in Appendix A and a guide for determining the extent to which an instructional activity supports POGIL follows in Appendix B. These examples are only to show the structure of a potential POGIL activity. More information about the POGIL model can be found at www.pogil.org.

RESULTS

In the following tables, PreTest/Pre stands for an initial assessment given on the first day of class which measured student familiarity with the course subjects. Blocks 6, 7, and 8 refer to each assessment (exam) given at the conclusion of the specified learning block. Final stands for the final exam for the course, which was cumulative. Initial knowledge assessments and final examinations were compared using a *t*-test (assesses only whether the means of two groups are statistically different), and block exams 6, 7, and 8 and final assessments were compared using an ANOVA (compares the means of multiple groups). For significance, the critical *p* value was $p < .05$.

Table 2 shows the descriptive statistics for IFR Regulations and Procedures for the control group (11 students) and the experimental POGIL group (19) students). The samples' N values remain constant throughout the experiment. The mean test scores for each group are shown, with the standard deviation and other descriptive statistics for the groups' exam scores. These descriptive statistics were used for further testing in an Analysis of Variance (ANOVA) below.

Table 2. *IFR Regulations and Procedures Class –Descriptive Statistics*

						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
PreTest	Control	11	62.7273	10.46987	3.15678	55.6935	69.7610	41.00	78.00
	POGIL	19	61.8947	10.99947	2.52345	56.5932	67.1963	44.00	81.00
	Total	30	62.2000	10.63306	1.94132	58.2295	66.1705	41.00	81.00
Block 6	Control	11	88.0909	5.61168	1.69198	84.3209	91.8609	81.00	97.00
	POGIL	19	88.1579	5.18827	1.19027	85.6572	90.6586	76.00	97.00
	Total	30	88.1333	5.25051	.95861	86.1728	90.0939	76.00	97.00
Block 7	Control	11	93.2727	2.37027	.71466	91.6804	94.8651	89.00	97.00
	POGIL	19	86.1579	9.18491	2.10716	81.7309	90.5849	68.00	100.00
	Total	30	88.7667	8.15236	1.48841	85.7225	91.8108	68.00	100.00
Block 8	Control	11	94.9091	4.18221	1.26098	92.0994	97.7187	86.00	100.00
	POGIL	19	88.9474	6.32871	1.45191	85.8970	91.9977	76.00	100.00
	Total	30	91.1333	6.27932	1.14644	88.7886	93.4781	76.00	100.00
FINAL	Control	11	89.4545	3.58786	1.08178	87.0442	91.8649	84.00	93.00
	POGIL	19	94.2632	4.56852	1.04809	92.0612	96.4651	81.00	99.00
	Total	30	92.5000	4.79044	.87461	90.7112	94.2888	81.00	99.00

Table 3 shows there was no significant difference between the pretests (*p* = .840) or the block 6 exam (*p* = .974) between groups. There was a significant difference between the block 7 (*p* =. 018), block 8 (*p* = .010) and final exams (*p*= .006) between groups.

Table 3. *IFR Regulations and Procedures Class – ANOVA*

		Sum of Squares	df	Mean Square	F	Sig.
PreTest	Between Groups	4.829	1	4.829	.041	.840
	Within Groups	3273.971	28	116.928		
	Total	3278.800	29			
Block 6	Between Groups	.031	1	.031	.001	.974
	Within Groups	799.435	28	28.551		
	Total	799.467	29			
Block 7	Between Groups	352.659	1	352.659	6.271	.018
	Within Groups	1574.708	28	56.240		
	Total	1927.367	29			
Block 8	Between Groups	247.610	1	247.610	7.739	.010
	Within Groups	895.856	28	31.995		
	Total	1143.467	29			
FINAL	Between Groups	161.089	1	161.089	8.942	.006
	Within Groups	504.411	28	18.015		
	Total	665.500	29			

Table 4 shows the group statistics for the Aviation Law samples for both control (N=30) and experimental POGIL group (N = 25). One subject from the POGIL group failed to take the final exam which was treated as missing data in the analysis.

Table 4. *Aviation Law Class –Group Statistics*

	Group	N	Mean	Std. Deviation	Std. Error Mean
Pretest	Control	30	60.5000	14.64464	2.67373
	POGIL	25	55.9200	10.90841	2.18168
Final	Control	30	88.6000	5.86398	1.07061
	POGIL	24	91.9583	5.52842	1.12848

Table 5 shows an independent samples test for the Aviation Law class. A *t*-test was used for Aviation Law because the individual assessment data for in-class assignments, quizzes, and tests was aggregated into frequency-only data and the original data was lost. Since standard deviation could not be calculated from frequency data alone, an ANOVA could not be performed to assess whether there was an effect within the class assessments. The results table from the *t*-test shows that there was no significant difference between pretests (p = .202 or .190) but there was a significant difference between the final exams (p = .037 or .036).

Table 5. *Aviation Law Class – Independent Samples T-Test*

		Levene's Test for Equality of Variances		*t*-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tail)	Mean Diff.	Std. Error Diff.	Lower	Upper
Pre	Equal variances assumed	3.77	.057	1.292	53	.202	4.58000	3.54360	-2.5275	11.68755
	Equal variances not assumed			1.327	52.403	.190	4.58000	3.45088	-2.3434	11.50343
Final	Equal variances assumed	.199	.657	-2.14	52	.037	-3.35833	1.56593	-6.5006	-.21606
	Equal variances not assumed			-2.15	50.554	.036	-3.35833	1.55553	-6.4818	-.23480

DISCUSSION

Limitations

The small sample sizes, lack of longitudinal assessment and consequent absence of *post-hoc* tests limit the conclusions that can be drawn from this study. Demographical limits in the samples may limit the applicability of the conclusions. Missing data from the Aviation Law in-class assessments (which would otherwise mirror the block 6, 7, & 8 tests from IFR Regulations and Procedures) limit the findings from the Aviation Law class. Finally, the two classes measured are inherently different and no conclusions can be drawn from their comparison.

Differences

Overall, the data support rejecting the null hypothesis and supports H1, that POGIL made a significant difference ($p < .05$) on collegiate aviation students' learning. This difference was significant in both IFR Regulations and Procedures and Aviation Law (courses with a flight lab component and without a flight lab), namely that the differences between the initial knowledge assessments of both groups compared with the final exam scores was significant.

While the two classes in the experimental group are qualitatively different and no conclusions can be drawn from their comparison, the author found it interesting that the effect of POGIL on the flight lab class appeared to be stronger than for the non-flight lab class. This was contrary to what the author expected to see as a general matter, since flight lab courses are similar to POGIL on their own. More research needs to be done to determine the extent of this effect. Additionally, the effect of POGIL on the depth of learning appeared to increase throughout the semester. The *p* values continued to move linearly towards stronger significance ($p < .01$) throughout the semester for IFR Regulations and Procedures. More research needs to be done to explore these effects as well.

CONCLUSIONS

Aviation educators can increase the depth of student learning in their classes by implementing POGIL. While a drawback to adopting POGIL is the initial amount of preparation in terms of learning the POGIL method as a teacher, student learning in both flight lab courses and non flight lab courses can be significantly improved by implementing POGIL. From the results of this study, it appears that the POGIL model itself is adaptable to the aviation discipline. While further research is necessary to determine the magnitude of POGIL's effect within different kinds of aviation classes, this study supports the existing body of research that indicates POGIL can increase the depth of student learning in the sciences and extends the principles of POGIL specifically to aviation education.

REFERENCES

Aviation Instructor's Handbook (2008). Federal Aviation Administration.

Bauer, Cole, & Anderson (2007). POGIL Scoring Rubric. Retrived from http://www.pogil.org

Biggs, J.B. (1989). Approaches to the enhancement of tertiary teaching. *Higher Education Research and Development*, *8*, 7-25.

Entwistle, N. (2009). *Teaching for Understanding at University*, Basingstoke, UK: Palgrave Macmillan.

Effectiveness of POGIL (2010). Retrieved from http://www.pogil.org/about/effectiveness

Farrell, J.J., R.S. Moog, & J.N. Spencer. (1999) A Guided-Inquiry General Chemistry Course. *Journal of Chemical Education, 76*(4), 570-574.

Hanson, D.M. (2006). *Foundations of Chemistry: Applying POGIL Principles*. Lisle, IL: Pacific Crest.

Heller, P., R. Keith, & S. Anderson. (1992). Teaching Problem Solving Through Cooperative Grouping. Part 1: Group Versus Individual Problem Solving. *American Journal of Physics, 60*, 627.

Hockings, S.C., DeAngelis, K.J., & Frey, R.F. (2008). Peer led team learning in general chemistry: Implementation and evaluation. *Journal of Chemical Education, 85*(7), 990-996.

Niemczyk, M. & Ulrich, J. (2009). Workplace Preferences of Millennials In the Aviation Industry. *International Journal of Applied Aviation Studies, 9*(2), 207-219.

Ratey, J.J. (2002). *A user's guide to the brain: Perception, attention, and the four theaters of the brain*. New York: Pantheon Books.

Straumanis A., and Simons E. (2006). *Assessment of student learning in POGIL organic chemistry*. Abstracts of papers of the American Chemical Society, 26 Mar 2006, Vol. 231.

Tagg, J. (2003). *The learning paradigm college*. Boston, MA: Anker.

Trochim, W. & Donnelly, J. (2006). *The Research Methods Knowledge Base*. Cincinnati: Atomic Dog Publishing.

What is Process Oriented Guided Inquiry Learning (POGIL)? (2010). Retrieved from http://www.pogil.org/about

Wiggins, G.P. (1998). *Educative Assessment: Designing assessments to inform and improve student performance*. San Francisco: Jossey-Bass.

APPENDIX A

Sample POGIL Activity

Go time!

It's go time! You have an emergency airlift to do today. Your mission is to transport a critical care patient from Baudette, MN to Duluth, MN, and pick up a package of live human tissue at Duluth and get it to Anoka, MN (near Minneapolis).

PREREQUISITES
IFR Enroute chart legend
AIM 5-3-1 to 5-3-7

LEARNING OBJECTIVES
Identify elements of IFR low altitude charts
Plan an efficient route of flight using low altitude charts

EXPLORATION
In your groups, identify the fastest way using both Victor airways and direct routing from BDE to DLH and from DLH to ANE. Write down your proposed route of flight. Your group manager should be prepared to explain why you chose the route you did.

KEY QUESTIONS
1. What is the MEA to HIB?
2. What is the MOCA to HIB?
3. What is the distance from BDE – SQEAK?
4. What is the distance from HIB – DLH?
5. Near SQEAK there is an 88 in a box, what does this mean?
6. What airspace are you flying through on your way to HIB?
    a. Is this airspace active?
    b. Are there any problems with you flying through it if it is active?
    c. What do the Green (Jepp) or Brown (NOS) circles mean within this airspace?
7. What does the X (AYIHE) between HIB –DLH indicate?
8. What class airspace is KDLH?
9. Does DLH have HIWAS?

SKILL EXERCISES
1. What altitude would you file for the route section DLH – ANE? Why?
2. What is the brown line you cross?
3. Rush City has a holding pattern depicted. Why?
4. What do the grey dashed lines around MSP mean?
5. What frequency would you use to contact FSS in DLH?
6. How can you tell if there is DME at DLH?

PROBLEMS
1. Assume you're in BDE right now and ready to take off in 15 minutes. You choose to fly direct. Use the current weather and winds aloft. What altitude of flight would you choose and file?
2. You've made it to DLH and are ready to depart to ANE. In you updated briefing, you hear that flow control is in effect for MSP and to expect preferred IFR routes. Where do you find those, and would that affect your flight?

APPENDIX B

POGIL Screening Rubric

Chris Bauer, Renee Cole, & Karen Anderson, 2007

This rubric guides initial review of an instructional activity to determine how well the activity supports process-oriented and guided-inquiry learning. The review pertains only to the written description of the activity and not to how an instructor might facilitate its use. A "yes" response should indicate that evidence for that characteristic can be found in the instructional activity itself. The evidence must be explicit, i.e. reviewers should not assume that an instructor using the activity will provide anything that seems to be missing. If no explicit evidence can be found, then a "no" response is appropriate. If evidence is found, then a "yes" response is appropriate, irrespective of the perceived quality of that characteristic. The Initial Screening Rubric Guide elaborates on the meaning of each item.

ESSENTIAL CHARACTERISTICS	Yes	No	Comments
1 Independent of the instructor, students are expected to explore or study something – data, equations, diagrams, text, graphics, processes, methods, hands-on activities, etc. Some authors refer to this as "the model".			
2 This exploration is the first task in the activity regarding a new topic.			
3 Students are expected to articulate and record explanations			
4 The activity is structured to build towards a central idea.			
5 Students are expected to engage in practice or application of developing ideas.			
6 Students are expected to process information (describe, summarize, calculate, transform data to another representation).			
7 Students are expected to engage in problem solving or critical thinking tasks.			
8 In the body of the written materials, students are cued to share or interact with each other.			
9 Students are expected to assess what they have learned from the activity in terms of either process or content.			