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The Effectiveness of Project-Based Learning in the Science Classroom

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Abstract

The purpose of this action research project was to determine the effect of project-based learning on middle school science students. A science classroom was taught with a traditional method for a unit and data was collected to be measured for growth. Then another class was taught with project-based learning on the same unit with data collected to measure their growth. Analysis of the data collected suggests that while both strategies are effective in providing growth of knowledge, project-based learning showed a greater growth within special education, at risk, and ESL students.

The Effectiveness of Project-Based Learning in the Science Classroom

This paper looks to explore if project-based learning (PBL) increases student scores versus a traditional classroom model. There has been a recent push to implement the Next Generation Science Standards (NGSS) into the science curriculum and many professionals are interested in studying the benefits of shifting from a traditional model of teaching to a PBL model to better meet these standards. Many people have been taught with a traditional model and have enjoyed that style of teaching, so the push and shift from the traditional model is being met with some skepticism from many teachers. If the researcher is able to quantify the benefits of PBL, many teachers may be far more likely to accept the shift.

With a background in scientific study, the researcher is hesitant to implement something just on the recommendation of others. Making sure one has the data and personal experience with something before accepting it is vital. There is also an undercurrent of professionals that are worried about adopting a different style of teaching. Typically, this is from experienced teachers that are hesitant to change without definite backing to do so. Being able to quantify the effects of PBL and to communicate those benefits to other professionals is a necessary commitment that needs undertaking.

Literature Review

Many studies have been done on project-based learning in the classroom, and there is an article written by Hoppe (2010) that provides insight into understanding PBL in the science classroom. Hoppe (2010) conducted a study with the goal of finding out how to provide students with an engaging program and an environment where students will not only have the greatest opportunity for success in summer school but also become engaged in content with which had previously been a struggle. This was important because this was a relatable study done by the summer school program to what the researcher is looking at doing in their classroom. When looking at how they set up their action plan, they used an independent variable of the curriculum itself and compared its effectiveness to the control of the previous summer's data when there was no PBL curriculum (Hoppe, 2010). They measured the attendance, discipline referral rates, passing rates, and student interest surveys to justify their results (Hoppe, 2010).

One of the first limitations of the study is fact that the interest survey was open ended, it lends itself to be open to bias and is not comparative across the board. Another key limitation is the fact that this study takes place over different summers; therefore, the students are not the same. Because of this change in students, it creates a variable that is difficult to account for. Different students will tend to have different experiences, interests, and abilities. The positive of this test however, is that it has numerous years of data as the control which minimizes the discrepancy it could face. If the study would continue for multiple years as PBL, it would greater enhance their findings.

Another factor of the study that is not accounted for is the selections of the students. They are a variable as it is a summer school program of children who did not complete their credit during the school year. This particular selection of students is a unique set, and the results of the data could be difficult to generalize to all students. The main bit of quantitative data that they did give and analyze came in the form of referencing referral reports being down from 38 to 2. The other quantitative data were the passing rates of the students and the attendance rates. Hoppe did not give specific numbers for these results; they just reported that passing rates went up as well as attendance rates. The qualitative results were explained by giving us the predominant answer in both pre-and post-curriculum. The analysis is fairly non-existent but said that the predominant answer pre-curriculum to what they know about math and science was, “I don’t know” while post- curriculum was “pythagorean theorem” (Hoppe, 2010, p. 59.) Within the article, no validity or reliability are discussed. However one would argue that the three quantitative tests (attendance rates, discipline referral rates, and passing rates) are very valid as one can accurately measure exactly what they wanted to measure. For example student referrals decreased from the previous year from 38 to 2 (Hoppe, 2010). The same can be said of the attendance and passing rates. The qualitative student summary was open ended, so the validity of that instrument by itself is, in my opinion, somewhat suspect. However, when coupled with the results of the other tests, it adds to the overall validity of the action plan.

The findings of this research suggests that project-based learning increases student engagement and has changed student attitudes toward learning. It also suggests that PBL can be a productive tool in increasing student achievement as well. The next steps Hoppe (2010) proposes seem to be focused on revising the curriculum based on teacher and student input. One focus in the revision process is to create a seamless integration of the math and science and to include more math into the curriculum (Hoppe, 2010). The ideas and data gathered lends itself for a merging of suggestions and improvement of the program year to year.

Krajck (2015) wrote an article about the benefits of PBL in the science classroom and how it also aligns with the NGSS. This article discusses how project-based science is an exciting way to teach science that aligns with the NGSS. It does so by focusing on some main ideas but mixing in different practices and crosscutting concepts. This creates learning environments where teachers and students engage in science by designing and carrying out investigations, as well as communicating through data based reasoning (Krajck, 2015). It argues that a project-based approach allows learners to engage in making sense of the world or by designing solutions to real-world problems. By looking at real-world questions, students learn the science through doing. PBL helps all students by engaging them in science as they become invested in different projects (Krajck, 2015). This article argues these points, and really pushes science teachers to find a way to implement these features into their own teaching.

Schooler (2004) writes about a project that combined math, science, and technology in a seventh-grade classroom. Schooler (2004) designed a curriculum where the students worked in teams to design and build a cooler of sorts to hold ice and keep it from melting for 24 hours. Schooler (2004) used this idea to investigate surface area and volume of three-dimensional objects in math. Schooler (2004) studied technology in the design and science through the understanding of thermodynamics. The author pays close attention to the assessment processes of PBL by providing the students with guidelines with a rubric at the start of the project, and then continually checking in on the students throughout the process. The author argues that this way of assessing the students created a great deal of success but also strongly recommend scaffolding the students within the course of the project to help them along.

Matthews, Huffling, and Benevides (2014) discuss their learning experiences setting up a project-based learning program. The authors show a field-based study done with high school students that involved lizards during a summer herpetological research experience. Data collection is done on lizards captured, identified, and marked as a part of a mark-recapture program. The authors describe that their driving focus is to give their students “real-world” experience, building off the idea that “the most powerful connections between science teaching and learning are made through thoughtful practice in field experience” (National Research Council, 1996, p. 67). The authors lay the groundwork for what a PBL environment should look like. They include many tips for teachers looking at going into this teaching method. Although the article focuses on lizard fieldwork, it also includes classroom components and encourages other teachers to develop field-based science studies. In their experience, students quickly became very proficient in field-work and scientific principles and students described their own attitudes toward science as “knowledgeable and excited” (Matthews, Huffling, & Benevides, 2014, p. 325).

Methodology

Participants

The students within this study are 7th grade students in a science classroom in Northwest Iowa over the course of two separate school years. There is a fair amount of diversity of the students in this classroom in terms of ability. In the test class, the 65 students were broken up into three sections in which 29.2% of students are in the ESL program, 10.7% of students are on a 504 or IEP, and 23% classified by our school as “at-risk”. In the control class, the 52 students were broken up into two sections in which 19.2% of students are in the ESL program, 9.6% of students are on a 504 or IEP, and 11.5% classified by our school as “at-risk”.

Data Collection

The data from this research was gathered from a diagnostic test on an online textbook via Pearson Successnet. The researcher had the students both years take their pre-test on their laptop computer on the cells and heredity unit where they instantly had access to their quantitative results upon their completion. The researcher then proceeded to teach the unit on cells and heredity over the course of the next several weeks with the independent variable being how the units were taught. In the control year, the lessons were taught in a traditional classroom model with little hands-on activities outside of a few labs, verbal lectures with note taking, and unit worksheets as the primary homework mechanism. In the test year, project-based learning was the primary mechanism of delivery with many hands-on projects with a focus on student-centered inquiry. After the units were taught, the researcher had the students take the exact same diagnostic test from Pearson Successnet on their laptops to be used as their post-test. Both sets of data shown in Tables 1 and 2.

Table 1

PBL Individual Test Scores

Student	PRE	POST	DIFF	% Gain/Loss
1A	30	60	30	100%
1B	47	77	30	64%
1C	50	74	24	48%
1D	40	58	18	45%
1E	50	87	37	74%
1F	40	43	3	8%
1G	43	60	17	40%
1H	43	50	7	16%
1J	33	67	34	103%
1K	47	65	18	38%
1L	53	98	45	85%
1M	37	57	20	54%
1N	40	90	50	125%

1O	50	43	-7	-14%
1P	50	88	38	76%
1Q	53	85	32	60%
1R	40	81	41	103%
1S	43	95	52	121%
1T	23	56	33	143%
1U	27	60	33	122%
2A	37	45	8	22%
2B	37	70	33	89%
2C	27	40	13	48%
2D	33	40	7	21%
2E	27	57	30	111%
2F	37	57	20	54%
2G	30	70	40	133%
2H	57	85	28	49%
2I	43	77	34	79%
2J	43	60	17	40%
2K	43	40	-3	-7%
2L	43	67	24	56%
2M	30	68	38	127%
2N	17	64	47	276%
2O	40	75	35	88%
2P	37	43	6	16%
2Q	37	58	21	57%
2R	47	77	30	64%
2S	30	64	34	113%
2T	33	87	54	164%
2U	35	58	23	66%
2V	40	62	22	55%
2W	27	50	23	85%
3A	27	60	33	122%
3B	40	43	3	8%
3C	27	23	-4	-15%
3D	37	57	20	54%
3E	43	81	38	88%
3F	33	60	27	82%
3G	50	62	12	24%
3H	30	40	10	33%
3I	50	60	10	20%
3J	43	76	33	77%
3K	43	37	-6	-14%

3L	37	43	6	16%
3M	13	45	32	246%
3N	27	48	21	78%
3O	27	57	30	111%
3P	37	57	20	54%
3Q	50	43	-7	-14%
3R	40	76	36	90%
3S	43	74	31	72%
3T	53	64	11	21%
3U	40	62	22	55%
3V	47	57	10	21%
AVERAGE	**38.55**	**62.05**	**23.49**	**61%**

Table 2

Non-PBL Individual Test Scores

Student	PRE	POST	DIFF	% Gain/Loss
1A	30	33	3	10%
1B	40	53	13	33%
1C	37	67	30	81%
1D	20	33	13	65%
1E	45	73	28	62%
1F	43	63	20	47%
1G	40	73	33	83%
1H	37	53	16	43%
1I	33	63	30	91%
1J	37	32	-5	-14%
1K	20	63	43	215%
1L	27	57	30	111%
1M	60	80	20	33%
1N	37	39	2	5%
1O	53	77	24	45%
1P	33	63	30	91%
1Q	30	67	37	123%
1R	43	67	24	56%
1S	30	63	33	110%
1T	33	33	0	0%
1U	30	63	33	110%
1V	27	63	36	133%
1W	27	47	20	74%

1X	33	80	47	142%
1Y	37	67	30	81%
1Z	57	67	10	18%
2A	43	77	34	79%
2B	7	17	10	143%
2C	70	87	17	24%
2D	37	60	23	62%
2E	50	97	47	94%
2F	47	90	43	91%
2G	60	93	33	55%
2H	45	73	28	62%
2I	43	80	37	86%
2J	39	67	28	72%
2K	36	27	-9	-25%
2L	63	97	34	54%
2M	33	54	21	64%
2N	39	35	-4	-10%
2O	30	43	13	43%
2P	47	67	20	43%
2Q	50	90	40	80%
2R	47	90	43	91%
2S	43	83	40	93%
2T	50	80	30	60%
2U	23	83	60	261%
2V	47	87	40	85%
2W	50	77	27	54%
2X	40	73	33	83%
2Y	43	43	0	0%
2Z	30	83	53	177%
AVERAGE	**39.44**	**65.23**	**25.79**	**65%**

Findings

Data Analysis

The results of the study showed a 23.49 point increase from the pre-test to post-test in the experimental PBL group (table 1). This equates to a 61% increase in the test scores. The results of the non-PBL control group (table 2), showed a 25.9 point increase from pre-test to post-test. This equates to a 65% increase in test scores. Both group's pre-test scores were similar, only being separated by .89 points in favor of the control group.

Some notable scores include the fact that the PBL group had five students score lower on their post-test (1O, 2K, 3C, 3K, 3Q). It is important to note however, that three of those five students are on either an IEP or 504. In this same group, sixteen students showed an increase of 100% or more. That is 24% of the total population. In the non-PBL control group, three students showed a decrease in test scores (1J, 2K, 2N), noting that all of these students are on a 504 or IEP. Ten of these students showed increases of 100% or more. That is 19% of the total population.

Discussion

Summary of Major Findings

This study at first glance suggests that there is minimal difference between project-based learning and the traditional method of science education. However there are some notable differences within the groups and the results from them. Both groups experienced growth with the non-PBL group slightly outscoring the PBL group. When you look closer at the difference in the make-up of the groups themselves, you can possibly start to account for the differences. The PBL group had 62.97% of all students in either the ESL, special education, or "at-risk" programs. On the contrary, the non-PBL class only had 40.3% of students in the same programs. This is a staggering difference of 22.67% in what many people use as an indicator of academic ability level. When this factor is taken into account, the growth of the PBL group seems much more significant.

The finding that the data reveals is the fact that more students in the PBL group experienced a growth of 100% or more. This is significant because of the differential between the groups of ESL, special education, and at-risk students. This result suggests that PBL can better reach those students. Research also supports this idea. In their article, Petersen and Nassaji (2016) discuss the positive impacts of PBL on ESL students. They show that PBL has a marked improvement on language development through the hands-on style learning (Petersen & Nassaji, 2016). Through many manipulatives and language that is not purely spoken but felt and show, learners that can struggle in normal classrooms can show drastic growth within a PBL classroom.

Limitation of the Study

One of the things that may impact the study is that there are different students from year to year. Because of the relatively small sample size of just two years, the students themselves create a possible factor in the outcome of the study as they may not have had similar ability levels. For example, if one class has several students that are considered upper level and few lower level students, then the results could show that whatever variable was applied to that specific group, could show more growth than an average. Carrying out this study over many more years, should help make the scores more valid.

Another thing that can affect the study are the times of the year or events surrounding the test dates. Since the students in the study are not isolated, they have other things going on. If school events, such as homecoming or a school dodgeball tournament, are going on for one group but not another, test scores could be skewed as external factors could alter the focus of the students. Also, students moving in or out of the district can alter the data if it happens in between the pre- and post- tests. These results were excluded from the study to keep it from affecting the results.

Further Study

Looking ahead, it would be beneficial to continue this study into other units and with more participants. The more data that can be accumulated, the more reliable the results would be. Also in order to take analyzing the data a step further, a two-way factorial test should be done to help determine if both groups started out at the same level, if the traditional learning group showed a growth (or decrease), if the PBL learning group showed a growth (or decrease), and if there is a statistical difference between the post-tests. This type of test works best for this because it helps distinguish between multiple variables to help know if the groups start at the same place from year to year, and to see if PBL is effective at increasing student knowledge of cells and heredity by examining statistical differences between these variables (2x2 Between Subjects Factorial Design, n.d.).

Conclusion

As one looks at the effects of project-based learning in the classroom, they can see the positive impact it has on education. When compared to a traditional framework in this study, overall scores were not noticeably different as both showed growth. However, when looked at through a lens of growth of individual populations, one can start to notice the difference. In this study, PBL had a dramatic impact on ESL, special education, and “at-risk” students showing significant growth compared to their peers in a traditional setting. As more research is done to support the benefits of PBL, one can see the importance of the shift of standards away from The Core and to the Next Generation Science Standards. Knowing the “why” of doing things is always important for any implementation of new ideas or procedures, and education is no different. The shift to embrace the NGSS and how heavily embedded it is with PBL, has been met with skepticism by some of the professionals. The results of this study have shown that there can be quantitative benefits to embracing PBL, especially growth of historically underserved populations of ESL, special education, and at-risk students. This should help alleviate some of the hesitation to implementing it into the classroom.

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